

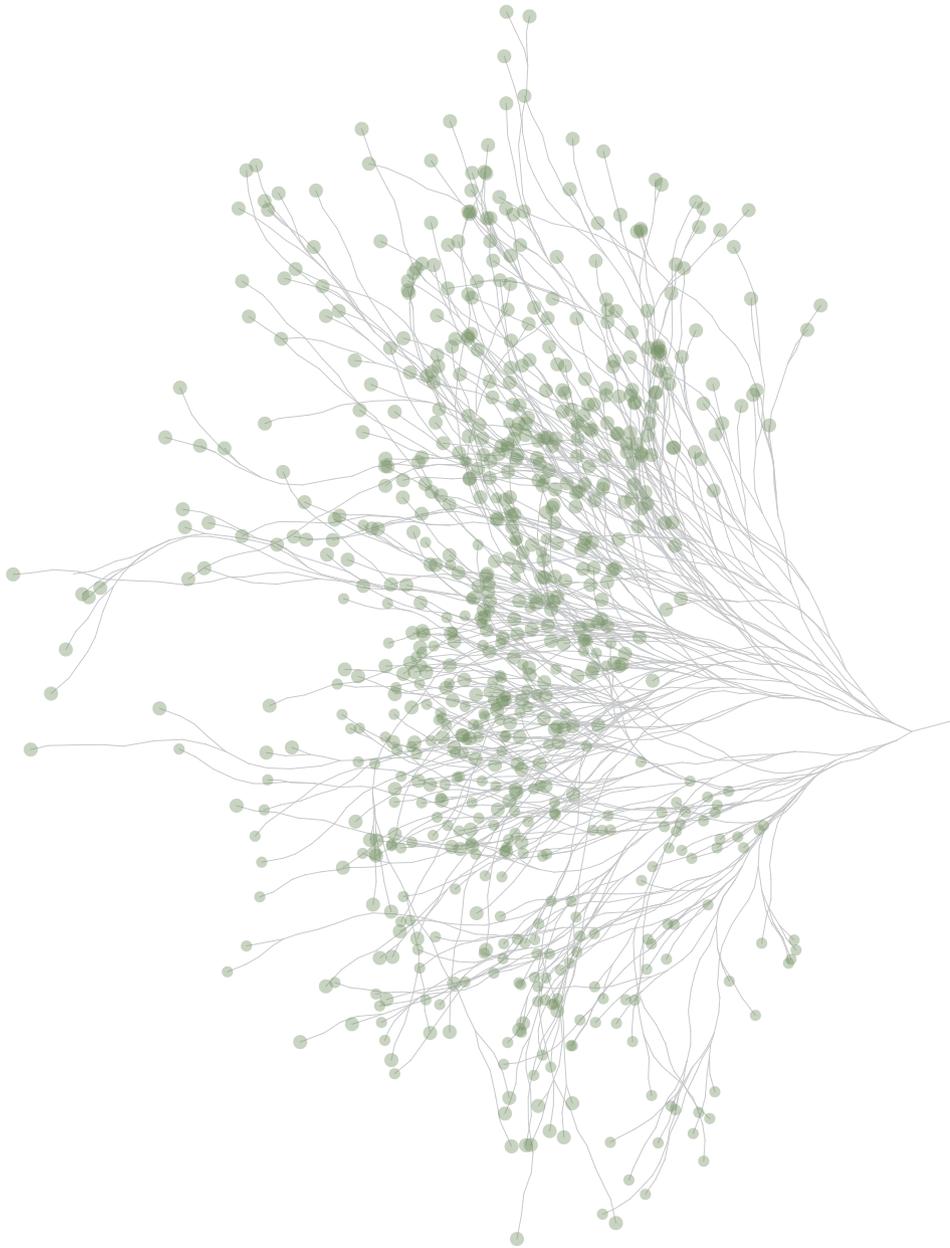
The talking species

Edited by
Eva Maria Luef *and*
Manuela M. Marin

Perspectives on the evolutionary, neuronal
and cultural foundations of language



up



Eva Maria Luef &
Manuela M. Marin (Eds.)

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Edited by Eva Maria Luef and Manuela M. Marin
Book design by Andreas Kolli

ISBN 978-3-902666-52-9

Printed in Graz, Austria

This publication was supported by Seoul National University (South Korea) and the Vice-Rectorate for Research of the University of Innsbruck (Austria).



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Contents

Preface	9
Notes on Contributing Authors	15
List of Contributing Reviewers	23

I. Language Evolution

1 Tracing the human brain's classical language areas in extant and extinct hominids <i>Eva Maria Luef</i>	29
2 Times change, values change: Criteria for attributing language in species comparative research <i>Robert Ulrich and Katja Liebal</i>	57
3 From grasping to pointing: The evolution of referentiality in man and animals <i>Adolf Heschl</i>	79
4 Emotion communication in animal vocalizations, music and language: An evolutionary perspective <i>Piera Filippi and Bruno Gingras</i>	105
5 Speech processing in congenital amusia: A review of the literature and future directions <i>Manuela M. Marin</i>	127

II. Language Development

6 The attainment of independence from the mother in primate infants and its implications for the evolution of cooperative breeding in hominins <i>Iulia Bădescu</i>	169
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7	Nod, nod, ignore: An exploratory observational study on the relation between parental mobile media use and parental responsiveness towards young children <i>Monika Abels, Mariek Vanden Abeele, Toke van Telgen and Helma van Meijl</i>	195
8	Episodic and phenomenal aspects of chaotic itinerancy in language development <i>Annette Hohenberger</i>	229
9	Interfaces (traveling oscillations) + Recursion (delta-theta code) = Language <i>Elliot Murphy</i>	251

III. Language Learning

10	Lessons learned from brain responses: The second language learning experience <i>Margit Reitbauer</i>	273
11	The effect of age in L2 ultimate attainment: Revisiting the evidence <i>Pia Resnik</i>	291
12	Age constraints in phonological learning: On the relevance and efficiency of pronunciation training <i>Milena Kong-Insam</i>	317
13	Exploring the neurofunctional underpinnings of dyslexia: A review focusing on dyslexic children <i>Sabrina Turker</i>	337

IV. Writing about the Brain

- 14 HEAFOD ('head') and BRÆGEN ('brain') in
Old English medical texts
Peter Bierbaumer 377
- 15 The brain is like a muscle – the brain is like a control center:
Conceptualizing the brain in expert and popularized scientific
discourses
Georg Marko and Ute Wimmer 393

V. Cultural Aspects of Language Use

- 16 The humble linguist: Interdisciplinary perspectives on
teaching intercultural citizenship
Manuela Wagner, Fabiana Cardetti and Michael Byram 423
- 17 Frames, cognition, ideology. And Chomsky.
Johannes A. Scherling 449
- 18 Monats- und Wochentagsbezeichnungen im Wandel der Zeit
Wolfgang Viereck 469

Appendix

- Annemarie Peltzer-Karpf: An Appreciation
Nancy Campbell 485
- Tabula Gratulatoria 489
- Index 491

Preface

LINGUISTIC STRUCTURE is woven into the fabric of human origins and lays the foundation for *humanness* more than any other trait. The biological, neuronal and social bases for *language* are immensely complex in the sense that a multitude of cognitive origins, their versatile networks of brain cells and their intricate interactions among one another form the critical core of the language ability.

Trying to understand the cognitive foundations of human language is a scientific endeavor that can best be described as convoluted and far-reaching. At the moment, researchers are following a mosaic-type approach where different disciplines are working together and complementing one another to help further our understanding of how language is anchored within human cognition. The notion of disciplines working in parallel and charting the linguistic brain from distinct perspectives, is critical when trying to develop a *grand unifying theory* – a complete mosaic – by connecting all linguistic functions and their cognitive foundations.

Naturally, any mosaic is an artistic undertaking where the composition of the pieces is entirely at the discretion of the creator. For this book, we have chosen a particular set of angles from which we will try to illuminate the study of language cognition, in the hope that – in their entirety – all 18 chapters will reveal the multidimensionality of linguistic ability. Our mosaic is modeled after the multi-faceted research interests of our mentor and friend Annemarie Peltzer-Karpf, a cognitive linguist who has devoted her life to studying language acquisition and development. Over the last decades, she has served as an advisor to many of her colleagues and students, nurturing scientific interests and furthering academic careers. We, the editors, are immensely grateful for her dedication to science and all she has done to help us in our academic lives. Many of the authors in this book feel equally indebted to Annemarie, some of whom have chosen to address personal messages to her in their chapters.

The mosaic nature of our book will be laid out in five general sections, which are composed of several chapters, all representing a specific approach to the study of language and cognition. The first part, 'Language Evolution', sets the stage for brain-language studies by focusing on the evolutionary origins and phylogenetic development of morphological structures pertaining to language functions (Eva Maria Luef) and the implications that arise for the study of animal communication in relation to human speech and language (Robert Ullrich and Katja Liebal). Adolf Heschl advances the hypothesis that relaxing selection processes may lead to an unfolding of cognitive linguistic skills (in his case, referential communication), as opposed to direct selection of traits. Piera Filippi and Bruno Gingras explore the Darwinian idea of language evolution, which puts emotion, animal vocalizations, language and music at its center. The final chapter of this section addresses the question of the language-music overlap in the human brain by examining the neurodevelopmental disorder of congenital amusia (Manuela M. Marin).

The second part, 'Language Development', includes papers on the importance of the mother-infant dyad with regard to the cognitive and physiological development in chimpanzees (Iulia Bădescu) and human children (Monika Abels, Mariek Vanden Abeele, Toke van Telgen and Helma van Meijl). Annette Hohenberger describes chaotic itinerancy and self-organizing neural processes in the study of child language acquisition. Elliot Murphy suggests a departure from a static and localizationist approach to language processing in the brain and argues for a dynamic approach based on brain frequency couplings and travelling oscillations.

Part three, entitled 'Language Learning', focuses on how second language learning is achieved by the human brain. Margit Reitbauer surveys work on brain response measurements during linguistic experimentation and formulates suggestions on how to integrate these findings into a pedagogical framework. Further chapters discuss the age factor in language learning and how it impacts phonological perception and production (Milena Kong-Insam) and the role of neural plasticity and critical periods in learners of advanced age (Pia Resnik). This section concludes with a discussion of the language impairment dyslexia and what it can tell us about neurolinguistic processes (Sabrina Turker).

The fourth part of this volume, ‘Writing about the Brain’, deals with neurolinguistics in a particularly creative way. Peter Bierbaumer presents his analysis of the use of the words *head* and *brain* in Old English medical texts, and Georg Marko and Ute Wimmer discuss their application of discourse analysis tools to conduct an investigation into the cognitive-semantic concepts underlying the term *brain* in scientific texts.

The final part, ‘Cultural Aspects of Language Use’, consists of papers discussing various approaches to how language is shaped by cultural convention. Manuela Wagner, Fabiana Cardetti and Michael Byram take an intercultural perspective on language teaching methodology. Johannes Scherling’s chapter focuses on frames and metaphors and draws a parallel between Noam Chomsky’s criticism of political discourse and theories on language and ideology advanced by Charles Fillmore and George Lakoff. Wolfgang Viereck provides an overview of the origins of modern terms for weekdays and months in Indoeuropean language history (written in German). To conclude, Nancy Campbell reflects on the time with her former colleague and friend Annemarie Peltzer-Karpf.

This book is intended to help fill various gaps in our understanding of some of the major issues in the study of human language, cognition and culture by bringing together insights from different disciplines. Its target audience comprises scholars and students of all disciplines with an interest in the psychological and neurocognitive aspects of linguistics and beyond. The presented reviews, theoretical articles and research reports either explore, or are based on, a wide variety of recent and influential contributions to the study of language origins, development and the cultural significance of language use. We are aware that the fields of theoretical and empirical language studies are rapidly expanding, thus new discoveries are reported on a daily basis. Therefore, this volume can only represent a snapshot of the scientific theories and approaches that are currently being explored.

We are sincerely grateful to the authors who devoted much time and effort to crafting their contributions, drafting and revising their chapters to our exacting standards. We would like to extend a special thanks to the 54 international expert reviewers who advised our authors with their expertise and helped mold each chapter into its final version. We are indebted to Andreas Kolli for his thoughtful layout of this book. We would

also like to thank Jong-seung Sun and Yejin Jang for their help with managing the administrative issues associated with this book project, and Joa Ahern-Seronde and Bruno Gingras for language editing. Finally, we acknowledge Seoul National University, South Korea, for generously funding our project with the award of the ‘Research Resettlement Fund for New Faculty’. In addition, we were supported by the ‘Overhead Fund 2017’ of the College of Education of Seoul National University. We were also financially supported by the Vice-Rectorate for Research of the University of Innsbruck. This book – this mosaic – is the product of walking on a long and, at times, arduous road, and we truly thank all our contributors for patiently traveling along it with us.

Eva Maria Luef

Manuela M. Marin

Seoul & Innsbruck, July 2018

To Annemarie

Thank you for all the years of encouragement and support

Notes on Contributing Authors

MONIKA ABELS received her PhD from the University of Osnabrück in Germany and is a cross-cultural, developmental psychologist. She has worked on infants' daily experiences and caregiving since her time as an exchange student in Gujarat, India, in 1998. Her current research interests include the development of shared attention and communication. She has recently conducted a project at Tilburg University (funded by a Marie Skłodowska-Curie Individual Fellowship) on a hunter-gatherer tribe in Tanzania using new, portable technology that records language, heart rate and caregivers' distances from the observed infant. She is also interested in aspects of cultural change due to changes in lifestyle and technology.

IULIA BĂDESCU is an Assistant Professor at the Department of Anthropology at the University of Montreal, Canada. She holds a PhD from the University of Toronto, and an MA and BSc from the University of Calgary. She currently studies wild chimpanzees in Uganda and has worked on ursine colobus monkeys in Ghana. Her research focuses on identifying the key differences and similarities between primates in infant care, development and maternal investment to evaluate the dynamic evolutionary processes that have shaped variable patterns of infant feeding and care in our own species.

PETER BIERBAUMER pursued degrees in English, German and Russian studies at the University of Vienna and the University of Graz before completing a PhD in English and German studies at the University of Graz in 1969. After his habilitation in the field of English linguistics in 1979, he worked as a researcher and professor at the Department of English Studies at the University of Graz until his retirement in 2007. His main research interests include historical linguistics, with a particular focus on Old English, and English for specific purposes. Besides serving in several university functions, Peter Bierbaumer was one of the initiators of the Graz International Bilingual School and also founded the International Language Centre at the University of Graz.

MICHAEL BYRAM is Professor Emeritus at Durham University, England, and Guest Professor at Luxembourg University. He has worked in initial teacher training and doctoral supervision, and taught courses on intercultural competence. He has researched bilingual and minority education, residence abroad for language students and intercultural competence in foreign language learning.

NANCY CAMPBELL has a PhD from Strathclyde University and has been teaching linguistics and English language at the University of Graz since the mid-80s. Her main interest is in developing innovative approaches to teaching academic writing and in developing effective methods of assessing writing. She is also academic coordinator of a Joint Master's program which is run in conjunction with universities in Bamberg, New York, Paris, Pécs and Venice.

FABIANA CARDETTI is Associate Professor of Mathematics and Graduate Director for Instructional Development at the University of Connecticut, USA. She has extensive experience in mathematics education research, with a recent focus in supporting the enactment of mathematical practices to enhance students' understanding of mathematics through an ICC lens. Currently, she leads and co-leads several major interdisciplinary initiatives for the mathematics education of teachers and the improvement of mathematics teaching and learning across different educational levels. She holds a PhD in mathematics, specializing in control theory on Lie groups, from Louisiana State University.

PIERA FILIPPI received a PhD in philosophy of language and mind at the University of Palermo, Italy, in 2012. From 2012 to 2016, she conducted her postdoctoral research project at the department of Cognitive Biology of the University of Vienna, Austria, at the Artificial language laboratory of the Vrije Universiteit Brussel, Belgium, and at the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands. She is currently conducting her research work at the Brain and Language Research Institute of the University of Aix-Marseille, France. Her research focuses on the analysis of prosody, emotion communication and language evolution through a comparative approach between human and nonhuman animals.

BRUNO GINGRAS first completed an MSc in molecular biology before turning to music theory, graduating with a PhD from McGill University, Canada, in 2008. After a postdoctoral fellowship at the Department of Computing at Goldsmiths, United Kingdom, he was a postdoctoral fellow at the Department of Cognitive Biology of the University of Vienna, Austria, from 2011 to 2014. He is currently a University Assistant at the Department of Psychology of the University of Innsbruck in Austria. His research interests include biomusicology, music-induced emotions and music performance.

ADOLF HESCHL is an evolutionary biologist working on questions about cognitive evolution in humans and animals. He was trained in zoology and botany at the University of Graz in Austria and was a member of the so-called “Altenberger Kreis” around Konrad Lorenz, Karl Popper and Rupert Riedl, whose work was focused on the development of an evolutionary account of epistemology. As a result, he published a book entitled *The Intelligent Genome* (1998) in which he defends the position that most behavior is genetically determined. In recent years he has been active in the emerging field of microbiome research.

ANNETTE HOHENBERGER is a Senior Lecturer at the Institute of Cognitive Science at the University of Osnabrück, Germany. She has a twofold academic background and holds degrees in linguistics (MA, PhD) and psychology (diploma, habilitation). Her main research areas are cognitive development (episodic cognition, theory of mind, understanding of goal-directed human action), language and emotional development. With adults, she studies psycholinguistics (language perception and production, sign language), cognition/perception/action, time perception, as well as reasoning about climate change and sustainability. Conceptually and methodologically, she has worked in an interdisciplinary perspective and subscribes to a nonlinear dynamic systems approach, in particular in relation to language development.

MILENA KONG-INSAM received a PhD in English Studies and teaches English linguistics and language at the University of Graz in Austria. Her research areas are acoustic phonetics and phonology, with a special focus on foreign language acquisition. Her PhD project dealt with comparing

acoustically measurable cues of accentedness, with a focus on sound segments, and current research interests also include suprasegmentals, such as tones and pitch contours. She has been working on an interdepartmental project which is testing and implementing an innovative pronunciation training software for L2 learners of English. She was nominated for *Ars Docendi* (i.e., state award for excellence in teaching) by the University of Graz in 2013.

KATJA LIEBAL is a Professor of Comparative Developmental Psychology at Freie Universität Berlin, Germany. Her main research focus is on the gestural and facial communication of nonhuman primates and how informed, systematic comparisons with human non-verbal communication help shed light on the origins of human language. She uses both observational and non-invasive experimental methods to investigate the cognitive mechanisms underlying primate communication and how different communicative means are acquired during ontogeny.

EVA MARIA LUEF is a faculty member at the College of Education at Seoul National University in South Korea. Her research focuses on the acoustics of sounds in connection with cognitive science, and she has studied communication in great apes, corvids and humans. She conducts observational and experimental studies involving both work in the lab and in the field. The two main strands of her work, anthropology and linguistics, help answer the larger question of how communicative systems adapt to evolutionary pressures.

MANUELA M. MARIN has a multidisciplinary academic background and received degrees in English, physics and musicology from the University of Graz, Austria, and an MSc in psychological research methods from Goldsmiths, University of London, UK. She is currently finishing her PhD studies in psychology at the University of Vienna and working as a University Assistant at the Department of Psychology at the University of Innsbruck, Austria. Her research interests include empirical aesthetics, music and emotion as well as music-language comparisons. She is a co-founder and promoter of the annual conference series “International Conference of Students of Systematic Musicology (SysMus)”, which has been running for more than ten years.

GEORG MARKO studied English and American Studies at the Universities of Graz and Lancaster and is now an Associate Professor of English Linguistics in Graz. His main area of expertise is the theory, the methodology and the application of corpus-based critical discourse analysis. His research is mainly concerned with expert and lay discourses on health, especially in connection with medicalization and the construction of risk. He is also interested in the interaction between language and different social phenomena and domains and has organized several workshops on this topic (language in connection with sexuality, religion, health, mobility and populism, respectively).

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PIA RESNIK is a Senior Lecturer in English language teaching and applied linguistics at the Department of English at the University of Vienna, Austria. Previously, she worked at the Departments of English Studies in Graz and Salzburg, Austria, and spent research visits at Newcastle University, UK, the University of London, UK, and Kasetsart University, Thailand. Her research interests include all aspects surrounding learning of English as a foreign language, with a particular focus on emotions in multilingual contexts. Recently, she has started investigating the ef-

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ROBERT ULLRICH is a pre-doctoral researcher at Freie Universität Berlin, Germany. During his undergraduate and graduate years he worked in the Biology Department in the group led by Constance Scharff, focusing on multimodal communication in songbirds. Currently he is doing research for his PhD thesis in the group led by Katja Liebal studying primate communication research. His cross-species and cross-disciplinary background, which also includes studies in philosophy of science and language, motivated his current meta-research stance to investigate the role of values in science by using a mixed-method approach.

MARIEK VANDEN ABEELE has a PhD from the University of Leuven, Belgium, and is Assistant Professor at Tilburg University in the Netherlands. She is also an affiliated researcher at the Media & ICT research group at Ghent University, Belgium. Her research is centered on the social implications of mobile communication technology, with a particular focus on children and youths. She serves as editor on the board of Mobile Media & Communication (Sage) and is the secretary of the Mobile Interest Group of the International Communication Association.

HELMA VAN MEIJL graduated from Tilburg University in August 2017 with an MSc, having worked on smartphone use during parent-child interactions in her thesis. Before she went on to obtain her Master's in business communication and digital media, she studied commercial economics at Fontys Hogescholen and had a job in marketing and PR for a large bookstore in Eindhoven. Currently she is working as an (online) marketer at Acknowledge, a large ICT firm in the province of North-Brabant, the Netherlands.

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UTE WIMMER studied English and American Studies and mathematics at the University of Graz and taught several linguistic courses at the Department of English Studies. Encouraged by Annemarie Peltzer-Karpf, she became interested in the dynamics of language death and revival and presented her research project at an international conference of minority languages. In her doctoral thesis, which was published by the Cornish Language Board (2010), she assessed the sociolinguistic situation of the revived Cornish language. She is currently teaching English and mathematics at a college for elementary education in Linz, Austria.

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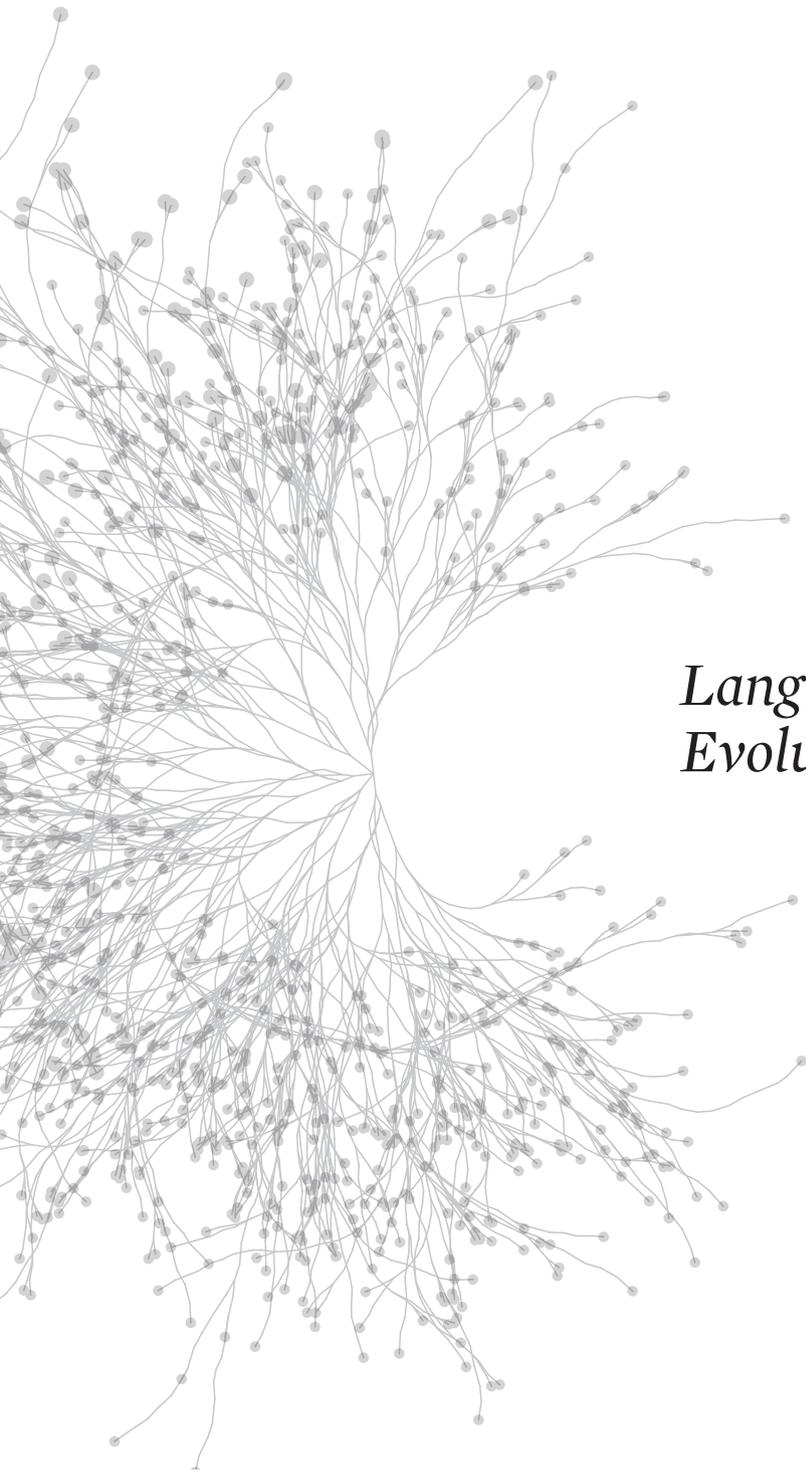
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I

*Language
Evolution*

Tracing the human brain's classical language areas in extant and extinct hominids

Eva Maria Luef

Seoul National University, College of Education

ABSTRACT Language is a cognition that makes us human. It is a function of the structure of the human brain that is made possible by complex wiring of neural networks that evolved over millions of years since humans shared the last common ancestor with the great apes. The human brain accommodates two principle cortical areas that are strongly involved in computing linguistic processes: Broca's and Wernicke's areas. Discovered in the latter half of the 19th century, the regions represent localized but relatively segregated linguistic modules which are linked through connective pathways. Broca's and Wernicke's areas are ancient parts of the primate brain, however, their functional specializations have undergone significant transformations during primate evolution. This chapter will review neurobiological findings concerning the internal make-up and function of the homologous brain areas to Broca's and Wernicke's areas in extant nonhuman primates and discuss relevant knowledge that exists on the brain morphology of extinct hominins. Comparative neurobiology holds the key to understanding how the core language areas have developed their specialized functions in human brains

by offering insights into developments that could have been the driving forces for language during evolutionary history.

KEYWORDS brain, Broca's area, classical language areas, evolution, origins, Wernicke's area

1 INTRODUCTION

From so simple a beginning, endless forms most
beautiful and most wonderful have been,
and are being, evolved.
— Darwin, 1859

Throughout history, many societies believed that language was a gift from God to humans. According to the Bible, immediately upon creation Adam received the task from God to give names to all living things and hence develop a language with which he could communicate with Eve. Human society and language are treated as inseparable entities not just by the authors of the Bible, but even more so by modern science that has demonstrated how deeply ingrained language is into our biological and social existence. Contrary to biblical belief, this close relationship is a result of the evolutionary pressures of the ancestral past moulding and shaping the unique human mind as we know it today.

Language is a multifaceted cognitive ability dependent on a complex brain to support it. For humans, communication requires a wide range of different cerebral processes contributing to construct linguistic meaning in the brain. The essence of the neurobiology of language consists of identifying particular linguistic functions and their cerebral control centers to be able to assign functions to specific brain areas. Many contemporary language-brain models are deeply rooted in the premise that two cortical left-hemispheric areas govern the majority of language processes (Price, 2012). This is not to say that no other cerebral regions contribute to linguistic tasks or that the core language areas exclusively compute language. A variety of subcortical structures may be involved in lexical, phonological, syntactic, and/or semantic processes (e.g., Duff

& Brown-Schmidt, 2017; Duffau, Moritz-Gasser, & Mandonnet, 2014; Tiedt et al., 2017). In addition, right-hemispheric structures also make important contributions to language (Silbert, Honey, Simony, Poeppel, & Hasson, 2014). More generally, linguistic processing can build upon and benefit from non-linguistic cognition, such as numerical or spatial processing (see, e.g., de Bruin, Roelofs, Dijkstra, & Fitzpatrick, 2014; Hauser, Chomsky, & Fitch, 2002), which makes the definition of what constitutes a language area difficult. The two core language areas, namely *Broca's* and *Wernicke's areas*, are historically important and well-researched brain regions in terms of linguistic cognition, and a considerable body of research has consolidated their undebated role for language.

This review will discuss the evolutionary development of the core language areas of modern human brains as we know them today. Starting with an historical overview of their discoveries and important findings from early brain-language research of the 19th century, it will continue with a description of which *cytoarchitectonic* studies have contributed to our current knowledge of the language areas and their functions. Neurobiological studies on nonhuman primates will show how equivalent brain regions in monkeys and apes process information related to species-specific communication and how functionality of those areas changed during the evolution of *Homo sapiens*. Lastly, archaic humans – extinct members of the genus *Homo* – which are considered as evolutionary intermediaries between the great apes and humans, will be the focus of discussion. Evidence relating to the existence of the core language areas in the brains of various species of extinct hominins can provide compelling insights into the evolutionary history of neurolinguistic structures of the human brain.

2 THE HUMAN CORE LANGUAGE AREAS

The neurobiological basis of language has traditionally been considered as centered upon two core language areas called Broca's area and Wernicke's area. They are named after their discoverers, the French physician Pierre Paul Broca (1824–1880) and the German neurologist Carl

Wernicke (1848–1905), who were among the first to describe their role in linguistic processing.

Examining two patients who were unable to speak, Broca discovered that damage to the left inferior frontal gyrus of the cerebral cortex led to language production deficits (so-called *Broca's aphasia* or *non-fluent aphasia*, see Broca, 1861, 1865). Neither claims of location nor left-lateralization of this brain area were entirely new (for a review of the historical debate over the discovery of the lateralized language area known as Broca's area see, e.g., Finger, 2010). However, previous work was rather preliminary and lacking in many of the evidential details that were later provided by Broca, who has thus historically been credited with the discovery of that language area (Cubelli & Montagna, 1994). Traditionally, Broca's area has been described as a productive region concerned with the encoding of vocal signals into meaningful syllables, words (e.g., Indefrey & Levelt, 2004; Papoutsis et al., 2009) and sentences (Embick, Marantz, Miyashita, O'Neil, & Sakai, 2000).

Post-mortem analyses of the brains of both Broca's patients and recent re-examinations with modern neuroimaging techniques revealed their lesions to be more extensive than solely to the posterior part of the left inferior frontal gyrus. They include the insula, anterior parts of the superior temporal lobe and parts of the inferior parietal lobule as well as subcortical parts, such as the claustrum, putamen and globus pallidus (Cabanis, Iba-Zizen, Abelanet, Monod-Broca, & Signoret, 1994; Castaigne, Lhermitte, Signoret, & Abelanet, 1980; Dronkers, Plaisant, Iba-Zizen, & Cabanis, 2007). Based on these findings, it has become clear in the last few decades that the clinical description of Broca's aphasia also involves substantial subcortical and insular damage (Petrides, 2014) and that a localized lesion to solely Broca's area results in a rather mild and reversible language production problem (Mohr et al., 1978; Penfield & Roberts, 1959).

In 1874, Carl Wernicke identified another cortical area whose damage led to language impairment, in this case in the domain of language perception. Disruptions to the posterior portion of the left superior temporal gyrus result in a type of aphasia, which is primarily characterized by poor speech/language comprehension but relatively fluent language output (so-called *Wernicke's aphasia* or *fluent aphasia*, see, e.g., Benson & Ardila, 1996). Wernicke's area is most commonly described as a recep-

tive region for processing and integrating auditory sensory information (Guenther, 2016) and lies immediately posterior to the primary auditory cortex, which is considered crucial for the perceptual processing of speech (Petrides, 2014). Wernicke (1881) suggested that the critical region for auditory language comprehension spans the superior temporal gyrus, including the cortex of the superior temporal sulcus and the adjacent lip of the middle temporal gyrus. He proposed the existence of a larger peri-Sylvian cortical and insular language region in the human brain, including the core language region identified by him. This postulation proved remarkably consistent with the findings of the majority of studies that would follow within the next century, including neuropsychological as well as modern functional neuroimaging studies (e.g., Dronkers, Redfern, & Ludy, 1995; Friederici, 2011; Penfield & Roberts, 1959).

Typical language processing in the human brain is relatively strictly lateralized. Broca's and Wernicke's areas, as well as Heschl's gyrus and the insula, are primarily left-hemispheric regions (Bidula & Króliczak, 2015; but see Keller et al., 2011), whereas a number of right-hemispheric brain regions also play a role, such as the mid part of the superior temporal sulcus (Glaser et al., 2011; Leroy et al., 2015).

After the discoveries of Broca and Wernicke, the German physician Ludwig Lichtheim developed a model of language function that placed both core language areas at the center and attempted to describe how they interact for linguistic computing (Graves, 1997; Lichtheim, 1885). Broca's view of brain language processes corresponded with a mosaic map of specific and separate language function centers, including a *general faculty for languages* and a *specific faculty of articulation* and different input/output pathways (peripheral sensory, motor nerve), between which no connection was described (Broca, 1865). Wernicke, on the other hand, drawing upon his teacher and mentor Theodor Meynert, proposed connective pathways between different language centers and saw all linguistic functions as inter-related in both functional and anatomical terms (Wernicke, 1874, 1881). Based on Wernicke's paradigm, Lichtheim formulated the *Wernicke-Lichtheim Model* of linguistic processing (later modified most notably by Geschwind, 1965) which defines Wernicke's area as the auditory center, Broca's area as the motor output center, and both connected to an (non-localized) *conceptual center* (Lichtheim,

1885). The model puts strong emphasis on the functional connectivity of cerebral areas and their associative networks, a view that was supported by other researchers at the time who showed fiber tracts linking the core language areas (e.g., Burdach, 1822; Dejerine, 1895). Thanks to the pioneering work by Geschwind (1970), a large fiber tract between Broca's and Wernicke's area, the *arcuate fasciculus*, was identified as a crucial pathway for language processing (see also Marin in this volume). Later research identified additional fiber tracts linking lateral areas of the temporal cortex with the frontal cortex (Petrides & Pandya, 1988; Schmahmann et al., 2007), and a part of the superior longitudinal fasciculus was described as most crucial for language processing (e.g., Schmahmann et al., 2007). In the last ten to fifteen years, numerous studies using *diffusion tensor imaging* (DTI-tractography) have delineated with modern neuroimaging techniques the relationship of language to white matter pathways, such as the arcuate fasciculus, ventral pathway and uncinate fasciculus (Catani & Jones, 2005; Frey, Campbell, Pike, & Petrides, 2008; Saur et al., 2008). Whether the arcuate fasciculus actually plays the role in linguistic processing that Geschwind described has been debated recently (see Dick & Tremblay, 2012, for a review).

Undoubtedly, most researchers agree with the general premise of the *dual-pathway model* of language/speech processing, where a dorsal stream maps auditory speech sounds to articulation and a ventral stream maps auditory speech sounds to meaning (Ungerleider & Haxby, 1994); however, the exact neural connections comprising the system are often considered controversial (Hickok, 2009; Rauschecker, 2011; Rauschecker & Tian, 2000; Saur et al., 2008; Weiller, Bormann, Saur, Musso, & Rijntjes, 2011). Although the extensive degree of connections between the different brain language areas was not known at the end of the 19th century, Wernicke's and Lichtheim's work guided future researchers in the direction that proved to be most useful for finding the neurobiological foundations of language. The *Wernicke-Lichtheim Model* came to be the standard neuropsychological model for language and was elaborated on extensively over the following 100 years (Ben Shalom & Poeppel, 2008; Graves, 1997), spawning many modern descendants (see, e.g., Friederici, 2002; Hickok & Poeppel, 2004; Indefrey & Levelt, 2004; Price, 2000).

Broca's and Wernicke's areas are often inconsistently defined in the literature as both involving large portions of the cortex with relatively

vague boundary markings (Guenther, 2016). In general, there is substantial variation concerning the precise boundaries of the areas among individuals as well as between hemispheres of the same individual (Amuts et al., 1999; Steinmetz & Seitz, 1991). One way to delineate discrete cortical areas more narrowly is to define them on the basis of their cellular organization (i.e., the cytoarchitecture). Cells receive, compute and send out information to other cortical and subcortical structures with which they are linked (Petrides, 2014), and their internal make-up is relevant to understanding their particular functions. The procedure of hardening brains to stain cellular elements of thinly sectioned slices only became possible in the latter part of the 19th century and was pioneered by Carl Wernicke's teacher Theodor Meynert, who was able to demonstrate different cell types and various layers of neurons in different cortical regions (Meynert, 1867). His work was followed by other researchers, including the German neuro-anatomist Korbinian Brodmann who in 1909 published the most famous *cytoarchitectonic map* of the human cerebral cortex, introducing the numerical nomenclature to denote the cortical regions that is still widely used today (i.e., "Brodmann area" or "BA" plus corresponding number of his cytoarchitectonic map). The following two centuries saw a rise in interest in cytoarchitecture due to the development of new methods and techniques (e.g., Economo & Koskinas, 1925; Sarkissov, Filimonoff, Kononowa, Preobraschenskaja, & Kukuew, 1955), and beginning in the 1980s, functional neuroimaging of distinct foci of functional activity in the human brain drew on cytoarchitecture to define cortical regions (e.g., Talairach & Tournoux, 1988).

Both Broca's and Wernicke's areas correspond to more than one Brodmann area. Broca's area includes Brodmann's areas 44 and 45, with area 44 lying on the pars opercularis and area 45 on the pars triangularis of the inferior frontal gyrus (Amuts et al., 2010), while Wernicke's area corresponds to parts of Brodmann's areas 21, 22 (central and posterior superior temporal gyrus), 41 and/or 42 (Ardila, Bernal, & Rosselli, 2016). Even though there are no exact correspondences between the core language areas and their cytoarchitecture, the cytoarchitectonic divisions of the human cortex are particularly useful in cross-species comparisons. Cortical cells, like all other biological structures, change slowly and thus remain highly conserved for a longer evolutionary period (Geschwind &

Rakic, 2013), opening up the possibility of comparative neurobiological studies across related species.

3 **HOMOLOGUES OF BROCA'S AND WERNICKE'S AREAS IN NONHUMAN PRIMATES**

Primates first appeared in the fossil record around 55 million years ago (Seiffert, Perry, Simons, & Boyer, 2009), with the evolutionary lineage leading to modern humans splitting from the great ape lineage about seven to eight million years ago (Langergraber et al., 2012). The diverse order of primates includes prosimians, such as lemurs and tarsiers, and a multitude of simian species, for instance marmosets, capuchins, macaques and apes. The great apes (*Hominidae*) are the closest living relatives of humans and share over 97% of genes with them (Locke et al., 2011). Macaque monkeys are, after humans, the most widespread primate genus and share about 93% of their genes with humans (Gibbs et al., 2007). Research pertaining to the evolution of human behavior is often focused on chimpanzees, but neuroscience widely uses macaques to model functions of the human brain.

During human evolution, there was substantial neurological rewiring and reorganization of the cortex, wherein some areas increased in size (e.g., the anterior prefrontal cortex) while others decreased (e.g., parts of the insular cortex, see Semendeferi, Armstrong, Schleicher, Zilles, & Van Hoesen, 1998, 2001). The increase in white matter volume of the precentral cortex indicates that the frontal lobes in humans have increased in neurological complexity as compared to those in great apes (Schoenemann, Sheehan, & Glotzer, 2005). The human brain is not just an enlarged version of the chimpanzee brain but differs with regard to form and function (Rilling, 2006).

Cytoarchitectonic studies have helped trace the nonhuman origins of specific human brain regions to draw conclusions as to their evolutionary development. Cortical regions homologous (in cell make-up) to Broca's and Wernicke's areas have been identified in macaque monkeys (Galaburda & Pandya, 1982; Preuss, 2000) as well as in all great apes (Cantalupo & Hopkins, 2001; Spocter et al., 2010), and those areas seem

to be involved specifically in the processing of species-specific vocal and gestural communication signals (Gil-da-Costa et al., 2006; Petrides, Cadoret, & Mackey, 2005; Tagliabata, Russell, Schaeffer, & Hopkins, 2008). The function of Broca's area in humans may thus be a specialization of more ancient brain functions related to vocal and gestural communication in Old World primates (Schenker et al., 2010).

The macaque homologue of Broca's area has gained fame with the discovery of *mirror neurons*, which are a class of neurons that represent meanings of actions (in the sense of an *action vocabulary*) accessible through auditory stimuli (Kohler et al., 2002). Therefore, the link between motor action and speech is not new to the human Broca's area but has an evolutionary precedent, a fact that has fed various hypotheses on language origins (e.g., Gallese, 2008).

While Broca's area is lateralized to the left cortical hemisphere in most humans (Toga & Thompson, 2003), the degree of lateralization of homologous regions in nonhuman primates is still unclear. Allometric measurements of the homologue of Broca's area in chimpanzees are not in agreement over hemispheric specialization (Cantalupo & Hopkins, 2001; Schenker et al., 2010). Human brains are characterized by the so-called *Broca's cap*, a bulge at the level of the temporal pole that includes a part of Broca's area, namely Brodmann area 45 (see Falk, 2014). A similar structure in chimpanzees, called the *orbital cap* (which does not exactly correspond to Broca's cap, see Falk, 2014), may or may not show size difference between the two hemispheres (Cantalupo & Hopkins, 2001; Schenker et al., 2010; Sherwood, Broadfield, Holloway, Gannon, & Hof, 2003). Nevertheless, behavioral studies suggest a certain degree of lateralization of communicative functions in nonhuman primates (Vauclair, 2004). Chimpanzees have been shown to possess a tendency to process species-specific sounds primarily in the inferior frontal gyrus of the left hemisphere (Tagliabata et al., 2008; Wilson & Petkov, 2011). In macaques, stimulation of the left Broca's area homologue elicits orofacial movements (Petrides et al., 2005), and orofacial asymmetries were shown to be associated with the production of species-specific calls in marmosets, macaques and chimpanzees (Fernández-Carriba, Loeches, Morcillo, & Hopkins, 2002; Hook-Costigan & Roger, 1998; Schenker et al., 2010). Due to the fact that chimpanzees tend to produce asymmetric orofacial movements during the production of (learned) calls, it has been

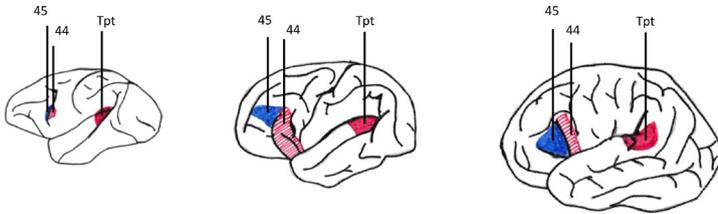


Figure 1. Schematic drawing of macaque (left), chimpanzee (mid) and human (right) brains (left hemispheres) with Brodmann areas 44/45 and temporo-parietal areas (*Tpt*) indicated (based on Amuts et al., 2010; Frey, Mackey, & Petrides, 2014; Gannon, Holloway, Broadfield, & Braun, 1998; Schenker et al., 2008; Spocter et al., 2010). Images are not to scale.

suggested that both tasks are functionally lateralized to the left hemisphere (Losin, Russell, Freeman, Meguerditchian, & Hopkins, 2008).

While lateralization of the nonhuman homologue to Broca's area is still contested, more agreement exists concerning asymmetry in the chimpanzee homologue of Wernicke's area (Hopkins et al., 2016; Spocter et al., 2010). In humans, the planum temporale at the core of Wernicke's area is significantly enlarged in the left hemisphere, with the left-hemispheric area being approximately ten times larger in size than the right one (Geschwind & Levitsky, 1968). The nonhuman homologue area of Brodmann area 22, comprising the largest part of Wernicke's area, is called the temporo-parietal area (*Tpt*) and has been localized in macaques, galagos (Gannon, Kheck, & Hof, 2008; Preuss & Goldman-Rakic, 1991) and all great apes (Hopkins, Marino, Rilling, & MacGregor, 1998, see Figure 1). The human-like lateral asymmetry is already evident in baboons and great apes (Hopkins et al., 1998; Hopkins & Nir, 2011; Marie et al., 2017), indicating that the planum temporale asymmetry dates back to a common ancestor of catarrhine primates (Sherwood, Subiaul, & Zawidzki, 2008).

A number of behavioral studies suggested that perception of species-specific vocalization may be lateralized to the left cerebral hemisphere in macaques (e.g., Ghazanfar, Smith-Rohrberg, & Hauser, 2001; Hauser & Anderson, 1994; Petersen, Beecher, Zoloth, Moody, & Stebbins, 1978). Neurobiological studies confirmed some of these findings and, additionally, identified the left *Tpt* area in macaques to be specifically in-

involved in the processing of conspecific calls (Heffner & Heffner, 1986; Poremba et al., 2004). Rauschecker et al. (1995) demonstrated that pure tones are processed at the core region of the superior temporal cortex in macaques, whereas complex, species-specific vocalizations are processed in more lateral regions.

A neuroimaging study measuring planum temporale activity of chimpanzees during the perception of species-specific vocalizations confirmed that the planum temporale region of the chimpanzee brain is functionally specialized for the processing of species-specific vocal signals, though no evidence was found for a lateralization effect (Tagliatela, Russell, Schaeffer, & Hopkins, 2009). The majority of studies on nonhuman primates corroborate the fact that the temporal region of the primate brain, including humans, is home to a voice recognition system that is specialized in processing communication signals from conspecifics (see, e.g., Belin, Zatorre, Lafaille, Ahad, & Pike, 2000; Petkov et al., 2008; Spocter et al., 2010).

There is ample evidence indicating that species-specific communication signals of great apes are lateralized to the left cerebral hemisphere, although the exact brain regions involved may be yet unclear. Studies that directly measure neurological processes during communication tasks are scarce (e.g., Tagliatela et al., 2009), but numerous behavioral studies have revealed a trend of left-lateralization. Manual gestures in most great apes seem to be governed by left-hemispheric structures (e.g., *chimpanzees*: Hobaiter & Byrne, 2013; Hopkins & Leavens, 1998; *bonobos*: Hopkins & Vaclair, 2012) and the laterality effect may be even stronger when vocalizations accompany these gestures (Hopkins & Cantero, 2003; Tagliatela, Russell, Schaeffer, & Hopkins, 2011). Both Broca's and Wernicke's areas have been implicated in those communicative processes. Hopkins and Nir (2011) and Spocter et al. (2010) identified a correlation between the degree of asymmetry of the planum temporale and the propensity for right-handedness of gestures in chimpanzees (Hopkins & Nir, 2011; Spocter et al., 2010). Tagliatela et al. (2006) described the same correlation for gesture handedness and size of the inferior frontal gyrus. As shown by Meguerditchian et al. (2012), both the planum temporale and inferior frontal gyral surface asymmetry are correlated with communicative gesture in chimpanzees. At the moment it is unclear which of the two brain regions is more closely linked to communication.

Handedness, in general, has been described to be strongly associated with language in modern humans, with the majority of right-handed people demonstrating left-hemispheric specialization for language function (Knecht et al., 2000). A study of hand preference in chimpanzees, however, has shown that the neurobiological correlates of handedness in chimpanzees do not seem to be related to the language areas (Hopkins & Cantalupo, 2004). Handedness may have co-evolved with language only during human evolution (Corballis, 2003), and the connection between the two is possibly related to gestural communication or tool use (see, e.g., Hopkins, Russell, & Cantalupo, 2007; Meguerditchian, Vauclair, & Hopkins, 2013).

Broca's and Wernicke's areas and their nonhuman homologues are not only different in size and situated in different cortical locations across species, but are also characterized by differences in their internal cell-makeup. Broca's area and the temporal plane in humans display wider cortical *minicolumns*, and this is particularly pronounced in the left hemisphere (Rilling & Stout, 2014). Moreover, notable differences between the association networks of the language areas have been described, with human Broca's areas displaying more extensive connections to the temporal gyrus than the homologue in nonhuman primates' brains. Concerning white matter pathways, comparable frontal connections can be found in humans and nonhuman primates, including the superior longitudinal fasciculus, the uncinate fasciculus, the cingulum, the arcuate fasciculus and the inferior fronto-occipital fasciculus (de Schotten, Dell'Acqua, Valabregue, & Catani, 2012; Makris & Pandya, 2009; Rilling, Glasser, Jbabdi, Andersson, & Preuss, 2011). While some of these pathways have been relatively preserved during the evolution of great apes and humans, others were substantially reorganized. The trajectory of the arcuate fasciculus, for instance, has been strongly modified in human brains, linking the left frontal cortex to the middle and inferior frontal gyri and parts of Broca's and Wernicke's areas (de Schotten et al., 2012). In contrast, in macaques the terminal connection of the arcuate fasciculus leads to areas of the visual cortex, whereas in chimpanzees connections with the inferior parietal lobe (supramarginal and angular gyri) are dominant (Rilling et al., 2008). This suggests that the cortical organization and connections of the arcuate fasciculus have undergone significant changes during human evolution by establishing connections

to and from the core language areas, supposedly subserving linguistic functions in the human brain.

In summary, the existing literature on the neurobiology of Broca's and Wernicke's areas and their connections in human and nonhuman primates notes a number of similarities as well as differences between the species. One of the key questions that now emerges is when the human-typical adaptations arose during human evolution.

4 **PALEONEUROLOGY: LANGUAGE AREAS IN THE BRAINS OF ARCHAIC HUMANS**

As language is ubiquitous to all modern humans, it must at least date back to before 200,000 years ago when all modern humans shared a common ancestor (Cann, 2012). In line with evolutionary theory, language could have been formed through gradual adaptations within the existing gene pool of variation and without any extreme mutations prevailing to spread to future generations (Bickerton, 2002).

Because of a lack of data, no definite evidence exists that could tell us about the presumed communication systems of the extinct members of the *hominin group* (i.e., the genus *Homo*) or the neurobiological correlates of their linguistic ability. However, indirect evidence can be gathered by studying brain morphology of archaic humans. This is possible with skull imprints, so-called *endocranial casts* (or *endocasts*, see Figure 2) that show the indentations of the former brain and blood vessels on the inside of the skull (Holloway, Broadfield, & Yuan, 2004). By using this method, particular brain regions can be identified and analyzed in terms of their size. Endocast studies are a standard methodology of *palaeoneurology*, but unfortunately, researchers are often confronted with the problem of incomplete and fractured skulls from which sulcal indentations can be difficult to determine. Therefore, a certain degree of uncertainty is imminent to this method. Nonetheless, endocast models are valuable and crucial tools for understanding hominin brain evolution when very little direct evidence is available.

The immediate ancestors of humans, the *Australopithecines*, likely did not appear until four million years ago during the Pliocene in East Africa



Figure 2. Endocasts from Sambungmacan *Homo erectus* from Indonesia. Broca's area is enlarged in the left hemisphere in comparison to the right one (reprinted from *The Anatomical Record*, Vol. 262, Broadfield et al., Endocast of Sambungmacan 3, p. 375, Copyright (2001) with permission from Wiley).

(see Figure 3; Leakey, Feibel, McDougall, Ward, & Walker, 1998). Their cranial capacity was about 400–450 cubic centimeters (which is comparable to large chimpanzee brains) and tentative evidence suggests an occipital asymmetry (Holloway, 1983). Concerning the language regions, it is disputed whether Broca's area is clearly defined on Australopithecine endocasts (Holloway, 1983). Falk (1980), for instance, sees enough evidence for the argument that the Australopithecine Broca's area resembles that of great apes. For Wernicke's area, only tentative evidence exists. The assumed increase in the posterior parietal association cortex of Australopithecine brains could have resulted in reorganization of certain temporal regions, including Wernicke's area, by around three million years ago (Holloway, 1983; Spocter et al., 2010).

With the advent of the genus *Homo*, evidence for the core language areas becomes clearer on endocasts. When exactly the first archaic human emerged has been a matter of discussion, though it is assumed that by 1.9 million years ago *Homo rudolfensis* had appeared in East Africa (Antón, Potts, & Aiello, 2014). Those bipedal, terrestrial creatures possessed a brain the size of around 530 cubic centimeters, and the endocast of a famous skull from the Turkana Basin (KNM-ER 1470) shows clear imprints of an asymmetric Broca's area similar to that of modern humans (Holloway, 2015). Contemporary species to *H. rudolfensis* may have in-

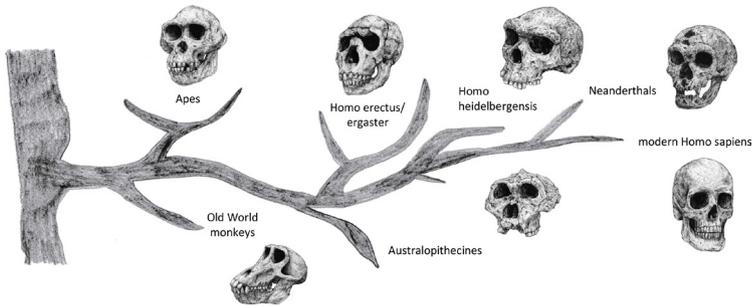


Figure 3. Human family tree.

cluded *H. habilis* and *H. erectus/ergaster* (Boyd & Silk, 2015), and endocasts of specimens of both species seem to demonstrate an asymmetric enlargement in Broca's area (Harris, 1998; Tobias, 1998). Wernicke's area is assumed to have resulted from the general growth of the superior temporal areas (see, e.g., Oubre, 1997). *H. erectus*, the first human to expand beyond Africa and a direct ancestor of modern humans (e.g., Sept, 2015), had evolved larger brains (approximately 1,000 cubic centimeters) with a clear left-occipital-right-frontal asymmetry and a pronounced Broca's cap, as is characteristic for modern humans (Wu, Holloway, Schepartz, & Xing, 2011). Wynn (1998) suggests that both Broca's and Wernicke's areas in *H. erectus* were distinctly human-like.

Approximately 600,000 years ago, a new species appeared in Europe, *Homo heidelbergensis*, which was only a bit smaller-brained (approximately 1,200 cubic centimeters) than modern humans (which is around 1,250 cubic centimeters, see, e.g., Boyd & Silk, 2015). Endocast prints show that their brains were left-occipital-right-frontal asymmetric and showed a prominent bulge in the left hemisphere over Broca's area (Holloway et al., 2004). By 300,000 years ago, the evolutionary transition began that would lead to *Homo neanderthalensis* in Europe. Neanderthals had a brain larger than those of modern humans (approximately 1,500 cubic centimeters) and displayed a clear asymmetry in Broca's area (Holloway, 2015; Jerison, 1997). According to Holloway (1985), Broca's area is as developed on Neanderthal endocasts as it is in those of modern humans. *Homo sapiens altai* (or *Homo sapiens* *ssp.* *Denisova*, or simply

Denisovans), close relatives of Neanderthals and modern humans whose fossils were recently discovered in Russia and China, had the largest brains of all archaic humans known today (approximately 1,800 cubic centimeters, Li et al., 2017). At present not much is known about Broca's and Wernicke's areas in this species.

While left-hemispheric asymmetry is well established in archaic humans, its relation to language function is unclear. In an attempt to put together more puzzle pieces to supplement the scarce data that exists on the neurobiology of archaic humans' language capabilities, researchers have started to include additional information from fossils that could be related to linguistic function, such as hand preference (Steele & Uomini, 2009). The archeological record can provide evidence for hand preference of a species through material culture (tools, artefacts) as well as through skeletal asymmetries resulting from preferential use of one limb. Even though right-hand preference is suggested to date back as far as 1.9 million years ago (Toth, 1985), the evidence becomes substantial with *H. heidelbergensis* (Lozano, Mosquera, Bermudez de Castro, Arsuaiga, & Carbonell, 2009) and the Neanderthals (Frayer et al., 2012; Uomini, 2011). Whether language and handedness evolved in tandem in archaic hominins is difficult to answer based on the current data, and the exact nature of the concatenation of language and handedness in hominins remains unknown at present.

The existence of the modern core language areas in the brains of archaic humans is certainly tantalizing for research into language origins, though the evidence is mostly uncertain or even highly speculative at times. An enlarged Broca's cap, for instance, may also appear on endocasts of large chimpanzees, indicating that language does not need be the driving force behind its increase (Holloway, 1983). More generally, there is no evidence that these areas in archaic humans functioned as speech/language centers. Without additional evidence regarding respiratory control and vocal tract anatomy of a species, it is difficult to ascertain solely from neuropaleontological data whether a species possessed the abilities to develop a verbal form of *proto-language* (Deacon, 1997; however see Fitch, De Boer, Mathur, & Ghazanfar, 2016). Anthropological research often has to draw on circumstantial evidence to construct a case for language in archaic hominins, connecting, for instance, the production of art or tools to symbolic language.

A new research avenue that has recently opened up is the inclusion of genetics into the question of the origins of human language. Advances in molecular technology have made it possible to start to relate specific brain regions to a set of underlying genes, whose expression directly influences the development of that region. Relevant findings concerning the neurobiology of language have resulted from this research and the forkhead box protein p2 (known as *FOXP2*) has been suggested to play a role in the functioning of Broca's and Wernicke's areas (Liégeois et al., 2003). The gene has also been identified in Neanderthals (Krause et al., 2007) and Denisovans (Meyer et al., 2012), which has spurred hypotheses on language abilities in those close relatives of modern humans. Another recent gene discovery could make important contributions to the genetics of language: *GPR56* is strongly linked to the Sylvian fissure language region, including Broca's area (Bae et al., 2014). New emerging hypotheses on the genetics of language should take into account what role the gene might have played during human evolution.

The field of language evolution has naturally suffered from paucity of data, due to the fact that cognitive abilities do not fossilize, and one way forward can be seen in modern *neurogenetics*. Through the identification of particular sets of genes that are crucial for the development of relevant language areas in the human brain and by comparing those data to genetic information gathered from extant nonhuman primates and extinct hominins, new insights will be possible. The field of *paleogenetics* is only just emerging as a key player in the evolution of language, but it may well turn out to be the missing link between primatology, paleoanthropology and modern linguistics that can move the field of language evolution forward in the 21st century.

5 CONCLUSION

In modern humans, Broca's and Wernicke's areas are complex cerebral regions mediating a versatile range of functions related to language. In terms of their evolutionary history, it can be assumed that the new linguistic functions of *Homo sapiens* brains arose most likely through the modification of existing brain circuitry that was present in the last an-

cestor of humans. The neurobiological correlates of today's linguistic abilities were built on pre-existing neural structures that subserved different cognitive abilities in primate history. It is the most likely evolutionary scenario that Broca's and Wernicke's areas originally processed information in ways that happened to be useful to language: Broca's area may have evolved to extract and analyze sequential and motor patterns while Wernicke's area may have evolved out of a more general ability to analyze species-specific calls. Both of these skills make a useful substrate for language to utilize and their neural connectivity and behavioral interplay could have provided the crucial impetus for the development of the linguistic mind.

ACKNOWLEDGEMENTS

This work was made possible by the *Research Resettlement Fund for New Faculty* and the *Overhead Fund 2017* of the College of Education of Seoul National University. I thank Jong-seung Sun for her help during the preparation of the manuscript and the artist Jaehyeong Yoo who created the drawings. In addition, I am grateful to five thoughtful reviewers who provided valuable comments for improving the manuscript.

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Times change, values change: Criteria for attributing *language* in species comparative research

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ABSTRACT Charles Darwin's idea of a common origin of species stimulated cross-species comparative research on all kinds of phenomena, among them *language*. Research on language, however, is faced with the problem of defining the term at issue. Across times and disciplines, researchers ascribed a notoriously diverse set of properties to the faculty of language. The consequent ambiguity surrounding the term still exists, which is – as we hypothesize – the result of divergent scientific norms and historical influences. The current chapter aims to reconstruct three selected properties of language that historically had an important impact on species comparative language research, but which emerged in fact from social norms and subjective values, namely: (i) the *norm of directed progress*; (ii) the *oral norm*; and (iii) the *behavioristic norm*. The idea of *primitive* compared to *more complex* species (i), for instance, marginalized the complexity of birdsong. A narrow focus on the oral modality (ii) precluded the serious investigation of gestures in humans and non-humans. Also, excluding inner mental processes from the area of scientific knowledge (iii) disqualified non-humans from cognitive comparison. In the history of the species comparative language discourse, those value-based norms often created a narrative of human specialty by constraining the applicability of the defining properties to a narrow subset of skills. The current chapter aims to reconstruct the change of values over time in order to point to

recurring thoughts and methodological pitfalls such as sampling biases, a priori assumptions and anthropomorphism. By consulting the history of the language discourse, it is possible to explain and reveal the aftermaths of the norms, which strongly influence current research using cross-species comparisons and consequently enter current debates about language definitions.

KEYWORDS cross-species comparative sciences, history of science, language theory, meta-research, values in science

1 INTRODUCTION

Some scientists consider language to be the “most salient behavioural difference” and “separator” between humans and non-human animals (Wallman, 1992, p. 5). From cross-species comparative perspectives, prominent questions are: *Is human language unique?* (e.g., Smit, 2016) and *Do other species possess analogue or homologue language abilities?* (e.g., Fitch, 2017). Yet, underneath those and similar questions rests an ongoing discussion about the definition of language. The closer life sciences investigate the topic, the more a theory of *language* disintegrates. Instead of a commonly shared definition, there remain constructions with sometimes incompatible conclusions (see Botha, 2016; Wacewicz & Zywickzynski, 2015). For instance, for some scientists the communicative function of language is a side effect complementing the more important *system of thought* (e.g., Chomsky, 2011), while for others it is the other way around where the function of communication caused “language to be a vehicle of thought” (e.g., Okanoya, 2017, p. 1).

The apparent lack of unity between scientists regarding the defining properties of language is as old as the debate about the origins of language. According to Rudolf Botha (2016), this might have its roots in (a) conflicting judgments about the theory at issue, (b) different ideas about the methods of finding evidence, and (c) divergent interpretations of the strength of evidence. Consequently, in all aspects, it is the scientist’s *judgment* that is at the core of diverging assessments. Judgments, however, are not made by unbiased brains, but are underpinned by a set of implicit historical influences and social values. Those values – sometimes denot-

ed as *social norms* – not only influence judgments on (a) to (c), but also leave their marks on the theory of biological evolution and linguistic ontology that scientists employ. For that reason, it is the aim of the current chapter to focus on social norms influencing the assessment of the design properties of language. Norms are especially potent where “social categories and the images they embed are inescapably value-laden” (Davis, 2013, p. 554). That is assumed to be the case with the species comparative language discourse, where scientists try to create a valid human self-conception with reference to a supposedly unique human characteristic, namely language. Given the entanglements between science and values or norms, it appears to be more productive to monitor them instead of combating them in their entirety. The current chapter aims to present three examples of how historical norms influenced, and sometimes still influence, the discourse. Unveiling those historical norms might help future empirical research in clarifying the experimental design, the formulation of questions and subsequent interpretation of data. As such, the chapter contributes to the process of scientific self-correction.

2 **FROM SCALA TO CONTINUUM: TELEOLOGY IN BRAIN ARCHITECTURE**

In 1999, the primatologist Frans de Waal wrote: “the comparative aspect of comparative psychology is essentially anthropocentric: extrapolations are generally from animals to humans along a *linear progression from lower to higher forms*” (de Waal, 1999, p. 257, italics added). The direct consequences of what de Waal criticizes are spelled out for the language discourse by Martin Sereno:

There is a powerful perennial tendency outside fields explicitly focused on evolutionary processes to think of evolution in terms of a ‘Great Chain of Being’ and to ignore the mosaic nature of evolution. Thus, birdsong has often been dismissed as a model of human language for the reason that monkeys seem much smarter than some birds (Sereno, 2014, p. 5).

The observation from Sereno and the phenomenon addressed by de Waal belong to a social norm whose validity in fact was supposed to belong to a bygone era. There is talk of the norm of *directed progress*, also known as *Scala Naturae* or *Great Chain of Being* (Ghiselin, 2005; Hodos & Campbell, 1969; Ruse, 1996). Behind the idea of a *Scala Naturae* there is the assumption that evolution proceeds in a linear *upward* way from a simple or *primitive* condition towards an *improved* (mostly human) state.

Although some researchers stick to the metaphor even today (e.g., Lourenço & Bacci, 2017, p. 1 “[...] with *Homo sapiens* putatively at the top of the scale”), this is not how evolution proceeds. Evolutionary processes are initiated by random variation with natural selection, but they are not directed towards a *most sophisticated* end state (Johnson, Lahti, & Blumstein, 2012). Indeed, as mentioned by Sereno, until the beginning of the 20th century, species were divided into *lower* and *higher* ones. Birds, at this point, are just one example for an allegedly *primitive* species among others (see Hodos & Campbell, 1969). The empirical foundation of the idea was laid in earlier works by neurologists Hughlings Jackson (1835–1911) and Ludwig Edinger (1855–1918), to name a few. Jackson was highly influenced by Herbert Spencer (1820–1903), also known as “Britain’s chief prophet of Progress” (Ruse, 1996, p. 30). Following Spencer’s teleological assumptions about evolution in general,¹ Jackson proclaimed a “climax of nervous evolution” (Jackson, 1884, p. 591) where *higher* neurological areas – such as the cortex – suppress the function of the *lower* parts (York & Steinberg, 2011). Edinger came to similar conclusions when he compared brains of fish, birds, amphibians and mammals. He was the first to assign the names *palæencephalon* to *lower* brain areas and *neëncephalon* to the *higher* ones. The names were later modified into *paleocortex* and *neocortex* by Dutch neurologist Ariëns Kappers (Kappers, 1929). The prefixes *paleo-* and *neo-* were supposed to represent the alleged age of their evolutionary origin. Edinger identified the palæencephalon in all species, but he found the neëncephalon only “above fish [where] it increases to that enormous organ, the cerebrum, which in man fills almost the entire skull” (Edinger, 1908, p. 438).

¹ “Evolution is a passage from the most simple to the most complex” (Jackson, 1884, p. 591)

The typical narrative of that time leads from *primitive* reptiles to humans *at the top*. As a consequence of that narrative, scientists considered birds as incapable of any “intelligent action” because of their “purely instinctive behavior” which is “governed by emotion” (Emlen, 1948, p. 37). Similar statements can be found frequently at the beginning of the 20th century, for instance in a book from Judson Herrick, who was a comparative neurologist and publisher of the *Journal of Comparative Neurology*. He wrote: “It is everywhere recognized that birds possess highly complex instinctive endowments and that their intelligence is very limited” (Herrick, 1924, p. 213). Those claims found their way into classic textbooks such as *Principles of Animal Psychology* from Maier and Schneirla: “Birds possess an extensive repertoire of highly stereotyped activities” and “seem to behave rather stupidly” (Maier & Schneirla, 1935, pp. 235 & 478). Bird’s *primitive* origin and their *simple* brains were perceived as exhibiting reflexes and instincts only,² while “in the mammals we meet a brain which has so large a neöencephalon that we may well expect a subordination of reflexes and instincts to associative and intelligent actions” (Edinger, 1908, p. 453).

Because of this line of argumentation, birds were excluded from the mainstream of comparative language discourse, especially from the 1880s to the 1950s (see Baker, 2001, for more details). Birdsong was perceived as something purely instinctive, in stark contrast to intentionally produced human language. While language “must be learned laboriously by the human child”, song was considered to be a “purely innate code”, hard-wired and genetically determined (Lorenz, 1949/2002, p. 74). In 1951, Otto Koehler noticed that common field guides for songbirds did not mention *subsong* (German ‘Jugendgesang’) because most scientists did not expect learning to be involved in song acquisition (Koehler, 1951). The birds’ small and light brains were not considered to be an ecological adaption for flight, but interpreted as indicator for their *primitive* status (Emery, 2006). Some were convinced that birds and their *reptilian brains* would “lack the neural machinery for verbal communication” (MacLean, 1977, p. 159). A sampling bias towards chicken, quail or pigeons further

² Edinger admittedly adds: “instincts whose perfection is so great that it has not always been possible to distinguish them from activities which are dependent upon the cortex” (Edinger, 1908, p. 451)

reinforced prejudices as exemplified by a passage from psychologist David Premack: “Although the rat and pigeon may have property-identifying tags, I rather doubt that I could exploit these tags, associating different pieces of plastic with each of them, thereby teaching these non-primates something functionally equivalent to the words *color of, shape of* and the like. Yet this is exactly what we have been able to do with the chimpanzee” (Premack, 1983, p. 133). Note that parrots and corvids are able to perform those tasks very well (Güntürkün & Bugnyar, 2016; Güntürkün, Ströckens, Scarf, & Colombo, 2017), but unlike primates, bird behavior was usually interpreted from a low-level perspective. While birdsong was often seen as mere expression of the callers’ emotional state (Thorpe, 1958), primate signals were considered “referential”, as means to “convey information about salient objects and events in the environment” and “allow individuals to make adaptive responses” (Hauser, 2000, p. 463; but see Liebal, Waller, Burrows, & Slocombe, 2014, p. 171 for the classical dichotomy between intentional and emotional signals in primate communication).

Back in the 1960s, the neurologist Harvey Karten wondered how “the richness of avian behaviour” could exist without “the presence of an intact neocortex” (Karten, 2015, p. 4). But it took until the 21st century to change the perspective on the significance of birdsong drastically (Emery, 2006; Shimizu, 2009). Only very recently, a consortium recognized the *old* bird brain nomenclature as wrong, misleading and motivated by a *norm of progress*. The Avian Brain Nomenclature Consortium decided to rename and reassess large areas of the bird brain and “eliminated all phylogeny-based prefixes (palaeo-, archi- and neo-) that erroneously implied the relative age of each subdivision” (Jarvis et al., 2005, p. 155). The new paradigm encouraged scientists to question the cognitive performance ranks across species and to proclaim gradual parallels between birdsongs and human language in terms of neural circuits (Nottebohm, Stokes, & Leonard, 1976), vocal learning (Thorpe, 1958), imitation (Marler, 1970) and dialects (Baker & Michael, 1985). The failing of the *norm of progress* did now encourage an unbiased debate about what scientists believed to be the shared biological substrates of *language* (see Doupe & Kuhl, 1999). Although implicit indicators sometimes still point to the persistent presence of the norm of progress in current literature (Ullrich, Mittelbach, & Liebal, 2018), the debate no longer explicitly excludes cer-

tain species based on their phylogenetic distance to humans (Güntürkün et al., 2017). Widening the scope to non-mammalian species revealed traits in songbirds that were supposed to be uniquely human, such as critical learning periods (e.g., Bolhuis, Okanoya, & Scharff, 2010), social shaping of babbling (e.g., Goldstein, King, & West, 2003), phonology (e.g., Yip, 2013), syntactical structure (e.g., Berwick, Okanoya, Beckers, & Bolhuis, 2011), specialized brain circuits (e.g., Jarvis, 2013), and genes related to vocalizations, such as the transcription factor FoxP2 (e.g., Scharff & Petri, 2011).

In sum, there are various reasons why birdsong became a model for comparisons with human language. However, an additional important reason for the interest in birdsong might also be its vocal modality, shared with human language. The oral-vocal modality did and still does motivate researchers to assume a close relationship between human and bird utterances, which implies another social norm that is described as *oral norm* hereafter.

3 **FROM SPEECH TO GESTURE: OVERCOMING A TOO NARROW CONSTRUCTION**

Until the middle of the 20th century, scientists had no doubt that one decisive characteristic of *language* was its verbal nature, and more specifically, the oral modality, which has a number of important implications. The American psychologist James Coleman wrote the popular sentence: “The fish will be the last to discover water” (Coleman, 1960, p. 59). Thus, the fact that the oral-vocal modality was set as a defining feature of language was rarely noticed. Authors from the early modern period interpreted *speech* and *language* as being inextricably linked with each other (Serjeantson, 2001). The linkage entails that “language is a necessary condition of thought [...] and was translated by the body machine into action [= *speech*, added by author]” (Kiriazis & Slobodchikoff, 1997, p. 365). Linguist Edward Sapir implicitly continued to share those ideas in 1921, when he published an influential textbook titled *Language: An Introduction to the Study of Speech* (Armstrong & Karchmer, 2009). In his famous article *The Origin of Speech*, Charles Hockett wrote that the “vocal-au-

ditory channel” is the most obvious design feature, which “appear[s] so trivial that no one looking just at language would bother to note” (Hockett, 1960, p. 6). Consequently, scientists using cross-species comparisons continued to promote an oral picture of language: “a language, if it is to achieve its full potentialities, must be a language of sounds” (Thorpe, 1958, p. 537). The implicit preference for oral-vocal utterances similarly affected research on primates:

If one were looking for parallels with the process of human vocal learning, the most obvious place to look would be in our closest surviving relatives, the apes and monkeys. Surprisingly, no one has yet discovered a non-human primate with any facility for vocal imitation (Marler, 1970, p. 669).

Peter Marler wrote this sentence after at least six failed attempts to teach verbal utterances to various ape species (see Kellogg, 1968; Miles, 1997; Radick, 2007). To what extent those teaching attempts are informative is the matter of an ongoing debate on a methodological and semantic level (e.g., Kellogg, 1968; Lameira, 2017). However, in the 1970s those results led researchers to conclude that apes were of little use in research about vocal learning:

In broaching the comparative investigation of vocal learning it might seem logical to study the abilities of nonhuman primates in this regard. This approach has yielded results which though interesting in themselves, are in some respects disappointing. [...] Thus, apes demonstrate no great facility for vocal imitation (Marler, 1970, p. 1).

Evidence on hand suggests that the socioecology of present-day non-human primates is an unsatisfactory springboard for vocal learning of any consequence (Nottebohm, 1972, p. 133).

The reasons why Marler and Nottebohm preferred the communication of songbirds over primates when comparing human language to non-human forms were grounded in their reservations towards other, non-verbal means of communication. Until the 1960s those reservations also inhibited the realization of suggestions from the psychologists Robert

Yerkes and Lev Vygotsky, who promoted the teaching of visual-gestural signs or symbols instead of vocalizations (Vygotsky, 1934/1986; Yerkes, 1925). To understand the delay in implementing those suggestions, reference to the separate deaf-discourse provides valuable insights. The institutional education of deaf students at the beginning of the 20th century was dominated by the so-called *oral method*. The use of *manual gestures* was mostly forbidden at schools for deaf students in Europe and North America (McDonnell & Saunders, 1993). Instead, deaf students were forced to learn oral utterances. As a result of inadequate *oral* teaching methods, students suffered dramatic deterioration of education and frequently became functional illiterates (Sacks, 1990). One reason to suppress manual and to force oral communication was a long held conviction that manual signs cannot be a *natural language* and must be *deficient* compared to oral sounds:

Beside speech there is no other generally used universal sign system. [...]. Other sign systems, like the deaf-mute language [...] are either transposed, restricted or parasitic (Lotz, 1950, p. 712).

Ideographic language systems, in comparison with verbal symbol systems, lack precision, subtlety, and flexibility [...]. Comparatively, a verbal language is more abstract (Myklebust, 1964, p. 241).

It took decades of research by early pioneers like William Stokoe, Robert Johnson, Adam Kendon and Scott Liddell (linguists); Edward Klima and Ursula Bellugi (psychologists); and Harlan Lane and John van Cleve (historians) to uncover, challenge and overcome the pre-empirical claims as expressed by Lotz and Myklebust (see Ullrich, 2016). A new generation of researchers broadened the – in their view – too narrow perspective on *language*. For them, language entails more than the oral-vocal modality. Rather, it includes gesture and body posture (Goldin-Meadow & Brentari, 2017; Kendon, 2008; McNeil, 1992). By and large, the defining properties of language became independent of modality associated with an increasing promotion for multimodal or cross-modal accounts of human language (Vigliocco, Perniss, & Vinson, 2014).

The cross-species comparative language discourse absorbed many of the ideas sketched above. However, it was only after *American Sign*

Language was acknowledged as a natural *language*, and only after the failure of oral-vocal in contrast to alleged success of visual-gestural experiments with apes (Gardner & Gardner, 1969; Premack, 1971) that the gestural origin was reconsidered (Hewes et al., 1973). While the results of both the oral and gestural *ape language* experiments received fundamental criticism after their publication (Leavens, Bard, & Hopkins, 2010; Rivas, 2005; Terrace, 1979), the idea that the defining properties of language are independent of their modality became prevalent. Nowadays, research focuses both on oral accounts (Lameira, 2017) and on gestural accounts (Liebal, 2017), but most importantly, there is an increasing attention on an integration of multimodal or cross-modal research (Partan & Marler, 1999; Slocombe, Waller, & Liebal, 2011). In fact, the last two decades of multi- and cross-modal research have shown that the use of a certain modality is not necessarily a marker for sophisticated communication but may rather be explained by environmental conditions (Partan, Fulmer, Gounard, & Redmond, 2010; Waller, Liebal, Burrows, & Slocombe, 2013). The more the defining properties of language became independent of normative attributions about modality, the more types of animal communication could fit the concept of *language* in principle. However, some scholars strictly reject that perspective, claiming that the external features of language are ontologically different from the inner mental functions (Bolhuis, Tattersall, Chomsky, & Berwick, 2014). This demands a closer look on the presumed dichotomy of *internal* and *external*, to understand the historical roots of the *cognitive turn*, which was meant to overcome the *behavioristic norm*.

4 **FROM EXTERNAL BEHAVIOR TO INTERNAL PROCESSING: THE EXAMPLE OF INTENTIONALITY**

The term *intentionality* has made it to the top of the most discussed defining properties of *language* (see, e.g., Liebal et al., 2014; Townsend et al., 2016). Its usage started with Franz Brentano (1838–1917) who reintroduced the term from scholastic philosophy (Brentano, 1874/2009). Paul Grice (1957, 1969) brought it forward to the language discourse, followed

by Daniel Dennett (1971, 1983) who transferred the concept into the species comparative discourse.

The term *intentionality* was introduced in the comparative sciences during the early 20th century, when behaviorism dominated the discourse on language in the United States. The *behavioristic norm* (see Graham, 2015 – here denoted as *doctrine*) arose as a countermovement to 19th-century *animal psychology*, where scientists ascribed *purposes*, *feelings* and *abstract thought* to their study species (e.g., Romanes, 1879; Radick, 2007). For critics of that *anthropomorphic mentalism*, the anecdotal approach of animal psychology was nothing other than unfounded metaphysics (Jamieson & Bekoff, 1992). In order to abandon the *metaphysical mind-matter-dualism* (see also Marko and Wimmer in this volume) and in hopes of unifying science towards a positivist orientation, behaviorists called for rigorously controlled experiments, where the “facts to be observed are external phenomena, physical occurrences in the objective world” (Morgan, 1903, p. 48). For researchers driven by the *behavioristic norm*, any science that does not focus on quantifiable entities (e.g., *introspective psychology*) is not a “proper science” (Radick, 2016, p. 73). In such a climate, a term like *intentionality*, defined by Brentano as *hallmark of the mental* (Jacob, 2014), was difficult to use. Still, it was used by European ethologists because for them descriptions of behavior freed from *mentalist* vocabulary were hard to sustain. When explaining and predicting behavior, ethologists like Oskar Heinroth (1871–1945), Konrad Lorenz (1903–1989), and Nikolaas Tinbergen (1907–1988) introduced the term “intention movement” (German ‘Intentionsbewegung’) (Heinroth, 1910/1990, p. 680; Lorenz, 1937, p. 292; Tinbergen, 1939, p. 223). According to the definition of Heinroth, the term *intention movement* serves as a methodological stance, where “the trained behaviour student can derive from their study a knowledge of what the animal is intending to do in the next few moments” (Daanje, 1950, p. 48). However, the understanding of *intention* at this stage of the debate was very different from what Brentano (1874/2009) had in mind when he revived it. As Lorenz once clarified, the fulfillment of an intention movement follows a “biological purpose” (Lorenz, 1937, p. 292). The beating heart has the *biological purpose* to keep the body alive. The heart, however, does not have a *psychological intention* to do so. The ethologists at the beginning of the 20th century did not use the term *intention* in the sense of Brentano’s coinage of an inner

mental state. For them, it was a method of explaining behavior as *biologically purposeful* (see Millikan, 1997).

The ethologist Peter Marler was clearly a direct descendant from ethologists with behavioristic influence. In his article *The logical analysis of animal communication*, he warns “about the dangers of the introspective method in animal studies” that comes with “anthropocentric pre-conceptions” (Marler, 1961, p. 297). In his view, animal communication has to be described as behavior in “objective terms” where “semantics are of doubtful value” (Marler, 1961, p. 299). In an earlier paper, Marler defines language as “a means of communication between individuals, by means of sound signals” (Marler, 1956, p. 245). As for many ethologists, Marler believes that language is first of all a communicative system, whereas research must transfer attention “from pragmatics to syntactics to consider the physical nature of some of the signals used” (Marler, 1961, p. 309). Those statements might be reminiscent of the American structuralist Leonard Bloomfield. His linguistic theory was also motivated by the *behavioristic norm* and led to the conviction that objective research on language must exclusively concentrate on form, including phonology, syntax, or morphology (Bloomfield, 1943; Levelt, 2013).

During the 1970s, Peter Marler started a collaborative project with Dorothy Cheney and Robert Seyfarth to investigate the alarm calls of vervet monkeys. Given his earlier remarks on the value of comparative research, the first sentence of their paper in *Science*, outlining the results from the collaboration, may come as a surprise: “A central but neglected issue in the study of animal communication is that of semantics” (Seyfarth, Cheney, & Marler, 1980, p. 801). Semantics, which he earlier denoted of “doubtful value” (Marler, 1961, p. 299), is now at the centre of the narrative. However, Marler did not turn into an anti-behaviorist. In principle, he opens up the possibility for unobservable mental representations, but he still uses behavioristic vocabulary and sticks to the study of *objective physical phenomena*. It is Daniel Dennett, philosopher and proponent of a concept of *intentionality* in the tradition of Brentano, who celebrates Seyfarth, Cheney and Marler as “new ethologists, having cast of the straightjacket of behaviourism” (Dennett, 1983, p. 343). It is he who exploits the vast potential of the study for his own *intentional system theory*. Dennett borrows his theoretical foundation from Brentano and Grice and uses intentionality in the philosophical rich sense as a form of

directedness of the mind towards a content or object (Glock, 2001). As Millikan (1997, p. 194) once explained:

The difference between merely biological purposes and intentional purposes is that in the latter case the animal's biological purposes are implemented via the manufacture and use of inner representations.

Consequently, Dennett experiences research with vervet monkeys as an opportunity to discuss representations, beliefs, desires and the like in animals. In his opinion, reference to inner mental realities is needed to sufficiently explain and predict the vervets' behavior and to answer questions about language and communication in general. Dennett was not the first to introduce intentionality in the philosophically rich sense into species comparative research (see Révész, 1944; von Glasersfeld, 1974, 1976), but his writings fell on fertile ground at a time when the cognitive turn in linguistics and psychology was well underway. The introduction of intentionality achieved further support from psychologists like David Premack (Premack & Woodruff, 1978) and Michael Tomasello (1985), as well as from the philosopher John Searle (1984). Robbins Burling summarized the consequence of the cognitive shift for the language discourse: "Given that language is inseparably bound up with human cognition, the most promising place to look for the antecedents of language is in primate cognitive abilities" (Burling, 1993, p. 25). Hence, questions about mental phenomena like *reference* (Sievers & Gruber, 2016), *recursion* (Martins, 2012), and *deception* (Oesch, 2016) became the subject of cross-species approaches in language research, with research about intentionality representing just one of many candidates serving as a potential defining property of language.

Peter Marler, like other ethologists influenced by behaviorism, never stepped back from his so-called *objective research approach*. Thus, he continues to use terms like *phonological syntax* instead of *syntax*, *functional reference* instead of *reference*, and explains behavior from the perspective of *biological purpose* instead of *psychological intention*. Marler justifies his position by explaining that "the role of the many dimensions of mindfulness still remains unclear" because of the impossibility of "introspection" and a lack of "appropriate experiments" (Marler, 2000, p. 32). Ethologists in behavioristic tradition nowadays use the term *inten-*

tionality as means of a *biologically purposive behavior* (e.g., Vail, Manica, & Bshary, 2013). In contrast, cognitive scientists often use it in the philosophically rich sense as *psychologically purposive behavior*. The behavioristic norm that banished the mind from *objective science* deceased, but the divergent use of the term *intentionality* still draws conclusions about its historical background. Once used to describe external behavior, it is deployed frequently nowadays to explain internal processing and thereby considered an integral defining property of language.

5 CONCLUSION

We have highlighted the influence of value-driven norms for defining the term *language* in the discourse involving species comparative approaches to language evolution. While the examples presented show how a theory of language was restricted or modified by various values throughout the 20th century, the use of values in science among all disciplines and all times is pervasive, as a body of classic studies (Feyerabend, 1975; Kuhn, 1977; Latour & Woolgar, 1979) and some recent publications (Davis, 2013; Douglas, 2016; Elliott & McKaughan, 2009) testify. However, while it is easy to identify values in research papers retrospectively, it becomes more complicated for contemporary publications because of their implicit character. Certainly, the history of the discourse can teach us that norms still govern recent language definitions. Those norms frame the narrative of publications and constitute the theoretical basis for defining properties as associated with *language*, as suggested by Ray Jackendoff (2010, p. 63): “Your theory of language evolution depends on your theory of language”. This chapter adds to this notion that the theories themselves are influenced by subjective norms. Yet, norms and values must not be immediate indicators for *bad science*. Instead, they can motivate scientists to choose a certain study species, to design their experimental procedures, to use a specific vocabulary, and to weigh the evidence found (Douglas, 2016). As shown in the current chapter, values might change over time, but they cannot be excluded from scientific practice. Also, they do not have to be excluded, as values might expose alternative answers to questions where empirical evidence is scarce. Good science is not to

deny subjective influence on scientific practice, but to bring that influence to light. That requires making transparent the individual scientific background of researchers and their personal motivation for the topic. As long as such details are not considered, meta-research about those issues is needed to uncover current norms influencing the discourse and to understand the latest attempts of answering the question: *What is language?*

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From grasping to pointing: The evolution of referentiality in man and animals

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ABSTRACT Pointing with the help of the index finger may be one of the most conspicuous human behavioral patterns. Even though similar behaviors can occasionally be seen in some great apes, the ritualized form of using a special pointing finger to show or explain something to a conspecific suggests that this behavior has become anatomically internalized by our species. Pointing in its various forms represents such a frequently used behavior that human cooperation would be barely imaginable without it. In addition, even the modern digital world still heavily relies on pointing devices, such as the computer mouse or a joystick. Hence, it appears justifiable to treat this unique motor pattern as one of the possible evolutionary ignition sparks which, approximately 6 to 7 million years ago, caused humans and apes to continuously drift apart with regard to their specific socio-cognitive abilities. In other words, the distinct social world of human symbolic communication in all its manifold facets may have begun with the invention of the act of pointing. This review attempts to show that it is possible to develop the following evolutionary scenario: First, the original grasping behavior, as already displayed by primitive primate species (lemurs) slowly evolved into a characteristic begging movement involving the extended hand (in monkeys), and finally, then into a ritualized pointing gesture using the index finger with a clear referential meaning in the *Hominoidea* (apes and humans). Second, during phylogeny the production of any higher cognitive behavior, such as pointing, always preceded its comprehension when shown by a conspecific. Third, young human

infants show grasping and then begging attempts toward remote objects before eventually pointing at them in an intentional manner, which supports the idea that ontogeny recapitulates phylogeny (the so-called *Biogenetic Law*). Fourth, relaxed environmental selection conditions might have been favorable to the evolution of referential pointing in primates. In sum, this may explain why humans and apes, to a certain degree, can communicate with each other in a clearly referential manner about concrete aspects of the world.

KEYWORDS Biogenetic Law, evolution of pointing, grasping, referential gesture, relaxed selection

1 INTRODUCTION

A short review of the literature shows that among higher vertebrates, true pointing gestures primarily occur in the family of primates (see, e.g., Leavens & Hopkins, 1999; Veà & Sabater-Pi, 1998). Few other animals appear to understand pointing (e.g., wolves and dogs: Kubinyi, Virányi, & Miklósi, 2007; seals: Shapiro, Janik, & Slater, 2003; and elephants: Smet & Byrne, 2013), or are capable of producing pointing-like behaviors themselves (e.g., horses: Malavasi & Huber, 2016; dolphins: Xitco, Gory, & Kuczay, 2001; fish: Vail, Manica, & Bshary, 2013; chickens: Evans & Evans, 2007; common ravens: Pika & Bugnyar, 2011, Australian magpies: Kaplan, 2011). However, their points typically consist of moving the whole body in a certain direction, while they never point by indicating a remote position in space with the same precision as does pointing with the index finger by an ape or a human. This obviously has to do with the fact that the hands of a primate are special organs which possess enormous degrees of freedom compared to the forelegs of most other vertebrates. In the latter case, locomotion still represents the main function and therefore strongly limits the options for producing pointing gestures.

It is important to note that not all primates point in the same manner as humans do. Most prosimians, for example, evolutionarily more primitive primates that have retained a wet nose (*rhinarium*) are unable to do so even though they have hands that – from a purely anatomical view – are quite similar to those of monkeys and humans. Their thumbs can be



Figure 1. Monkey and human infant displaying *begging* behavior consisting of grasping with the whole hand in a requestive manner for an object out of reach. Note the emotional expression on the infant's face (monkey picture reprinted with permission of photographer Audrey Maille, see Maille et al., 2012; right picture photographed by author).

opposed to the other fingers in nearly the same way as in monkeys. Nevertheless, there are no known instances in which a prosimian primate has been shown to point with the hand. This does not preclude that lemurs can be artificially trained to point at a particular location by grasping toward it or extending their arms in the direction of an object (Genty & Roeder, 2006), but they never do so spontaneously and with an extended index finger. This limitation may have to do with a basic inability to visually guide the movements of their forelimbs (Kaas, Stepniewska, & Gharbawie, 2012). But even monkeys with their agile hands and fingers are far from being pointing experts. In captivity, they occasionally show *begging* behaviors using their whole hands (Blaschke & Ettliger, 1987; Bourjade et al., 2014; Maille, Engelhart, Bourjade, & Blois-Heulin, 2012) that resemble the requestive form of pointing in human infants (see Figure 1), but so far they have never been observed pointing with the index finger neither in captivity nor in the wild.

By contrast, apes have been observed to show clearly recognizable pointing movements in the wild. At least in bonobos and chimpanzees, a few cases of either pointing with the whole hand (Hobaiter, Leavens,

& Byrne, 2013; Pika & Mitani, 2006), the index finger (Veà & Sabater-Pi, 1998; Povinelli, 1991), or the feet (*foot-pointing*: Douglas & Moscovice, 2015) have been reported. Compared to the natural habitat, however, pointing is much more common among apes held in captivity, even without any previous training. Captive orangutans, gorillas, chimpanzees and bonobos from time to time produce pointing gestures with their hands and fingers that are easily recognizable as such by a human observer (see, e.g., Call & Tomasello, 1994; Leavens, Hopkins, & Bard, 2005, 2008; Patterson, 1978; Savage-Rumbaugh & Fields, 2000), and thus are used by the animals to get otherwise unreachable food or toys outside their enclosure (see Table 1 in Leavens & Hopkins, 1999). The animals sometimes point in a very human-like manner with their extended index fingers (see Figure 2) but usually use all their fingers and point with the whole hand. However, there is one exception, and this is the group of the language-trained chimpanzees who use their index finger even more frequently than young human infants between the age of one and two years (Leavens & Hopkins, 1999). Some researchers have proposed to qualify pointing with the whole hand as a mere *reaching* behavior, without any social connotation. Yet the fact that it occurs only when a caregiver is present and never or very rarely when the animals are alone (Leavens, Hopkins, & Bard, 1996), indicates at least a *requestive intention* by the subject. Similar to human infants, apes raised in captivity develop pointing without having been trained to do so, suggesting that they behave in a spontaneous manner.

2 POINTING AS THE FOUNDING STONE OF LANGUAGE

What makes pointing – a rather inconspicuous behavior per se – so special a phenomenon that a multitude of studies have investigated its origin and development? True pointing in the sense of creating a *spatial reference* to parts of the external world is an exceptional behavior because it can be treated as providing access to all subsequent kinds of referencing behaviors. By pointing, the subject tries to develop a spatially well-defined proto-semantic reference to an external object or event. This apparently trivial kind of *showing things to others* represents the precondition



Figure 2. In captivity, great apes sometimes point with the index finger at interesting objects (e.g. food) in a clearly human-like and referential manner, easily recognizable through the ritualized, repetitive character of the behavior (picture taken from <https://www.youtube.com/watch?v=oDjwaWbrm8Y>).

tion for spoken language for the simple reason that vocalizations alone always remain ambiguous with regard to the attribution of meaning to particular entities of the external world. Hence, even though a young baby starts uttering a variable number of more or less distinct noises from very early on, it is not before the age of about one year that the first clear references to particular objects become recognizable (Mayo et al., 2013). It is at this age that one observes an important switch from the initial pointing with the whole hand, which still has a strong requestive and primarily dyadic character (“I want this object”), to the later canonical form of pointing with the help of the index finger, the nature of which is clearly more indicative in the sense of “Look, there is an object” (Franco & Butterworth, 1996; Leavens & Hopkins, 1999).

The necessity of the pointing gesture for creating the first semantic references has to do with the purely physical fact that an acoustic signal, in contrast to a visual gesture like pointing, is by itself necessarily unable to indicate a particular position in space. In air, sound waves propagate uniformly into all three spatial dimensions and thus are not qualified for

establishing any concrete semantic reference¹. For the growing child, a new word simply spoken into air without any simultaneous spatial reference to a concrete object makes no sense. Somewhat later in a child's life, as soon as at least a small repertoire of well-defined semantic meanings has been installed with the help of pointing, further vocabulary development is achieved by using primarily vocal referencing. Nevertheless, as soon as there exists some degree of uncertainty with regard to the concrete meaning of an utterance, even adult humans usually *regress* to the basic stage of gestural referencing, which means consciously going back to explicit manual pointing to avoid any semantic ambiguity (and this occurs also at the highest level of scientific work: see the use of laser pointers to clarify details in pictures).

By producing well-defined references, pointing automatically becomes a conscious social act. Neither animals nor humans, unless under some special conditions (e.g., rehearsal of a scene by an actor, gestural preparation of a speech before performance, counting by use of the index finger), would point at an object or event when alone. This apparently paradoxical asymmetry between pointing in a social context, the so-called *triadic* relationship between the *pointing agent*, the *referenced object* and the *addressee* (Bates et al., 1979; Bruner, 1981; Trevarthen & Aitken, 2001), and the total absence of any pointing behavior if nobody else other than the subject is present, is also readily explained by the perceptual substrate of reference. Knowing the object of reference by looking at it, the subject does not need to point at it to understand what s/he is looking at. Taken together, both basic features of true pointing, that is a) a clear spatial relationship to an external phenomenon, and b) an equally clear involvement of a conspecific through gaze alternation between object and addressee, presuppose that the pointing agent firstly understands the meaning of what a spatial direction (a geometrical line) is, and secondly uses pointing with the conscious intention of showing something to a conspecific. These requirements explain why true pointing, in its mature form, is quite rare among living beings or, in the words

¹ Alarm calls of some colony-forming (e.g., marmots, ground squirrels) or group living (e.g., monkeys, most hoofed animals) mammals are no exceptions to this rule since they do not work without a moving cue (predator, competitor) in an otherwise static visual scenery.

of modern developmental psychology: “Pointing things out for others seems like an exceedingly simple act. But it turns out that [...] it rests on a very complex and mostly hidden social-cognitive, social-motivational infrastructure” (Tomasello, Carpenter, & Liszkowski, 2007, p. 719). Ultimately, pointing necessitates the presence of a self-conscious agent that intentionally proceeds to instruct other group members about specific aspects of the surrounding world.

3 **UNDERSTANDING POINTING PRESUPPOSES BEING ABLE TO POINT BY ONESELF**

When we see another person pointing at an object we immediately understand what s/he is doing because we, too, already know how to point at an object and what that act is intended to signal to the addressed person. In our mind’s eye we follow an imagined straight line that extends in the indicated spatial direction of the index finger to a given point in space. This is valid for both the pointing person as well as the observing person and requires a basic understanding of visual perspective. By moving around while pointing, for instance during pointing at one and the same object from different angles, we construct a three-dimensional space of linear vectors that can be arbitrarily used for referencing purposes. In other words, understanding pointing is a rather demanding cognitive achievement that clearly exceeds simple perception.

All the more surprising, there are quite a few animal species that appear to perfectly comprehend pointing when performed by a human experimenter in front of them. By contrast, species that are capable of producing points themselves are much rarer. In a review by Miklósi and Soproni (2006), still the most comprehensive overview of animal pointing to date, dogs, wolves, cats, horses, goats, dolphins and seals appear to learn quite rapidly to correctly interpret helpful human pointing gestures when confronted with the problem of choosing between two non-transparent containers of which only one is baited with a reward. Surprisingly, our closest relatives among the primates, monkeys and apes do not perform markedly better than most other tested species. In these so-called *object choice tasks*, monkeys achieve results that are more

(Anderson, Sallaberry, & Barbier, 1995; Vick & Anderson, 2000) or less (Anderson, Montant, & Schmitt, 1996) comparable to other successful mammals like dogs and cats. Surprisingly, apes, with which we share the closest possible evolutionary ancestry of all animals, fared even worse: they seemed to have severe problems understanding that kind of experimental test (see Itakura, Agnetta, Hare, & Tomasello, 1999; Tomasello, Call, & Hare, 1998).

Since pointing is a *cooperative behavior* where the pointing agent consciously tries to draw the attention of the addressee to a particular place or object in the surrounding world, one explanation for their surprising failure in object choice tasks could be that chimpanzees and other great apes just do not engage in cooperative behaviors to the same extent than humans do (Hare, 2001). In other words, the social relationships of great apes may simply be of a more competitive nature. Alternatively, human experimenters were often located quite close to the objects at which they pointed during the experimental tasks and the tested apes could have interpreted this proximity as a demonstration of ownership on the part of the humans rather than as a sign of cooperativeness, which would explain the apes' generally poor performance. In fact, the behavior that was shown by the majority of chimpanzees during these tests – mostly nervousness and unfocused movements – supports such an interpretation.² However, a range of methodological issues surrounding object choice tasks in primates and other animals (see, e.g., Mulcahy & Hedge, 2012) should warn about reaching premature conclusions on the topic of point comprehension.

From an evolutionary standpoint, it is rather unlikely that distantly related species like dogs and cats are better at understanding the human pointing gesture than our closest relatives, the great apes. Despite superficial similarities between the domestication of these house pets and a presumed human *self-domestication* (see Hare, Wobber, & Wrangham, 2012), this apparent *pointing gulf* between apes and humans is difficult to reconcile with a largely identical evolutionary past. A closer analysis of what has been documented so far in the field of animal pointing brings

² Video showing mentality-based difficulties of chimpanzees with understanding human pointing: <https://www.youtube.com/watch?v=wdTEYQX3s2o>, retrieved on December 20, 2017.

the phylogenetic perspective readily into play again. The majority of research findings stem from object choice studies, in which the indicated object, the pointing agent and the addressee were located in close spatial proximity to one another. Some researchers attempted to elicit so-called *distal pointing* in different animal species, but even there, the distance between the pointing gesture and the object was not more than 50 cm (defined as *out of reach* by Miklósi & Soproni, 2006). However, pointing distances of several meters – not uncommon in human pointing – have rarely been tested with nonhuman animals. This suggests that purely associative and/or specific perceptual mechanisms could be responsible for the results of most of those experiments. Since proximity between objects is an important criterion for association to take place, many animals could have simply learned that the position and/or the movement of the human hand is related in a meaningful way to a particular resource, for instance hidden food (see Shapiro et al., 2003).

Dogs, like many other predatory species, are extremely sensitive toward even the slightest changes in their visual field that could code for the movement of potential prey. They are able to react rapidly by extrapolating the likely direction of flight. The details of the underlying perceptual mechanism were first described by Shaffer, Krauchunas, Eddy and McBeath in 2004. They observed dogs catching frisbees and found the same basic mechanism of intercepting the linear trajectory of a moving object as is in place in human baseball players. During play, this mechanism can be easily instigated in any dog by humans making short intention movements in different directions. The dog will instantaneously track and react to every small movement of its owner (Figure 3). Translated into the situation of an object choice test in which pointing gestures are used to indicate the spatial location of hidden food, dogs and cats should not show any difficulties in solving these tasks; and in fact, they often solve these tasks from the first moment on, without much associative learning required (Miklósi, Pongrácz, Lakatos, Topál, & Csányi, 2005).

In some object choice experiments, subtle indicators like gaze movement were used as a substitute of manual gestures to indicate the location of the hidden food, and yet most tested species had no serious problems solving the tasks. Instead of necessitating the formulation of a special *gaze following mechanism*, this merely speaks in favor of a very high sen-



Figure 3. Dog intently watching his owner (author) before searching for a tossed object in the classical stick fetching game. The animal very precisely foresees the correct trajectory of the object without attributing any referential meaning of an abstract *direction* to the observed movement (Shaffer et al., 2004; photographs by author).

sitivity of the underlying motion extrapolating perceptual mechanism as already described by Shaffer et al. (2004). This interpretation is corroborated by the fact that newborn human babies correctly understand to follow the gaze of an experimenter as long as they can see the movement of the pupils (Farroni, Johnson, & Csibra, 2004).

The only reliable method to verify whether different animal species are truly able to understand the meaning of human pointing is to confront them with gestures that refer to remote objects which are so far away that it is not possible to create a purely perceptual association based on proximity aspects and/or use simple visual reactions based on movement direction itself. Unfortunately, this has not been done with most species. With dogs, a simplified version of this method can be employed by any dog owner whereby it is comparatively easy to show that these animals are completely unable to understand human pointing gestures. For this purpose, it is sufficient to play a game of fetch with a dog in a meadow with high grass and wait until the dog, due to restricted vision, has difficulties finding the stick in the high grass. Then one would simply start pointing to the remote location where the stick is lying and

observe what the dog does. First, the dog may likely follow the pointing gesture if the gesture is done dynamically (i.e., with movement) and repeatedly. However, as soon as the arm is held static while pointing in the correct direction without movement, the dog, from that moment on, will ignore the indicated point in space. In fact, despite seeing the extended arm with the index finger pointing in a well-defined spatial direction, the dog usually runs around in circles that have nothing to do with the direction indicated. This provides support for the view that dogs do not interpret the human pointing gesture the same way humans do, namely as a referential gesture with the meaning of indicating a spatial direction.

Compared with dogs, apes perform surprisingly poorly in object choice tasks on pointing comprehension. Following conventional wisdom, they do so due to some hard to define disturbing factors mostly linked to the presence of a human experimenter which creates a competitive situation (for a critique of this view, see Mulcahy & Hedge, 2012, and Hopkins, Russell, McIntryre, & Leavens, 2013). But this does not mean that apes are unable to understand the referential nature of pointing. The fact that chimpanzees very well understand human pointing has been demonstrated by a recent experiment conducted by Roberts et al. (2014) on distal pointing with a distance of at least several meters between indicating subject and indicated object. In this experiment, the animals first witnessed how a human experimenter hid a valuable object (container with reward) somewhere outside of their enclosure. The objects were first shown to the chimpanzees at close distance and then buried at a remote but still visible place in the area surrounding the enclosure. Next, a second human experimenter who was ignorant of the hiding place came into play. This person was known to the chimpanzees as a very helpful familiar person who, in the recent past, had repeatedly provided food to them. When this person appeared, the chimpanzees immediately tried to elicit their help in retrieving the hidden food. Apparently, the animals knew from the start that the second experimenter could not know the place where the container with the tidbits was hidden. As a result, they immediately proceeded to guide the cooperative, but ignorant, human partner to the right place by basically deploying a strategy that we humans – if we assume having lost our voice for the moment – would also deploy in such a situation. They pointed with the extended index finger exactly to the place where the food was hidden and, by doing so, succeed-

ed in guiding the cooperative experimenter to the right place. Every time the experimenter stopped or deviated from the correct way to the envisaged goal, the chimpanzees started gesturing and indicated again the precise location with the help of the index finger. Finally, the closer the experimenter came to the unknown hiding place the more frequently the chimpanzees began to produce purely affirmative intentional gestures, like shaking the hand or bobbing the head, to signal to the experimenter that he was already very close to the desired location. Even though only two human-raised animals were tested in the study, the results are more than clear-cut: in 11 out of 12 trials the animals reached their goal by successfully leading the ignorant experimenter to the hiding place. The supplementary videos nicely illustrate the communicative expertise of these chimpanzees (see Roberts et al., 2014).

Generally, chimpanzees as well as all other ape species, including gibbons (Inoue, Inoue, & Itakura, 2004), appear to be qualified to use pointing in the same referential manner as humans. A female gorilla has recently even been shown to use a tool – different sticks which she specifically prepared – for various intentional pointing purposes (Luef & Heschl, 2017). But does this finding mean that they also interpret the pointing of another person, be it a conspecific or a human, in the same way we do? Unfortunately, no comparative experimental data exists to date on this topic. What appears to be overdue in this case is a simple role reversal of the actions of chimpanzees and humans as shown in Roberts et al.'s study from 2014. In such an experiment, a human experimenter would try to guide chimpanzees (or any other ape species) to a particular place in their enclosure by merely indicating via gestures the way to a previously hidden resource (e.g., covered feeding site). The traditional object choice tasks are inappropriate for this purpose because the average distances between indicator and object are normally too short to exclude purely associatively learned coincidences that have little to do with a true comprehension of referential meaning. This explains why a recent study done with capuchin monkeys, in which the cue giver was once a conspecific (another monkey reaching for one of two containers) and once a human person pointing to the baited container, ended with the disappointing conclusion that “results may be explained by simple rules of association learning and stimulus generalization” even though

nearly all monkeys tested perfectly mastered the task (Essler, Schwartz, Rossette, & Judge, 2017, p. 1).

So how is a reliable decision on whether monkeys are able to understand the referential aspect of pointing feasible? Again, the answer can be found in the videos made by Roberts et al. (2014) as well as in similar recordings on the internet. One particularly revealing video on YouTube, taken by chance by a zoo visitor, shows a chimpanzee pointing with the index finger at diverse objects lying outside the enclosure with the intention of inducing the visitors to either channel it through a hole in the glass pane (fruit juice) or to throw it (banana) over the pane into the cage.³ The decisive element in the behavior of this chimpanzee is the repetitive accentuation in the pointing movements. It is this ritualization of the pointing movement which shows that the animal really wants to *say something*, in exactly the same manner as humans who make a pointing gesture in an *unmistakable* and *urgent* manner. So far, no monkey has been observed producing such a clearly intentional pointing gesture. And – as we will see in the next section – since the comprehension of pointing done by a conspecific always follows the production of pointing, it can be excluded that monkeys are able to understand the referential character of the pointing gesture done by a human (see also Hess, Novak, & Povinelli, 1993). This is valid for both ontogeny and phylogeny.

4 ONTOGENY EXPLAINS PHYLOGENY

When observing the behavior of young human infants during ontogeny we realize that the ability to point always develops before (according to Leavens & Hopkins, 1999, at the age of 14-15 months) the ability to comprehend the pointing gesture as a referential signal (according to Morissette, Ricard, & Décarie, 1995, at around 18 months)⁴. Around the

³ Video “Smart chimpanzee wants to drink coke”: <https://www.youtube.com/watch?v=oDjwaWbrm8Y>; https://www.youtube.com/watch?v=yrI2_v_FhLs; https://www.youtube.com/watch?v=SG8d52cVG_E, retrieved on December 20, 2017.

⁴ Much earlier reported times for the onset of pointing comprehension are either based on simpler perceptual, non-cognitive mechanisms (see Bertenthal,

age of 11 months, the young baby starts grasping for objects that are out of reach by moving the hand with all its fingers extended toward the targeted object, seemingly ignoring the insurmountable distance between her/himself and the object (Leavens & Hopkins, 1999). However, this so-called *whole-hand point*, a seemingly non-functional grasping behavior, is only shown when another person is present who could help the baby in procuring the intended object. The behavior is usually accompanied by loud vocal utterances that signal the current mood of the baby, usually hunger, thirst or the wish to play with the object. Then, slowly, this characteristic *begging* behavior (see Figure 1) develops into a more clearly symbolic activity in which both the form of the behavioral pattern and the accompanying vocalizations begin to change. Around the age of 12 months, the whole-hand gesture starts to disappear and the characteristic pointing movement with the extended index finger becomes dominant (Leavens & Hopkins, 1999). At the same time, the loud vocalizations that accompany the young infant's pointing efforts change into less requestive and instead more indicative⁵ utterances that, for the first time, appear to *denote* specific objects in the environment. In other words, the young infant begins to speak with the help of the first pointing attempts with the index finger (see Figure 4, Butterworth, 2003). By doing so, the infant's inner urge to actively communicate with her social milieu meets a perfectly pre-adapted behavioral reaction by the parents/caregivers: as soon as the infant points at a concrete object, parents/caregivers automatically feel compelled to utter the corresponding name for the object. In this way, the child gradually enters the semantic world of her/his social environment and acquires a first, though still relatively limited,

Boyer, & Harding, 2014) or demonstrate that even slight modifications of the pointing gesture (e.g., angular pointing) are not understood (see Schmitow, Kochukhova, & Nyström, 2016).

⁵ The transition from predominantly emotional to the first pre- and proto-semantic vocalizations (*babbling* > use of *proto words*) becomes manifest by the infant's first use of consonants (Oller, 1980) which, in contrast to vowels, restrict airflow through the respiratory tract and thus are mainly produced when strong or negative emotions are absent (Scheiner et al., 2002). This important step is accompanied by a change from dyadic to triadic forms of looking that begin to coordinate one's own perspective, outer world, and social environment (Kutsuki et al., 2007).



Figure 4. A 13-month-old human infant points at an object and tries to repeat the naming (“lamp”) given by an adult (author). Note the relaxed expression on the infant’s face. Through pointing, the young child actively provides herself with a basic semantic vocabulary during the second year of life (photographed by author).

set of words allowing her/him nevertheless to finally conquer the whole mental cosmos of its culture in the years to come (Bates et al., 1994; Colonnese, Stams, Koster, & Noom, 2010). This close relationship between pointing and language is nicely corroborated by the fact that in human adults, a significant correlation between manual and semantic/verbal laterality exists in the brain (see also Luef in this volume). In the vast majority of humans, Wernicke’s and Broca’s area are located in exactly the same hemisphere as the motor areas that control the dominant, which is the pointing hand (Stein & Stoodley, 2006; for a detailed analysis of the neuroanatomical connections between pointing behavior and spoken language see Peeters et al., 2017).

The fact that the production of pointing tends to precede the comprehension and social imitation of pointing during a child’s ontogeny merits its own attention. Starting at the age of 12 months, a close correlation between production and comprehension of pointing characterizes the socio-cognitive development of the young infant (see Behne, Liskowski, Carpenter, & Tomasello, 2012). Provided Haeckel’s so-called *Biogenetic Law* (Haeckel, 1866) has at least some empirical value for the evolution

of behavior (see Parker & Gibson, 1979), this special temporal relationship between production and comprehension would also be applicable to the phylogeny of pointing. The implication would be that all animals that are unable to point in a clearly referential manner, as for instance dogs, cats and monkeys, should also be unable to *understand* the referential meaning of pointing. The question is why this should be the case and why not the opposite. After all, if the comprehension of pointing develops first, then the young animal could simply learn by mere observation and subsequent imitation how to correctly perform pointing at an object without struggling with the many details of an independent elaboration of the behavior. The answer has to do with the specific sensorimotor mechanisms that are associated with pointing. First of all, the young infant must learn how to visually control the movements of her/his hands and fingers. As soon as this is accomplished around the age of 9 months (see McDonnell, 1975), the infant starts grasping for objects that are within her/his reach. Only when such basic, visually guided reaching behaviors have been perfected, can the infant proceed to more distal forms of intentionally reaching and requesting in which the eye aligns hand and finger orientation with a remote object. Finally, the transition from such a still *begging*-like form of grasping with the whole hand to a fine-tuned targeting of a specific point in space with the help of the extended index finger makes the behavior referential in the proper sense of the word, that is translatable into the general meaning of “Look, there is something”. Only at this point does pointing by a conspecific become understandable for the young child because s/he can now transfer the observed scenery into her/his own perceptual interpretation frame. In the end, it is basically the same functional relationship that exists between reaching for an object by oneself and imitating an observed reaching movement of a conspecific with the help of so-called *mirror neurons* (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Here, too, the production of the behavior always precedes its comprehension and imitation during ontogeny (Kanakogi & Itakura, 2011).

By about 18 months of age, young children have already acquired a basic *expressive lexicon* of about 50 words that serves as a kind of semantic starting basis for all ensuing, much more elaborate utterances. After several years of continuous cognitive development, logically structured sentences with increasing syntactical complexity emerge (Peltzer-Karpf,

2012). Realizing that every word must have a concrete meaning, young children around the age of 2 years start to experience a regular *naming* or *vocabulary explosion* during which 10 words or more are acquired per day with relative ease by simply asking questions like “What (is this)?”. This vocabulary growth spurt continues through the third year during which the famous “Why?” questions emerge and persist (see McCarthy, 1954). It was found that a child who has not achieved the critical number of approximately 50 words by the age of 18 months must be called a *late talker* who needs additional time of socio-cognitive training to clear her/his backlog in linguistic competence (Thal and Tobias, 1992). Pointing plays a crucial role in vocabulary learning and is therefore immensely important for the acquisition of spoken language. During the second half of the second year, another developmental milestone appears that crucially shapes the mental faculties of the growing infant, namely the ability to recognize her/himself in the mirror (*mirror self-recognition* or MSR⁶, see Bertenthal & Fischer, 1978). This suggests that the acquisition of a first primitive *ego* represents a necessary step toward language, confirmed by the appearance of the word “me” shortly after the first successful instances of MSR. At the same time, pointing with the whole hand markedly decreases at this age in favor of the much more precise canonical form of pointing with the extended index finger (Leavens & Hopkins, 1999), an observation that nicely mirrors the emerging intention of the self-conscious mind to be as precise as possible in all of its actions, be they self-related, object-related and/or communicative.

The findings from human cognitive ontogeny should help predict the occurrence of pointing in nonhuman species, in particular for answering the question of which animal candidates come into question for a true, meaning referential, understanding of pointing. Apes (Parker, 1991) including gibbons (Heschl & Fuchsichler, 2009), dolphins (Reiss & Marino, 2001) and elephants (Plotnik, de Waal, Moore, & Reiss, 2010) have been shown to be able to recognize themselves in the mirror. By

⁶ Spontaneously acquired, not trained self-recognition in a mirror represents one of the basic requirements for self-consciousness (see Chang et al., 2017; Liu et al., 2017). Behaviorally, it is the expression of the rare ability of just a few vertebrate species to visually guide their locomotion (for details see Heschl & Fuchsichler, 2009).

implication this means that dogs, cats and even monkeys – who generally fail in mirror-self-recognition tests – should be unable to understand the referential meaning of pointing despite their comparatively successful performance in object choice tasks.⁷ Only self-conscious animals are able to produce referential pointing gestures, either with their hands (apes: Roberts et al., 2014), heads (dolphins: Xitco et al., 2001) or trunks (elephants: Smet & Byrne, 2013). Though monkeys can learn how to beg for food with the extended open hand, and do so so even when the experimenter is turned away and unable to see the addressed object (proving that the animals do not understand perspective; for more details see Lamaury, Cochet, & Bourjade, 2017), they have never been observed producing a clearly intentional pointing gesture with the index finger (see Essler, Schwartz, Rossette, & Judge, 2017), which correlates with their lack of a basic form of self-consciousness. For the most intelligent bird taxa, the corvids and parrots, which are at least potential candidates for self-consciousness (see Pepperberg, Garcia, Jackson, & Marconi, 1995; Prior, Schwarz, & Güntürkün, 2008), research on referential pointing is still in its infancy, but it may only be a question of time until a larger body of research will detail their exact referential abilities (a first step in this direction is Pika & Bugnyar’s study on ‘pointing’ ravens from 2011).

5 **RELAXED SELECTION CONDITIONS FAVOR THE EMERGENCE OF POINTING**

Finally, if we want to reconstruct the phylogeny of pointing we need to know the presumed selection conditions that may have favored the emergence of this behavior. Apes that are raised by humans spontaneously develop manual pointing gestures; however, in wild apes, pointing appears

⁷ Dogs are often overrated with regard to their cognitive abilities due to their impressive social behavior (see Moore, Mueller, Kaminski, & Tomasello, 2014), whereas cats, bears and monkeys clearly reach a basic level of higher cognition based on visually guided reaching, without however fulfilling *all* criteria of a whole body-related self-consciousness as given in hominids, cetaceans and elephants.

to be rather rare. So far the only documented instance is an individual bonobo was observed during the production of a pointing gesture at a group of slowly approaching human observers in a presumed attempt to alert her conspecifics to their presence (Veà & Sabater-Pi, 1998). The fact that pointing is rare in wild apes is revealing because it suggests a theoretical question that is not easy to answer: Why is pointing in nature not much more frequent when the ability to silently alert other group members to potential danger with the help of pointing should be extremely advantageous from an evolutionary perspective?

Leavens, Hopkins and Bard (2005) proposed the hypothesis that it is the rather confined conditions in an artificial enclosure that force animals to develop various gestures to communicate with the outside world (e.g., for requesting food). The situation in a narrow enclosure may indeed very well favor such a behavior, however, apart from the unavoidable spatial restrictions, zoo animals are at the same time provided with some specific ecological advantages. They are well-fed and for this reason do not need to worry about procuring food. In addition, any possibly *paralyzing* effect of stress on cognition, arising from a threat by potential predators, is widely lacking. Hence, instead of enforcing pointing through spatial limitation, it rather appears to be a question of allowing this new kind of behavior to emerge which may explain why it is so rarely shown in nature. The relaxed selection conditions that prevail in a captive setting could even represent the crucial impetus that is needed for apes to engage in referential pointing. If true, the hypothesis would predict that the most impressive examples of chimpanzee pointing should be found in rather relaxed situations, as given in zoos in which only a comparatively small extra portion of food in form of tidbits is the main goal of the behavior. This prediction is directly confirmed by the existing studies on pointing in captive apes. Consequently, pointing in wild apes should occur only under relatively relaxed environmental conditions when the animals are unrestrained from external or other pressures that impact their behavior.

Countless observations of chimpanzees in their natural habitat produced only a few rare indications of a possible whole hand pointing gesture (Hobaiter et al., 2013), whereas the still relatively poorly studied wild bonobo delivered the hitherto sole clear evidence of human-like pointing with the index finger (Veà & Sabater-Pi, 1998). The common chimpanzee

practices a more terrestrial lifestyle, whereas the bonobo spends most of its time high up in the trees and is therefore much more protected from potential predators (Rowe, 1996). This explains why chimpanzees are a comparatively frequent prey of leopards, whereas bonobos only rarely suffer such a fate (D'Amour, Hohmann, & Fruth, 2006; Zuberbühler & Jenny, 2002). From an adaptationist point of view, it should thus be extremely advantageous for chimpanzees to use pointing as an effective counter-strategy to avoid predation by leopards. By contrast, bonobos would not really need to develop any pointing habits at all for that special purpose. However, the exact opposite appears to be true. Wild bonobos have been observed pointing with the index finger and wild chimpanzees have not.

From a molecular biological perspective, new behaviors are always accompanied by genetic changes and the sequence difference in DNA between free-living and zoo-raised chimpanzees is probably not large enough to attribute differences in behavior to a change in the new genetic make-up. Since the DNA of wild and captive animals can be assumed to be more or less identical, the ability to produce referential pointing gestures must have evolved already in the natural habitat, maybe as a consequence of a general propensity for communicating in a semantically meaningful way, be it by means of gestures and/or vocal utterances. In this way, the impressive structural complexity of modern human languages might have been originated in the course of repeated phases of relaxed selection during our more recent phylogeny that allowed further semantic *explosions* to take place (Deacon, 2010).

6 CONCLUSION

Concerning our primate relatives, future studies should focus on free-living populations that live under *more favorable* environmental conditions, such as in those primate species that occur in variable habitats, to determine how specific socio-ecological circumstances, and maybe a significant decrease in general selection pressure, can influence the manifestation of referential behavior in a given species. Based on the observation of how fragile and comparatively rare higher cognitive skills usually are

in the wild, it seems that two renowned pioneers of classical field primatology were already heading in the right direction with the following remark:

Innovative behaviour achieved through exploration, learning and insight heavily depends on certain motivational, social and ecological conditions of short duration. We propose that more attention should be given to what these conditions are and where they are realized in natural groups of non-human primates. Only to the extent that such favourable conditions were frequently realized in a social structure or an extraspecific environment could selective pressures act on innovative abilities. There is hope that research into field conditions of innovative behaviour will help to identify its selectors in evolution (Kummer & Goodall, 1985, p. 203).

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Emotion communication in animal vocalizations, music and language: An evolutionary perspective

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ABSTRACT Emotions are a biological universal which allow each individual to react appropriately to the surrounding physical and social environment. Emotions can be expressed and perceived through several sensory modalities. Here, we focus on the communication of emotions in the auditory domain. Specifically, we begin by defining emotions from a broad comparative perspective before turning our attention to acoustic universals in emotion processing in animal vocalizations, human communication (including language), and finally, music. Building on recent findings on cognitive processes and mechanisms underpinning emotional processing shared by these three domains, and on the adaptive role of the ability for emotion communication, we hypothesize that this ability is an evolutionary precursor of the ability for language. Finally, our work offers insights for empirically testable questions within this research framework and proposes that future

investigations should incorporate a comparative lens and consider human non-semantic vocalizations, such as laughter, alongside animal vocalizations.

KEYWORDS arousal, comparative analysis, emotion, evolution, language, music, vocal communication

1 **EMOTIONS: BIOLOGICAL UNIVERSALS**

Consider a mother happily talking to her baby during playtime, a dog barking to get her owner to open the door and an instrumental melody played with increasing intensity. Although these three examples are quite different from each other in terms of communicative systems, they all share a key aspect: each of these signals expresses an emotional state and may trigger a physiological or behavioral reaction in the listener. In this chapter, we provide a comparative analysis of recent findings on the role of emotions in animal vocalizations, music and language. We do so with the overarching aim to shed light on the adaptive role of emotional communication in the auditory domain for the evolution of linguistic communication in humans.

As a first step into this comparative analysis, we propose an operative definition of emotional states (hereafter ‘emotions’), which we will use throughout this chapter: *Emotions* are physiological states of the brain that increase an animal’s ability to react appropriately in the surrounding environment or in the given social context, and are accompanied by preparatory tuning of the somatovisceral and motor systems (Scherer, 2005, 2009; see also Nesse, 1990).

Emotions have often been classified in multiple ways. For instance, a long-standing research tradition is centered around the study of emotions as discrete categories such as happiness or anger (Anderson & Adolphs, 2014; Cowen & Keltner, 2017; Ekman, 1992). These emotion categories are often referred to as *basic emotions* because they are thought to be culturally universal (Sauter, Eisner, Ekman, & Scott, 2010; Sauter, Eisner, Ekman, & Scott, 2015). In addition, *dimensional emotion models* (Anderson & Adolphs, 2014) argue that emotional states can be classified based on their *valence* (positive or negative) and their *arousal* level (i.e.,

activation or responsiveness levels, classified as high or low). Emotional arousal is a state of the brain or the body reflecting responsiveness to sensory stimulation, ranging from very low responsiveness to frenetic excitement (Russell, 1980). Accordingly, increases in arousal levels are correlated with increases in behavioral, hormonal and/or neurological activity. In addition, changes in emotional states may affect cognitive performances (Mendl, Burman, & Paul, 2010).

The identification of basic emotions is key for the investigation of physiological correlates and variance of human emotions. However, it may not be the best model to capture variance in non-human animal emotions. Indeed, while measuring degrees of valence and arousal is empirically possible (Briefer, 2012; Briefer et al., 2015; Briefer, Tettamanti, & Mcelligott, 2015), identifying the physiological correlates of emotional categories such as happiness or disgust in nonhuman animals is more challenging and may lead to a more anthropocentric interpretation of the signal (Briefer, 2012).

2 **ANIMAL VOCALIZATIONS: ACOUSTIC UNIVERSALS IN EMOTION COMMUNICATION**

Emotional communication is pervasive in animal vocalizations. A large number of studies have investigated the expression of affective states through voice modulation (see, e.g., McComb, Taylor, Wilson, & Charlton, 2009; Pongráz, Molnár, & Miklósi, 2006; Zimmermann, Leliveld, & Schehka, 2013). In particular, much research has focused on the expression of emotional arousal, which can be directly linked to the physiological state of the signaler. For instance, states of heightened emotional arousal correlate with quantifiable changes in physiological parameters and induce increased activation of muscles. Specifically, increased activation of muscles involved in vocal production, such as of the diaphragm, intercostals and vocalis muscles, alters subglottal pressure, that is the way air flows through the vocal tract. This may induce vocal folds to vibrate at their natural limit, generating sound waves at heightened amplitude. These sound waves may be perceived as harsh sounds (Taylor & Reby, 2010). In addition, states of heightened emotional arousal may induce heightened

muscular tension, which prepares the signaler for immediate action (Arnal, Flinker, Kleinschmidt, Giraud, & Poeppel, 2015).

In turn, the ability to recognize heightened levels of arousal in vocalizations may help avoiding threats or disturbances in the surrounding environment, as for instance the imminent approach of a predator. A vocalization produced by a signaler that is in a heightened arousal state, as for instance, an alarm call or a disturbance call, may induce fear or alertness in the listeners, thus prompting them to avoid dangers or disturbances in the surroundings. Hence, a high arousal vocalization may have been shaped by selection to affect others' behavior in an urgent manner (Fitch, Neubauer, & Herzel, 2002).

In a recent study, Filippi et al. (2017a) suggest that humans are able to recognize heightened states of arousal in vocalizations from nine animal species spanning across all classes of terrestrial vertebrates and varying in size, social structure and ecology. These vocalizations were emitted in negatively valenced contexts, namely threat, competition or general disturbance. Arousal level (high versus low) was the only emotional dimension that varied across calls. This research provides evidence showing that humans use acoustic parameters related to F0 (*fundamental frequency*) to recognize heightened states of arousal in calls across all these species. These results hold true across three different language groups (English, German and Mandarin native speakers), suggesting that this ability is biologically rooted in humans. Hence, this study points to a phylogenetic continuity of emotional communication across species, in terms of acoustic parameters involved in vocal production (Bowling, Gingras, Han, Sundararajan, & Opitz, 2013; Briefer, 2012; Linhart, Ratcliffe, Reby, & Špinka, 2015; Morton, 1977; Reichert, 2013; Stoeger, Baotic, Li, & Charlton, 2012; Stoeger, Charlton, Kratochvil, & Fitch, 2011; Templeton, Greene, & Davis, 2005) and in the perception of emotional content in these vocalizations (Belin et al., 2008; Faragó et al., 2014; McComb et al., 2009; Pongrácz et al., 2006; Sauter et al., 2010). In the context of emotional vocalizations, the ability to identify higher arousal states of callers expressed through voice modulation, which reflect higher levels of urgency or danger, is a necessary condition for adaptive reactions such as escape. Therefore, this perceptual ability is as important as the ability to produce calls that differ in the level of expressed arousal.

Furthermore, the findings of Filippi et al. (2017a) suggest that the ability to identify emotional arousal in animal calls, which constitutes a biological phenomenon key to survival, may have emerged in the early stages of the evolution of vocalizing animals and has been preserved across a broad range of animal species. Moreover, these results are in line with Darwin's hypothesis of a shared set of mechanisms grounding vocal emotional expression across terrestrial vertebrates (Darwin, 1871, 1872).

Within this research framework, Filippi et al. (2017b) further analyzed humans' sensitivity to high-arousal calls with negative valence and to high-arousal calls with positive valence in silver foxes. Interestingly, they found that humans are not able to identify high levels of arousal in vocalizations of positive valence. This may be due to a *negativity bias*, namely the fact that people are particularly sensitive to emotionally negative events (Kahneman & Tversky, 1984; Yuan et al., 2007). As argued by Filippi and colleagues, high-arousal calls with positive valence may not be as salient as high-arousal calls with negative valence to the human ear. In other words, these findings suggest that humans' ability to recognize arousal in calls with positive valence might have not been selected by evolution because they are not as crucial for survival as arousal calls produced in negatively valenced contexts. Certainly, in order to corroborate this finding, it is necessary to test humans' perception of vocalizations from more species. These vocalizations need to vary systematically in valence and arousal.

Taken together, these studies suggest two points: a) the modulation of acoustic features in the voice conveys information on the emotional arousal state of the vocalizing animal; b) the ability to identify emotional arousal in animal calls – which is linked to the ability to express emotional content by modulating specific acoustic parameters – may have been preserved across animal species, based on its key role in preparing for action in contexts that were crucial for survival. Building on these findings, we aim to provide a review on studies addressing whether – and if so, how – humans' ability to process animal vocalizations expressing heightened states of arousal is evolutionary linked to their ability for emotional processing in music and language.

3 **EMOTION PROCESSING IN HUMAN COMMUNICATION: INSIGHTS FOR THE STUDY OF LANGUAGE EVOLUTION**

Humans typically combine two sources of information to comprehend each other in communicative contexts: linguistic (e.g., segmental information, morphology or syntax) and nonlinguistic (e.g., body posture, facial expression, prosodic modulation of the voice and pragmatic context) information. For the purposes of this chapter, we will focus on the interaction of two auditory channels: *segmental information* and *prosodic modulation*, the so-called *musical* aspect of speech, which includes timing, frequency spectrum and amplitude (Lehiste, 1970).

Traditionally, studies have addressed language focusing on the segmental level of information, overlooking the analysis of prosodic modulation (Hockett, 1960; Martinet, 1980). These studies often fail to consider the role of prosody, although speakers across cultures and languages modulate segmental information *within* prosodic contours in the spoken signal. It is possible to distinguish two types of prosodic modulation of the voice: *affective prosody*, which affects perception of linguistic stimuli in a cross-culturally similar manner by expressing emotional content (Sauter, Eisner, Ekman, & Scott, 2010), and *linguistic prosody*, which affects the spoken signal in a way that is specific to natural languages.

Linguistic prosody strongly affects the segmental dimension of the signal, orienting the identification of segmental information (Bosker, 2017), lexical items (Van Donselaar, Koster, & Cutler, 2005) and syntactical connections (Soderstrom, Seidl, Nelson, & Jusczyk, 2003). Specifically, prosodic parameters affect perception of phrase boundaries, of a word (*lexical stress*), or of specific words within a sentence (*sentence focus*). Consider for instance, “MARY gave the book to John” vs. “Mary gave the book to JOHN”. Here, the two sentences are identical from a segmental point of view. However, by accenting one word or the other through voice modulation, the speaker orients the listener’s comprehension of the utterance. In addition, linguistic prosody may be used to distinguish word meanings (in tone languages) or statement types, for instance an assertion from a question or a command (Cutler, Oahan, & Van Donselaar, 1997).

Hence, in human communication, multiple channels may simultaneously determine utterance comprehension. But what is the relative sa-

lience of segmental and intonational channels in the process of meaning identification? Multiple brain and behavioral studies have addressed this question, mainly focusing on the communication of emotional valence (Pell et al., 2011; Schirmer & Kotz, 2003). Regarding emotional arousal, in line with Storbeck and Clore (2008), we suggest that the biologically anchored ability to express and identify heightened levels of arousal affects language processing and related cognitive processes in modern humans. Indeed, learning processes and long-term memory are enhanced when involving high arousal states, which are linked to urgency.

The analysis of emotional communication is crucial for the study of language evolution. Several studies suggest that the informational value of animal calls is given by their emotional content (Seyfarth & Cheney, 2003). Since the ability to both express and identify emotions may favor survival across animal species, it is plausible to assume that the ability for language in humans built on this pre-existing ability to express emotional content. In modern humans, emotional communication can take place by integrating multiple channels, which can interact with each other, for instance, through priming or simultaneous interaction. Research has shown that the verbal content and/or the prosodic modulation of spoken units prime the interpretation of a following target word in an emotion-congruent manner (Nygaard & Lunders, 2002). Evidence further shows that, when the two channels are congruent, emotional prosody biases memory of affective words (Schirmer, 2010; Schirmer, Kotz, & Friederici, 2002). Notably, in emotion communication, segmental information and prosodic modulation of the voice can simultaneously express different contents. For instance, this is the case when someone says “I’m sad!” with happy prosody. In this case, segmental information and voice modulation conflict in the meaning they convey. Recent research suggests that in cases like this, where the two communicative channels are incongruent, prosody dominates over segmental information in recruiting cognitive resources for emotion identification (Filippi et al., 2017c).

The analysis of the role of these two channels – segmental information and prosody – in emotion communication is relevant to the debate on the evolution of vocal communication. Indeed, as outlined in the previous section, humans use specific features in prosodic modulation of the voice to identify emotional content in non-verbal vocalizations, an ability that is universal and biologically rooted (Filippi et al., 2017a). The

combination of these data with evidence on the coexistence of prosodic modulation and segmental information in modern human's language suggests that the ability for emotional communication through prosodic modulation of the voice is evolutionary older than the ability to process segmental information (Brown, 2017; Darwin, 1871; Fitch, 2010; Filippi, 2016; Mithen, 2005; Panksepp & Trevarthen, 2009) and may have paved the emergence of the ability to articulate segmental information within prosodic contours. In line with this hypothesis, multiple studies suggest that prosody drives words' segmentation (Johnson & Jusczyk, 2001), the ability to map sounds to meanings (Filippi, Gingras, & Fitch, 2014) and syntactic disambiguation (Soderstrom et al., 2003). Accordingly, research shows that prosodic cues favor lexical access and syntactic analysis at an ontogenetic level, orienting language acquisition in preverbal children (de Carvalho, Dautriche, Lin, & Christophe, 2017; Gout, Christophe & Morgan, 2004).

4 **INTERPERSONAL COORDINATION IN EMOTIONAL AUDITORY SIGNALS: MUSICAL ORIGINS OF LANGUAGE?**

Human communication typically takes place in interactional contexts such as conversations. In these contexts, interlocutors take turn in exchanging utterances, following precise time patterns (Sacks, Schegloff, & Jefferson, 1978). Indeed, recent research provides cross-cultural evidence suggesting that, in conversations, listeners show the following abilities: a) predict the end of the speaker's utterance with the help of prosodic cues such as lengthening of final phrase, b) plan the production of an answer, and c) reply after an average time window of 250 ms (Levinson & Holler, 2014; Magyari, De Ruiter, & Levinson, 2017; Stivers et al., 2009).

A wide range of comparative studies investigating animal communication systems report on the ability for vocal coordination in a number of species spanning all classes of animals. At least three types of behaviors depend on this ability: *choruses*, *duets* and *antiphonal calling* (Yoshida & Okanoya, 2005). These temporally organized behaviors occur in contexts such as territorial defense, social bonding and sexual advertisement,

which evidently involve various degrees of emotional activation. Choruses, commonly found in insects, anurans and in some species of birds, are produced by males only, whereas duets, which are observed in insects, anurans, birds and mammals, are typically performed by male-female pairs. Antiphonal calls, encountered in several species of birds and mammals, occur between any species members, independently from their sex. In choruses, males simultaneously produce a signal for sexual advertisement or as an anti-predator defensive behavior. Duets occur when members of a pair (e.g., sexual mates, caregiver-juvenile) exchange calls within a precise time window. In duets, whose function is to strengthen and display pair bonding, two sexual mates vocally interact with one another, each responding to the preceding vocalization. An animal may respond to signals from one individual, while ignoring those from another. Antiphonal calling occurs when more than two members of a group exchange calls within an interactive context, favoring group cohesion and diverting outsiders.

In humans, prosodic modulation of the voice is key to coordinating these interactive behaviors (see Filippi, 2016, for a review). Darwin described these vocal interactions as *musical* (Gamba et al., 2016; Geissmann, 2000):

Primeval man, or rather some early progenitor of man, probably first used his voice in *producing true musical cadences, that is in singing*, as do some of the gibbon-apes at the present day; and we may conclude, from a wide-spread analogy, that this power would have been especially exerted during the courtship between sexes, – would have expressed various emotions, such as love, jealousy, triumph, – and would have served as a challenge to rivals (Darwin, 1871, pp. 56–57; our emphasis).

Following Darwin, the distinctive musical cadence of these interactions has induced multiple researchers to describe these behaviors using musical terms such as ‘rhythmic’ and ‘singing’ among others. For instance, Bryant (2013; see also Hagen & Bryant, 2003) suggests that human abilities for music evolved from the ability to use time-coordinated behaviors as a *coalition system*, as we find in other animal species.

Building on evidence on this kind of musical abilities in nonhuman animals, multiple studies have identified the evolutionary origins of

language in the ability for music production (Brown, 2001; Fitch, 2010, 2012; Mithen, 2005; Patel, 2006). This hypothesis is supported by recent evidence on neural and cognitive underpinnings shared by music and language. For instance, common cognitive mechanisms involved in the production and perception of structural relations have been identified in instrumental music and propositional morpho-syntax (Fedorenko, Patel, Casasanto, & Winawer, 2009; Patel, 2010). Moreover, brain imaging research suggests that amusic participants (see also Marin in this volume) show deficits in fine-grained perception of pitch (Foxton, Dean, Gee, Peretz, & Griffiths, 2004) and are not able to distinguish a question from a statement relying on pitch changes (Liu, Patel, Fourcin, & Stewart, 2010). These data supports the hypothesis that music and speech intonation share specific neural resources for processing fine-grained pitch changes. Further brain imaging studies report a considerable overlap in the brain areas involved in the perception of pitch and rhythm in songs and lexical units within sentences (Merrill et al., 2012; Zatorre, Belin, & Penhune, 2002) as well as in melodies and linguistic phrases (Brown, Martinez, & Parsons, 2006). In line with these findings, several studies on adults and children suggest that musical training facilitates syllabic and pitch processing in language (Schön, Boyer, Moreno, Besson, & Peretz, 2008; Schön, Magne, & Besson, 2004).

In addition to studies reporting evidence on the activation of overlapping brain areas for music and language perception, a key field for the investigation of musical abilities as the evolutionary precursor of language is the perception of emotions in both domains.

5 **EMOTION COMMUNICATION: COMMONALITIES BETWEEN MUSIC AND LANGUAGE**

As early as 1781, Jean-Jacques Rousseau noted that melody, by imitating the inflections of the voice, could express “all the vocal signs of the passions” (1781/1998, p. 322). A few decades later, Spencer linked music with the vocal communication of emotions (Spencer, 1857). More recently, Scherer’s (1986) theory predicted a correspondence between emotion-specific physiological changes and voice production (see also

section 2). On the basis of this theory, several authors have suggested that the communication of emotion in music may mimic the emotion-induced physiological changes leading to changes in voice timbre, pitch, loudness, or rate. For instance, Juslin & Laukka (2003, p. 799) suggested that “musicians communicate emotions to listeners on the basis of the principles of vocal expression of emotion”.

Indeed, to a large extent, emotions are expressed through shared acoustic correlates in music and language (Coutinho & Dikken, 2012; Juslin & Laukka, 2003). For example, both music and speech express heightened arousal through an increase in either tempo or loudness (Ilie & Thompson, 2006). Moreover, researchers have observed that smaller melodic pitch intervals tend to be associated with sadness in both speech and music (Bowling, Sundararajan, Han, & Purves, 2012; Curtis & Bharucha, 2010). However, one notable difference between music and speech is that whereas high-pitched speech is associated with increased arousal, there is no clear association between pitch height and music-induced arousal (Ilie & Thompson, 2006).

The commonalities between music and language are perhaps best exemplified in infant-directed speech or *motherese*, which is characterized by a simplified grammar, an exaggerated prosody and a repetitive structure. Infants prefer motherese speech to adult-directed speech (Fernald, 1985) and seem to extract information from its melodic patterns in the absence of semantic content (Fernald, 1992). Moreover, infants display more interest in maternal singing than in maternal speech (Nakata & Trehub, 2004; Trehub & Nakata, 2001). Along these lines, Juslin and Laukka (2003) noted that the developmental curve regarding the identification of emotions in music by infants and young children parallels that of vocal expression. There is also mounting evidence that the explicit recognition of emotions in both musical stimuli and nonsensical speech activates similar brain regions (Escoffier, Zhong, Schirmer, & Qiu, 2013).

As already noted by Bolinger (1978), speakers from different cultures use similar intonation patterns to convey emotions. Researchers have empirically confirmed that people can decode the emotional meaning in an utterance spoken in an unfamiliar language (Thompson & Balkwill, 2006), although a meta-analysis shows that the recognition accuracy of the vocal expression of emotions is lower across cultures than within the same culture (Juslin & Laukka, 2003). Analogously, people can recog-

nize emotions conveyed by music from unfamiliar cultures (Balkwill & Thompson, 1999; Fritz et al., 2009), suggesting that some acoustic features are associated with specific emotions (Balkwill & Thompson, 1999).

However, music-induced emotions also rely on domain-specific mechanisms, primarily those based on musical expectations induced by pitch structures (harmonic and/or melodic, Juslin & Västjäll, 2008). Thus, while 3-year-old children can detect basic musical emotions above chance accuracy (Kastner & Crowder, 1990), children up to the age of five years rely on tempo but are unable to use *mode* (e.g., minor versus major scales associated with Western common-practice tonality) to decode emotions (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001). Nevertheless, although pitch systems are more culturally determined, basic categories of musically-expressed emotions can be recognized across cultures. The universal conservation of arousal-inducing factors such as tempo, sound amplitude and pitch height across musical cultures was noted by Brown and Jordania (2013).

The link between emotion communication in music and speech can also be observed by examining the impact of musical expertise on the recognition of emotions in speech. On the one hand, Lima and Castro (2011) have shown that musical expertise enhances the recognition of emotion in speech prosody. On the other hand, individuals suffering from *congenital amusia*, a deficit related mainly to pitch perception, find it more difficult than matched controls to decode emotional prosody in semantically neutral sentences (Thompson, Marin, & Stewart, 2012).

Recent results suggest that the observation that the recognition of emotions in music and speech share similar mechanisms may be generalized to a wide range of environmental acoustic stimuli. For instance, Ma and Thompson (2015) showed that changes in acoustic attributes such as frequency, intensity, or rate (i.e., speed relative to the original version of the stimulus) affect the subjective emotional evaluation of environmental sounds including human and animal-produced sounds as well as machine and natural sounds in much the same way as with music and speech. These findings suggest that the subjective emotional evaluation of auditory stimuli may have an even more general basis than previously thought, insofar as basic attributes such as frequency and intensity are considered.

A clue regarding the nature of this general mechanism may be found in developmental research comparing emotion recognition in visual versus auditory displays. Siu and Cheung (2017) showed that the ability to recognize facial emotions was correlated with the ability to assess the emotional congruency of music-face displays in 20-month-old infants. Notably, these two abilities did not correlate with parental income, quality of parent-child interaction, or language skills, suggesting that these abilities may be subsumed by a common capacity to assess emotion from social cues. Along the same lines, recent findings indicate that the impairment in the detection of emotional prosody observed in congenital amusia also extends to nonverbal vocalizations and even to visual displays of facial emotions (Lima et al., 2016).

6 CONCLUSION

The theoretical and empirical studies reviewed in this chapter point to the ability for emotion communication in nonhuman vocalizations as the biological basis of the ability to process sound modulation in human music and language. Specifically, building on these studies, we hypothesized that the ability to process emotional states conveyed through the voice is a key aspect in the evolution of language. We propose that the systematic investigation of emotional arousal and valence lays out a fertile research venue that may favor comparative work across animal communication, music and language. This may, in turn, provide crucial insights for a fine-tuned analysis of the processes underlying language evolution.

In order to enhance our understanding of the role of vocal communication of emotions in the evolution of language, future research should investigate the ability for music through a *comparative adaptationist lens* across animal species. Furthermore, a fecund path of investigation can be envisioned by extending the analysis of emotional communication to domains other than the auditory and visual ones, focusing, for instance on the effect of chemo-signals (de Groot, Smeets, Kaldewaij, Duijndam, & Semin, 2012). Moreover, the emotional content of proto-musical behaviors in animals should be explored, with the aim to gather further evidence on the adaptive role of these behaviors in animals (Bryant, 2013;

Gingras, 2017). Finally, this research would benefit from the investigation of laughter, cries, and screams in humans. These are key nonverbal human behaviors that, similarly to nonhuman animal vocalizations, are produced in emotional contexts and as an automatic reaction, often within interactional dynamics. Hence, the study of these behaviors may provide a fruitful window for the investigation of the animal nature of human spoken utterances (Bryant & Aktipis, 2014).

To conclude, we suggest that the investigation of emotion processing in species spanning all classes of vocalizing animals, and across communicative channels and human cultures, will certainly help unravel the adaptive value of emotional communication. This line of research will accelerate our understanding of the biological roots of the human ability for language, thus fertilizing current debates on the evolution of language.

ACKNOWLEDGEMENTS

PF was supported by grants ANR-16-CONV-0002 (ILCB), ANR-11-LABX-0036 (BLRI) and the Excellence Initiative of Aix-Marseille University (A*MIDEX). BG was supported by grant 241135 from the Hypo-Tirol Bank.

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Speech processing in congenital amusia: A review of the literature and future directions

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ABSTRACT Human music, like language, is a cultural universal whose origins remain elusive. Some individuals have a congenital impairment in music processing and singing, which might be biologically rooted. Congenital amusia, a neurodevelopmental disorder, has been studied for around 15 years by only a few research groups worldwide. Although amusia was originally thought of as a music-specific disorder, it was demonstrated relatively quickly that it also affects the perception of speech intonation in laboratory conditions. This finding has spurred a fruitful research program, which has not only contributed to the ongoing debate about modularity by investigating pitch processing in music and speech, but which has also targeted various other aspects of linguistic processing. After a comprehensive introduction into the currently known characteristics of amusia, empirical studies on speech processing in non-tone and tone language speakers diagnosed with amusia will be reviewed. Research on English- and French-speaking amusics has primarily focused on the processing of phonology, linguistic and affective prosody, as well as on verbal memory. Amusics are impaired in several aspects of phonological processing, in differentiating between statements and questions, and further, in perceiving emotional tone. In the last few years, a growing body of research involving tone language speakers has reported impairments in processing of lexical tone and speech intonation among amusics. Hence, research on Mandarin

and Cantonese speakers has provided evidence for the notion that amusia is not a disorder specific to non-tone language speakers, and further, it has also increased our knowledge about the core deficits of amusia. Future research will need to replicate current findings in speakers of languages other than those already studied and also clarify how this auditory disorder is linked to other learning disorders.

KEYWORDS congenital amusia, modularity, neurodevelopmental disorder, pitch processing, speech processing

1 INTRODUCTION

Music is the divine way to tell beautiful, poetic things to the heart.
— Pablo Casals

Humans are social creatures who enjoy communicating by several means, and information sharing using *speech* (i.e., the vocalized component of language) is the most obvious way of communication experienced in daily life. Yet human auditory communication includes more than speech, namely vocalizations and music, notably song and instrumental music, which all use structured sound sequences propagating in time. Over the last decades, a considerable amount of basic research has dealt with the comparison between language and music, following either a theoretical (Lerdahl & Jackendoff, 1985; Martin, 1972), empirical (Gorin, Kowialiewski, & Majerus, 2016; Tillmann, 2012) or computational (Rohrmeier, Zuidema, Wiggins, & Scharff, 2015) stance of studying cognitive processes. Due to the rise of the cognitive neurosciences, these efforts were complemented by investigating the neuronal basis underlying language and music processing (Besson, Barbaroux, & Dittinger, 2017; Glushko, Steinhauer, DePriest, & Koelsch, 2016; Patel, 2003; Steinbeis & Koelsch, 2008). Other current approaches include the comparison of developmental processes regarding speech and music in infants and young children (Brandt, Gebrian, & Slevc, 2012; Marin & Peltzer-Karpf, 2009; McMullen & Saffran, 2004; Trehub, Trainor, & Unyk, 1993) as well as the link between speech and music processing in developmental dis-

orders (Don, Schellenberg, & Rourke, 1999; Flaunacco et al., 2014; Lee, Sie, Chen, & Cheng, 2015; Vaiouli & Andreou, 2018). Within these areas of investigation it is now generally accepted that language and music share many attributes, cognitive resources and underlying neural networks aside from their distinctive natures (Asaridou & McQueen, 2013; Morrill, McAuley, Dilley, & Hambrick, 2015).

The cognitive ability to process and produce both complex hierarchically-structured speech and music is frequently found on a list of traits explaining humans' unique standing among animals (Hauser & Watumull, 2017; Martins, Gingras, Puig-Waldmueller, & Fitch, 2017). Music, like language, is a universal social phenomenon (Blacking, 1973) whose origins remain elusive (Merker, Morley, & Zuidema, 2015) because they are less clearly rooted in biology than is the case for language, for which the selective advantage is apparent (Cross & Morley, 2009). However, we have archaeological evidence that music played a role in human cultures already 40,000 years ago (Higham et al., 2012). A growing line of research follows a comparative approach across species to illuminate the biological roots of music: *zoomusicology* studies music-like aspects of sound communication in animals (Doolittle & Gingras, 2015). Cross-species research may not only help elucidate the nature and origins of music (Fitch, 2006; Honing, ten Cate, Peretz, & Trehub, 2015) and language (ten Cate, 2017), but as Patel (2017) argued, studying music across species may also help better understand the cognitive mechanisms of speech. More recently, building on progress in the biological sciences, researchers have shown growing interest in the genetic basis of music, especially in explaining individual differences in musicality (Gingras, Honing, Peretz, Trainor, & Fisher, 2015; Mariath et al., 2017). This relatively unexplored avenue of research is gaining impetus from more advanced research on the underlying genetics of the human capacity for language (Fisher, 2017).

Genetics and genetic abnormality also play a role in our understanding of *neurodevelopmental disorders*, a term referring to impairments of the growth and development of the central nervous system. *Congenital amusia* (hereafter *amusia*) is a hereditary disorder (Kalmus & Fry, 1980; Peretz, Cummings, & Dubé, 2007; Pfeifer & Hamann, 2018) mostly affecting pitch processing in music (Ayotte, Peretz, & Hyde, 2002; Foxton, Dean, Gee, Peretz, & Griffiths, 2004). This auditory disorder was first de-

scribed by a team led by Isabelle Peretz (2002) in a patient called Monica, who was impaired in musical abilities, such as singing and melodic discrimination and recognition. Monica had no history of brain lesion, no hearing loss, normal cognitive abilities and was exposed to music from an early age onwards. This influential discovery has led to an intensive research program over the past 15 years, which has primarily aimed at identifying the core deficit of amusia, its neuronal basis, and how this disorder affects speech processing. Amusia is currently being studied by a half-dozen research groups worldwide.

This chapter provides a review of the literature on amusia and speech processing (perception and production) within the framework of music and language comparisons. After briefly introducing the reader to current research on pitch processing in amusia, I will present a section on speech processing in *non-tone language speakers*, followed by a section on amusics who are *tone language speakers* (i.e., they use pitch to communicate lexical or grammatical meaning). This chapter will highlight influential studies leading to the notion that amusia is not a music-specific disorder, introduce the reader to common concepts and research paradigms, and also include ideas for future directions.

2 WHAT IS CONGENITAL AMUSIA?

Musical tones are characterized by perceptual attributes such as pitch, loudness, duration and timbre. *Pitch* is the perceptual property of a sound that is mostly related to the *frequency* of a sound, describing whether a sound is low or high. Frequency can be understood as the speed of a vibration and refers to the number of wave cycles that occur in one second. Musical tones varying in pitch can be assigned positions on a *musical scale* (i.e., a set of notes ordered by pitch). A sequence of tones taken from a musical scale can form a *melody*, and consecutive tones form *melodic intervals* that are defined by the ratio of their frequencies. This ratio determines the perceived pitch difference. In Western music, a *semitone* forms the smallest interval between adjacent tones on a diatonic scale. Several musical tones in a row can form a *melodic contour*, a pitch pattern that describes the global nature of a tone sequence over time (e.g., rising

or falling). Since pitch is among the fundamental building blocks of music (McDermott & Hauser, 2005), it becomes obvious that being impaired in pitch processing has far-reaching effects for the appreciation of music.

Congenital amusia is commonly diagnosed with the *Montreal Battery for the Evaluation of Amusia* (MBEA; Peretz, Champod, & Hyde, 2003), which assesses different aspects of musical pitch and time processing. The MBEA comprises six subtests (contour, interval, scale, rhythm, meter and memory), involving short melodies following the rules of Western tonal music. After having listened to pairs of melodies in the pitch-related subtests, participants perform a same/different discrimination task based on detecting possible manipulations of the second melody such as violations of contour, interval among other things. Thus, this test probes important music perception skills. In general, amusics perform significantly worse than healthy controls on the three pitch-related subtests of the MBEA but not necessarily on the meter and rhythm subtests (Peretz & Coltheart, 2003), which has led some researchers to diagnose amusia mostly by focusing on these pitch-related subtests (e.g., Liu, Patel, Fourcin, & Stewart, 2010). People diagnosed with amusia should not be mistaken for people in the population whose music perception abilities are normal but who cannot sing in tune (Pfordresher & Brown, 2007). Importantly, the first studies on amusia already hinted at a *fine-grained pitch processing deficit*, rather than at a specific music processing deficit. For example, amusics have difficulties detecting pitch changes that are smaller than two semitones (Hyde & Peretz, 2004), and they are less sensitive to the perception of pitch direction (i.e., pitches moving up or down; Foxton et al., 2004).

Besides the use of the MBEA, researchers have employed psycho-acoustic pitch perception tests to shed further light on the nature of the underlying low-level pitch processing deficit. A recent meta-analysis (Vuvan, Nunes-Silva, & Peretz, 2015) included a wide range of tests comprising acoustic tasks, such as *pure tone pitch change detection* (Does one tone in a set differ from the others?) and *identification* (Which of the tones is different from the others?), as well as *pure tone pitch change discrimination* (Are two sets of tones the same or different?) and *identification* (Is the pitch change up or down?). Vuvan et al. also evaluated the performance of amusics in non-acoustic tasks (including tone and non-tone language speakers), mostly those involving the perception of pitch

as expressed by *speech intonation* (i.e., the perception of the pattern or melody created by pitch changes in connected speech). Such tasks can be labeled as either *speech intonation identification* (Is the sentence a statement or a question?) or *discrimination* (Is the intonation of the second sentence the same as the first?). The authors analyzed 42 studies with data stemming from five research groups who used the MBEA to diagnose amusia. Controls performed much better than amusics in the respective pitch tasks. Moreover, the effect sizes could be predicted by the size of the pitch change used in the task (i.e., the larger the pitch change, the smaller the performance gap). Furthermore, the performance gap was smaller in tone language speakers, and interestingly, no effect was found when comparing studies using either tone or speech stimuli. The latter finding is of particular importance because it suggests that amusia is a pitch processing deficit that equally impacts musical tone *and* speech intonation processing. Finally, the authors reported a moderate to strong correlation between the performance on the MBEA and the respective pitch tasks. Although this meta-analysis provided several interesting insights into the underlying pitch processing deficit of amusia, it is necessary to exercise caution when interpreting the results: most research groups have a limited pool of participants due to the very low prevalence of amusia, which lies between 1.5 and 4.2%, depending on the way amusia is diagnosed (Henry & McAuley, 2010; Peretz, 2016). Thus, there is likely a large overlap of tested people in the individual studies coming from the same research group. This exemplifies the need to establish new pools of amusics and the collaboration between research groups to increase sample size and statistical power.

In the last few years, several other elaborate studies have further examined the pitch processing deficit underlying amusia. Most sounds in nature are not pure tones (sine tones) but *harmonic complex tones*, consisting of several *harmonics* (partials) which are sine waves and multiples of a *fundamental frequency* (F_0). The lower *resolved* harmonics of such a complex tone largely determine the sensation of pitch and can even be heard out individually, whereas the higher harmonics do not strongly contribute to pitch sensation (Bernstein & Oxenham, 2003). Cousineau, Oxenham and Peretz (2015) demonstrated that amusics are impaired in pitch perception only when the resolved harmonics are not present in a complex tone, whereas pitch discrimination did not differ from controls

when the tones only contained higher harmonics. In addition, amusics had normal periphery auditory perception, with intact basic temporal, spectral and intensity coding. In another series of psychoacoustic tests, Whiteford and Oxenham (2017) found that amusics were impaired in pitch processing of very high frequencies, which are not commonly used in musical communication. They also showed deficits in the processing of frequency modulations (see also Albouy, Cousineau, Caclin, Tillmann, & Peretz, 2016), and most strikingly in the processing of amplitude modulations, which refers to a deficit in the perception of loudness changes. Their data also provided more support for the view that amusics have a pitch impairment that is independent from a concurrent short-term memory problem related to pitch processing (Tillmann, Leveque, Fornoni, Albouy, & Caclin, 2016; for counterevidence see Jiang et al., 2013).

Another line of research has focused on the hypothesis that amusia is particularly associated with the inability to identify the direction of pitch changes (i.e., contour processing), which may be independent from poor pitch memory (see also *Melodic Contour Deafness Hypothesis*, Patel, Foxton, & Griffiths, 2005; for counterevidence see Vuvan et al., 2015). Lu, Sun, Ho and Thompson (2017) developed a novel task (*Self-paced Audio-visual Contour Task*) that probes contour processing while keeping memory load minimal. Visual and melodic contours were simultaneously presented and participants were asked to judge the congruency between the two contours. Specifically, after the presentation of each individual tone forming the contour, the participants had to judge whether the tone was lower or higher than the preceding tone. The authors found strong support for the notion that amusics have a contour processing deficit in addition to a pitch discrimination and short-term memory deficit.

Zhou, Liu, Jing and Jiang (2017) studied neuronal responses during melodic contour processing in a cross-modal priming paradigm. They showed that for Mandarin-speaking amusics musical meaning conveyed by changes in pitch direction (in this case a scale moving upwards or downwards) did not evoke an N400 effect in semantically incongruent melody-image pairs, whereas an N400 effect was observed in healthy controls. The N400 is a component of the event-related potential measured by means of electroencephalography (EEG) and sensitive to the processing of meaning (Kutas & Hillyard, 1980). Zhou et al.'s findings suggest that the amusic brain does not process changes in pitch direction

as a semantically meaningful cue, which was shown for both implicit and explicit tasks. However, using more complex music as primes (stimuli that use other acoustic cues than pitch to convey meaning) revealed that amusics showed an N400 effect as controls did, indicating that they are able to process musical meaning based on other cues than pitch direction. Thus, recent empirical evidence stemming from different research groups clearly indicates that amusia, among other things, may be characterized by a *pitch direction processing deficit*.

A number of researchers have attempted to identify the neuronal underpinnings of amusia, especially in the context of pitch processing. Peretz (2016), reviewing the neurobiology of amusia, is a proponent of the view that “[t]he core deficit of congenital amusia is characterized by a lack of awareness of acquired musical pitch knowledge. The amusic brain shows abnormalities in neural transmission between the auditory cortex and the inferior frontal gyrus in the right cerebral hemisphere” (p. 857). Her opinion is mostly based on research involving Western language speakers and suggests that the amusic brain responds normally to small pitch changes in music, but that conscious detection is impaired. In other words, as Peretz puts it, the amusic brain is “[i]n tune, but unaware” (2016, p. 859).

Several brain imaging studies (for details see Peretz, 2016) have indicated that the amusic brain processes auditory information normally up to the *primary auditory cortex* (A1) and the *superior temporal gyrus* (STG), but it appears as if the top-down feedback from the *inferior frontal gyrus* (IFG) to the STG is not happening to the extent it does in healthy controls. Therefore, it is likely that the right fronto-temporal network is not intact in amusics due to a reduced *arcuate fasciculus* (AF) connectivity between these regions (Figure 1). Peretz (2016) further suggests that amusia, together with other cognitive learning disorders showing a disconnection between the perceptual and frontal cortices (e.g., *dyslexia*, a learning difficulty affecting reading ability, and *prosopagnosia*, an inability to recognize faces), may have a common origin and that a genetic variant may be shared between these disorders.

Some studies have provided evidence against the frontal-temporal pathway hypothesis and reported impairments regarding the auditory brainstem response (Lehmann, Skoe, Moreau, Peretz, & Kraus, 2015) or identified issues regarding the tractography algorithm used to de-

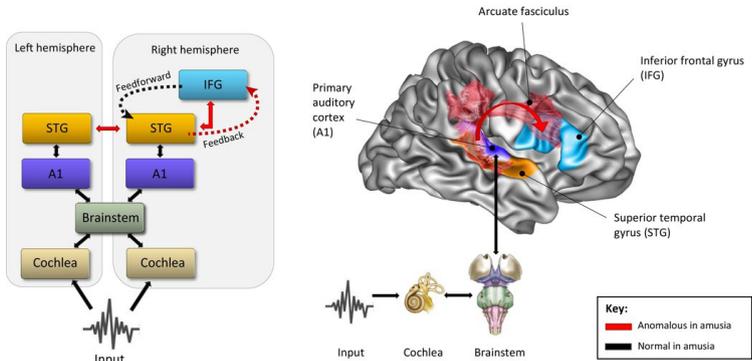


Figure 1. A schematic (left panel) and anatomical representation (right panel) of the anomalous recurrent processing in the right frontotemporal network in amusics (reprinted from *Trends in Cognitive Sciences*, Vol. 20, Peretz, *Neurobiology of congenital amusia*, p. 863, Copyright (2016), with permission from Elsevier).

tect the AF (Chen et al., 2015). Nevertheless, some further support for intact processing in the auditory cortex (Norman-Haignere et al., 2016) has accumulated using fMRI (for counterevidence using magnetoencephalography see Albouy et al., 2013), alongside recent reports that the amusic brain is characterized by a global connectivity deficiency of the white matter network, going clearly beyond a sole deficiency of the frontal-temporal pathway (Wang, Zhang, Wan, & Peng, 2017; Zhao et al., 2016). Moreover, it may be possible that the amusic brain differs between tone and non-tone language speakers, as recently suggested by Zhang, Peng, Shao and Wang (2017). With the rise of more advanced neuroscientific methods, future research will need to determine the precise neural processing deficiencies of amusia, especially how perceptual and memory processes are linked and how they are affected by missing feedback from other brain areas. This research will also need to integrate current findings suggesting that amusia is more than a fine-grained pitch processing deficit.

A vital question with respect to neurodevelopmental disorders is whether effective training programs can be developed to improve the impairment. Liu, Jiang, Francart, Chan and Wong (2017) have recently proposed

vided the first evidence for training effects on pitch direction perception. Twenty Chinese amusics were split into training and control groups. Over two weeks, the training group took part in a 10-session program which was individually tailored to improve the perception of pitch direction identification in speech and music. Amusics in the training group performed better in the pitch direction identification task after the training, but this improvement did not transfer to musical abilities. Nevertheless, this report will motivate further training studies on the *plasticity* of the amusic brain, especially since previous research has failed to show clear training effects (Anderson, Himonides, Wise, Welch, & Stewart, 2012; Goulet, Moreau, Robitaille, & Peretz, 2012; Wilbiks, Vuvan, Girard, Peretz, & Russo, 2016).

3 **SPEECH PROCESSING IN NON-TONE LANGUAGE SPEAKERS WITH CONGENITAL AMUSIA**

In the following section, I will review studies that investigated amusia in the context of phonology, linguistic prosody, affective prosody, syntax and verbal short-term memory. These studies go beyond the mere study of pitch processing in music and speech and target possible effects of amusia on various aspects of speech processing from a broader perspective.

3.1 **Phonology**

Phonological processing involves the use of sounds to process written and spoken language, comprising *phonological awareness*, *phonological working memory* and *phonological retrieval*. Phonological awareness refers to the awareness of sounds and oral language patterns within the words of one's language. More specifically, it alludes to the ability to work with syllables, to blend and segment *phonemes* in words (a phoneme, in a particular language, is one of the smallest units of speech making one word different from another). Phonological working memory refers to the short-term maintenance of speech sounds. Phonological retrieval, frequently assessed by *rapid automatized naming tests*, refers to the abil-

ity to recall phonemes associated with specific *graphemes* (the smallest meaningful contrastive units in a writing system; Wagner & Torgesen, 1987).

In healthy individuals, research has shown that phonological processing is positively associated with musical ability (Anvari, Trainor, Woodside, & Levy, 2002; Dawson, Aalto, Simko, Vainio, & Tervaniemi, 2017; Degé & Schwarzer, 2016; Lamb & Gregory, 1993; Linnavalli, Putkinen, Lipsanen, Huotilainen, & Tervaniemi, 2018; Marin, 2009; Moreno, Friesen, & Bialystok, 2011; Slevc & Miyake, 2006). The common explanation is that phonological processing relies on the effective processing of basic, low-level auditory features, namely changes in pitch and temporal variations. These changes in the auditory signal are shared attributes of speech and music, which are thus likely to share networks of auditory processing in the brain.

Remarkably few studies have been designed to test phonological processing in amusia. Jones, Lucker, Zalewski, Brewer and Drayna (2009) were the first to study whether a congenital pitch deficit observed for musical processing is associated with decreased phonological processing. The authors assessed *tune-deafness* (one of the precursor terms to amusia) by using the *Distorted Tunes Test* (Kalmus & Fry, 1980), which requires participants to indicate whether a popular melody sounds out-of-tune or not. Phonological processing was assessed with the *Comprehensive Test of Phonological Processing* (Lennon & Slesinski, 2003) and two other tests on auditory word comprehension and syllable segmentation, which in total led to five measures of phonological awareness (auditory word discrimination, elision, phoneme reversal, blending words and blending non-words) and three measures of phoneme awareness (segmenting words, segmenting non-words and syllable segmentation). Sixty-nine English-speaking participants took part in the main experiment, 35 of which were tune-deaf. In general, Jones et al.'s results indicated that tune-deaf participants performed significantly worse than controls in all eight tests probing phonological processing.

Sun, Lu, Ho and Thompson (2017), building upon the work of Jones et al. (2009), tested a group of English-speakers diagnosed with amusia using the MBEA. The authors assessed how pitch and rhythm processing in music are related to phonological processing in speech. They employed a pure-tone pitch discrimination task, a rhythm discrimination task as well

as four subtests of the Comprehensive Test of Phonological Processing (elision, memory for digits, non-word repetition and rapid-digit naming). Twenty amusics and twenty controls with intact reading abilities performed similarly well on all four phonological subtests. However, the authors identified a subgroup of amusics with particularly high pitch discrimination thresholds. Further analysis considering the two subgroups of amusics (i.e., with normal or abnormal pitch discrimination thresholds) and controls revealed group differences only for the elision test, which assesses the ability to remove phonological segments from spoken words to form new words. Amusics with abnormal pitch discrimination thresholds performed worse than amusics with normal pitch discrimination thresholds and controls (the latter two groups performed similarly well). IQ and reading ability could not explain why amusics with abnormal pitch discrimination performed worse. Regarding rhythm discrimination ability and its relation to phonological processing the authors reported a moderate correlation; however, further statistical analyses revealed that pitch discrimination ability was a stronger predictor of the performance in the elision test than rhythm discrimination ability and phonological short-term memory. Taken together, their results suggest that pitch discrimination ability, and not performance on the MBEA, is a reliable predictor of phonological awareness. Early stage deficits in auditory processing of pitch may thus have a negative impact on higher level processes of discriminating, segmenting and blending phonemes.

The studies by Jones et al. (2009) and Sun et al. (2017) present a first step towards our understanding of how impairments in basic pitch processing impact phonological processing. A comparison of results across the two studies is difficult because they differ in their way of assessing the ability to process musical pitch, and Jones et al. did not determine any pitch thresholds. Unfortunately, none of the studies employed a pitch direction discrimination task; therefore, future studies may include a wider spectrum of tests to assess general and musical pitch processing more comprehensively (Lu et al., 2017). At the moment, the choice of a specific pitch test is often unexplained and seems to depend on the research groups' views on the nature of amusia. However, an open and broad approach towards measuring pitch processing would shed light on the question of whether the ability to process musical and/or general pitch is linked to phonological awareness, which would have important

implications for issues surrounding the relationship between music and speech processing.

If we identified the key variable causing the observed deficit in phonological awareness in amusia, we might also be able to better understand the mechanisms underlying another developmental disorder, namely those of dyslexia (see also Turker in this volume). It is generally agreed that deficits in phonological awareness and poor reading abilities are related (Gillon, 2018; Ozernov-Palchik & Gaab, 2016; Ramus et al., 2003), but it is still unclear how a deficit in phonological awareness may eventually develop into a reading disorder (Raschle, Stering, Meissner, & Gaab, 2014). For example, deficits in *rapid auditory processing* have been described in pre-reading children with a familial risk for dyslexia (Raschle et al., 2014). Interestingly, impaired encoding of rapid pitch information has also been identified as a possible cause of amusia (Albouy et al., 2016). Albouy et al. argue that developmental disorders such as dyslexia, specific language impairment and congenital amusia may be characterized by a low-level sensory dysfunction. Clearly, future research will need to extend this growing area of investigation by taking on a broader view on auditory development and its disorders.

3.2 Linguistic prosody

In human communication, it is not only important *what* people say but also *how* they say it. The term *prosody* refers to the melodic and rhythmical aspects of speech, sometimes being described as “the music of everyday speech” (Wennerstrom, 2001, p. 1). Prosody is derived from ancient Greek *προσῳδία*, meaning “song sung to music, variation in pitch of the speaking voice, or pronunciation of a syllable on a certain pitch” (Oxford English Dictionary, 2007). In linguistic terms, prosody is the study of those aspects of speech that are above that of the individual phoneme (i.e., *suprasegmental*) and those that may also refer to sequences of words. Prosody is characterized by changes in vocal pitch, loudness, tempo and voice quality (Crystal & Quirk, 1964; Fonagy, 1978). *Linguistic prosody* is specific to a language and can signal phrase boundaries, put emphasis on individual parts of a word (*word stress*) or words within a sentence (*sentence focus*), or signal whether a sentence is a statement, question or command. *Affective prosody* can be partly understood cross-culturally

(Sauter, Eisner, Ekman, & Scott, 2010) and signals emotions and attitudes of the speaker in normal speech as well as *affect bursts* without semantic meaning (see section 3.3). In a meta-analysis, Belyk and Brown (2014) reported that although linguistic and affective prosody processing largely overlap in the right hemisphere of the healthy brain, affective prosody more likely activates Brodmann area 47 and linguistic prosody the ventral part of area 44.

Studying linguistic prosody perception in amusia is an interesting topic because amusics generally do not report any speech impairments in their daily lives. However, the first studies on music-speech comparisons in amusia already concerned themselves with speech intonation perception, probably motivated by the idea that melody processing in music may be related to the processing of speech melody. A considerable body of research has assessed how amusics perceive and produce linguistic prosody (Vuvan et al., 2015), which has largely shaped our understanding of the general pitch processing deficit underlying amusia (see section 2). Therefore, it is worth reviewing some of the most influential studies on this topic to demonstrate how the field has moved away from considering amusia as a domain-specific disorder (Peretz & Coltheart, 2003) by questioning initial results on speech perception and developing complex experimental tasks.

Ayotte et al. (2002) observed that amusics were *not* impaired in the processing of intonation patterns in sentences but in the processing of discrete tone sequences based on the intonation patterns of the same sentences, suggesting that amusia is a domain-specific disorder. Arguing that the pitch contours were not exactly matched across sentences and tone sequences, which may explain this dissociation, Patel et al. (2005) created discrete and gliding pitch-analogs of the intonation contour present in the sentences. Employing a discrimination task, they used two types of sentence-pairs (statement-question pairs and focus-shift pairs) that had the same semantic content but different intonation contours. Amusics performed worse on the discrimination of pitch-analogs mimicking the intonation patterns of the sentences than on the original sentences, corroborating findings by Ayotte et al. (2002).

Although Patel et al. (2005) observed no deficit in speech intonation processing among amusics, Lochy et al. (2004) had already noted that some French-speaking amusics may show an impairment. Motivated by

this observation, Patel, Wong, Foxton, Lochy and Peretz (2008) studied British and French-Canadian amusics and investigated the perception of statement-question pairs in more detail. Specifically, they examined whether deficits in the processing of the final pitch change (measured as *glide size* and *glide rate*), which differentiate statements from questions, can explain individual differences in amusics' performance. They found that around 30% of the tested amusics could not differentiate between a statement and a question characterized by a falling or rising pitch. The same amusics, however, were able to discriminate discrete pitch analogs based on the intonation contours of sentences. In addition, these amusics were not impaired when asked to detect changes in emphasis placed on individual words within a sentence. Taken together, these results indicate that the underlying problem of intonation processing in speech is related to an impairment of processing pitch direction.

Building upon this hypothesis, Liu et al. (2010) employed a series of five tasks probing discrimination, identification and imitation of statements and questions that differed in the pitch direction of the final word (i.e., statement-question discrimination in natural speech and gliding tones, nonsense speech, statement-question identification and imitation). They also conducted two psychoacoustic tasks which determined thresholds for pitch change detection and pitch direction discrimination. The authors observed that amusics performed worse than controls in all speech intonation tasks, for which smaller pitch contrasts were used than in Patel et al. (2008). Moreover, amusics' pitch direction discrimination thresholds were negatively correlated with their performance in most tasks. Altogether, this comprehensive study provided strong evidence that amusia is *not* a domain-specific disorder and that brain networks for music and speech processing may overlap in amusia (see section 2).

Trying to understand why some studies reported no deficit in speech intonation processing (Ayotte et al., 2002; Patel et al., 2005; Peretz et al., 2002) whereas others did (Liu et al., 2010; Patel et al., 2008), Hutchins, Gosselin and Peretz (2010) hypothesized that the reason for the discrepancy may lie in the fact that speech uses larger pitch differences to communicate relevant information than music, which would explain why amusics' impairment is more salient with musical stimuli. In other words, fine-grained differences in pitch play a larger role in music than in speech. Hutchins et al. used sentences and tone sequences which

followed the pitch contour of the sentences, and they manipulated the pitch of the final word/tone in 11 steps so that they represented a pitch continuum, indicating either a statement or a question at its endpoints. Participants judged whether a sentence was a statement or question or whether a tone sequence ended on a rising or falling contour. For both speech and music, amusics showed lower accuracy and consistency in their categorizations, with a similar performance for both stimulus types (see also Vuvan et al., 2015). Furthermore, the data showed that amusics could correctly identify unambiguous stimuli representing statements or questions, which may explain why amusics usually do not report any problems in their daily lives.

Another question of interest is whether discrimination ability is coupled with *imitation ability*, or whether these aspects of speech intonation and pitch processing are decoupled (Liu et al., 2010; Loui, Guenther, Mathys, & Schlaug, 2008). This question is of relevance because pitch processing may involve a dual-route in the brain: one pathway involving vocal production and another pathway involving representations that are necessary to perform conscious perceptual tasks. Hutchins and Peretz (2012) employed local pitch variations in sentences (i.e., pitch shifts within a sentence) and tested whether amusics and controls can perceive the similarity or difference of these variations when comparing pairs of sentences (discrimination task), and further, whether they can imitate pitch in speech after listening to the same sentences (imitation task). Their results supported the view that amusics are impaired in perceiving pitch changes in speech but have intact imitation abilities. These findings suggest that amusics are able to make use of a kind of motor-system based pitch representation when imitating speech intonation. As the authors point out, a decoupling of perception and production has also been reported for general visual (Goodale & Milner, 1992) as well as for speech processing (Hickok & Poeppel, 2004), which makes the existence of similar separate neural pathways for pitch processing also very likely.

In a follow-up study, Hutchins and Peretz (2013) examined perception and imitation of vocal pitch shifts in singing and speech within the context of the *dual-route model of pitch*. The *pitch shift reflex* “is a sophisticated system that produces a compensatory response in voice F0 [fundamental frequency] that is opposite in direction to a change in voice pitch feedback (pitch-shift stimulus)” (Bauer & Larson, 2003, p.

1048). The underlying psychological process is explained by the parity of motor and auditory representations of pitch, assuming that auditory input is transformed into a vocal-motor code representation. If a person sings or speaks and the voice pitch feedback is altered in pitch during the vocalization, the person makes adjustments in pitch even without conscious awareness of the pitch shift in the feedback. Hutchins and Peretz applied a self-matching method in which amusics and controls were first recorded while producing sung (three different notes) and spoken (three one-syllable words) materials. Then participants were asked to imitate their own recordings, including pitch shift trials in which imitations were either shifted up or down (25 or 200 cents) or left unaltered as a control. The results showed that amusics were generally less accurate than controls when imitating sung or spoken pitch prior to the onset of pitch shifts. Amusics performed particularly badly in the singing condition. In controls, the performance for sung and spoken materials was similar. Interestingly, only a few amusics did not show a normal pitch shift response, and nearly half showed a normal pitch shift response to small and large shifts. Their performance was predicted by vocal pitch matching ability and not by pitch perception ability. The authors conclude that their data provide support for the dual-route model of pitch, and further, that pitch perception and production are dissociated in amusia (see section 2).

To summarize, research on amusia and linguistic prosody has not only broadened our understanding of the underlying pitch processing deficit in amusia, but has also led to a research program that focuses on speech perception alongside production, following an embodied view of cognition. Research on amusia has thereby contributed to our understanding of pitch processing in healthy individuals. Future studies may address the issue of whether amusics show deficits in linguistics prosody processing that extend beyond speech intonation processing, such as speech rhythm processing, which may be worth testing in those amusics who are also impaired in musical rhythm processing.

3.3 **Affective prosody**

Affective or *emotional prosody* refers to the non-verbal expression of emotion in speech. By means of varying features, such as pitch contour,

intensity, duration and speech rate (Bachorowski, 1999; Bänziger, Patel, & Scherer, 2014), humans manage to communicate a wide range of emotions in social interactions. For instance, affective prosody plays a crucial role in infant-directed speech and has a positive impact on linguistic outcomes during language development (Spinelli, Fasolo, & Mesman, 2017). Affective vocal communication has also received attention in relation to the origins of language (see also Filippi & Gingras in this volume). None other than Darwin suggested in *The Descent of Man* (1871) that proto-musical emotional expressions, similar to singing, were a precursor of language (for a detailed discussion see Fitch, 2010), whereas Spencer (1911) argued the contrary, namely that affective prosody was the precursor of music. Brown (2017) has recently presented his *Musilanguage 2.0 model*, taking on an alternative perspective by putting affective and linguistic prosody at the core of his model and arguing that there were two sequential precursor stages, shared by language and music, prior to a bifurcation into two homologous communication systems at a later evolutionary stage.

Both music and language share acoustic cues in the communication of emotion (Juslin & Laukka, 2003), and overlapping brain networks in the processing of vocal and musical emotions have frequently been described in healthy individuals (Frühholz, Trost, & Kotz, 2016). Moreover, musical training and affective prosody perception are positively correlated (Lima & Castro, 2011). Motivated by these findings, several studies have addressed the issue of affective prosody perception in amusia, hypothesizing that if parts of the brain networks are shared between music and language, a pitch processing impairment may lead to deficits in affective prosody processing.

Thompson, Marin and Stewart (2012) were the first to show that Western amusics are impaired in decoding emotions from speech. Amusics and controls listened to semantically-neutral spoken phrases (e.g., “The broom is in the closet and the book is on the desk”) using headphones and were asked to report the conveyed emotion by choosing one out of six emotion categories: happy, sad, tender, irritated, afraid and neutral. Amusics performed worse than controls in classifying happiness, tenderness, sadness and irritation. They also reported some awareness of their emotion perception deficit in their daily lives. Lolli, Lewenstein, Basurto, Winnik and Loui (2015) further investigated the underlying cause of

this perceptual impairment by working with the same set of stimuli and applying filtering techniques to manipulate the frequency content of the phrases. Amusics and controls performed similarly in the unfiltered condition, which did not corroborate findings by Thompson et al. (2012). More specifically, their findings indicated that among amusics pitch discrimination ability correlated with the performance in the emotion categorization task in the low-pass filtered speech condition (preserving the speech contour but not formants) but not in the high-pass filtered (preserving speech rate, stress patterns and rhythm) and unfiltered conditions. The data suggest that amusics with poor pitch discrimination abilities did not rely on high-frequency speech cues to perform the task.

Lima et al. (2016) investigated whether amusics' emotional prosody deficit extends to deficits in affective processing of other auditory or visual socio-emotional cues. They studied amusics' ability to decode emotions communicated by affective prosody (using different stimuli than Thompson et al., 2012, and Lolli et al., 2015), non-verbal vocalizations and dynamic facial expressions. Across modalities amusics showed impairment in affective processing, as demonstrated by lower recognition accuracy and more ambivalent responses. An analysis of the underlying acoustic cues of the vocal stimuli, focusing on pitch and non-pitch attributes, revealed that amusics' profile of acoustic cues predicting affective responses differed from the one of controls. Furthermore, Lima et al. reported that amusics were less able to judge the authenticity of laughter (pose vs. spontaneous) but showed normal contagion responses. In summary, this is the first study to suggest that amusia is a developmental disorder affecting the processing of socio-emotional stimuli other than auditory.

Future research on amusia and vocal affect processing may study, besides emotional communication, aesthetic aspects of speech and music (see Loutrari & Lorch, 2017, for a case study on the perception of musical and prosodic expressivity), which may reveal why some amusics are able to enjoy music (Omigie, Müllensiefen, & Stewart, 2012). Moreover, the neural underpinnings of the impairment of affective processing in amusia are still unclear. It needs to be determined whether the deficit observed in amusia is due to the fact that the right hemisphere, which is impaired in amusics, is mainly active in affective prosody processing in healthy individuals (Frühholz et al., 2016). Another open question

is whether and how the ability to process affect in music is related to the processing of affect in speech. Several studies have assessed whether amusics show impairments in musical affect processing (Cousineau, McDermott, & Peretz, 2012; Gosselin, Paquette, & Peretz, 2015; Marin, Thompson, Gingras, & Stewart, 2015; Zhishuai, Hong, Daxing, Pin, & Xuejing, 2017), but these studies did not collect data on affective prosody perception. It is also unknown whether amusics can express and imitate emotions in speech to a similar degree as controls. Finally, future research may also reveal how amusia is linked to other developmental disorders in which socio-emotional processing is impaired, such as *autism spectrum disorders* (Griffiths et al., 2017). For example, current research seems to indicate that the ability to discriminate pitch direction may be correlated with melodic perception in individuals with autism spectrum disorders (Germain et al., 2018).

3.4 Syntax

Both language and music are auditory communication systems in which discrete elements are combined to form sequences of units that are arranged in a hierarchical structure. In both domains, these structures can be described by a set of *syntactic rules*. Patel (2003) hypothesized that language and music share syntactic resources in the brain, and abundant empirical evidence in support of this has accumulated since then. For example, a sharing of resources in Broca's area (see also Luef in this volume) in healthy individuals was demonstrated using fMRI (Kunert, Willems, Casasanto, Patel, & Hagoort, 2015). Studies using EEG have also shown that signatures of early and late processing stages are similar and overlap during language and music processing (Koelsch, Gunter, Wittfoth, & Sammler, 2005; Koelsch, Rohrmeier, Torrecuso, & Jentschke, 2013).

Sun et al. (2018) investigated English-speaking amusics and found that their brain responses to language- and music-syntactic irregularities (in speech and melodies) were abnormal compared to controls. Amusics were impaired in early, but not later, syntactic processing stages in both domains. To be specific, the authors could demonstrate that amusics showed no LAN (*Left Anterior Negativity*) and ERAN (*Early Right Anterior Negativity*), two event-related potential components associated with

the processing of syntactic irregularities in language and music, respectively (Koelsch, 2005). Amusics' N5 and P600 components were similar to those of controls, reflecting intact syntactic processing at later stages. Furthermore, the authors did not observe any impairment regarding language-semantic processing among amusics, providing more evidence for different brain networks involved in syntactic and semantic processing.

3.5 **Verbal short-term memory**

Due to their dynamic nature, speech and music communication draw heavily on short-term memory. Amusia has not only been associated with perceptual deficits in pitch processing, but also with deficits in short-term memory for pitch (Tillmann, Schulze, & Foxtan, 2009) and timbre (Marin, Gingras, & Stewart, 2012). However, it is important to state that short-term memory for the content of verbal materials, such as digits and words, is preserved in amusics (for a review see Tillmann et al., 2016). A recent review by Caclin and Tillmann (2018) suggests that the cognitive systems underlying short-term memory for musical and verbal materials only partly overlap. The authors also call for more systematic studies involving the comparison between short-term memory in music and speech, which could be accomplished by focusing only on one perceptual dimension in both domains (e.g., pitch) and by investigating individual components of short-term memory (i.e., encoding, retention and retrieval) in more detail.

4 **SPEECH PROCESSING IN TONE LANGUAGE SPEAKERS WITH CONGENITAL AMUSIA**

The substantial body of research on amusia in non-tone language speakers conducted during the first decade of the 21st century has provided a solid basis to initiate a similar research program in Asia. This move towards studying tone language speakers was partly motivated by the idea that being exposed to a tone language may compensate for being amusic (Peretz, 2008); however, as Jiang, Hamm, Lim, Kirk and Yang (2011) showed shortly after, Mandarin-speakers with amusia were impaired in

two fine-grained pitch discrimination tasks. Moreover, around the same time, studies testing French-speaking amusics revealed impairment in processing *lexical tone* (Nguyen, Tillmann, Gosselin, & Peretz, 2009; Tillmann et al., 2011). Lexical tone refers to the alteration of word meaning by small pitch variations (i.e., a change in pitch contour). In Mandarin Chinese there are four tones, namely *level*, *mid-rising*, *dipping* and *high-falling*. If, for example, the syllable *ma* is pronounced with a level tone, it means ‘mother’, if it is pronounced with a dipping tone, it means ‘horse’. Most research on amusia in tone language speakers has been conducted among Mandarin speakers, and more recently, some studies involved Cantonese speakers. Mandarin and Cantonese differ regarding pronunciation, grammar and lexicon. Since these two tone languages differ considerably, the research on speech processing in amusia is presented separately.

4.1 **Speech processing in Mandarin speakers**

4.1.1 *Lexical tone*

One of the first studies involving Mandarin-speaking amusics was published by Nan, Sun and Peretz (2010) who showed that the pitch impairment (i.e., the performance on the MBEA) in these amusics was comparable to the one reported for non-tone language speakers, which may suggest a common origin of the disorder. Moreover, they also assessed the perception and production of lexical tone (tone identification, tone discrimination and lexical tone production), and their results indicated that half of the amusics were impaired in lexical tone identification and discrimination while lexical tone production was intact (see section 3.2 for a description of a similar dissociation in non-tone language speakers). However, it was unclear whether the observed deficits were due to impaired phonological awareness or pitch processing because amusics were only impaired in tone perception when the syllables carrying the tone differed within a trial.

In a follow-up study on the same topic, Liu et al. (2012) used smaller tone contrasts in their word discrimination task, and they also minimized the demand for phonological awareness by adding Chinese characters to the tone identification task. They studied word identification and discrimination by using natural words as well as gliding tone ana-

logues. Their results indicated impaired performance in the word discrimination task but intact performance in the word identification task. Surprisingly, Mandarin amusics performed better in the condition with gliding tones than in the natural tone condition. Differences in the experimental design may explain the discrepancy between Nan et al. (2010) and Liu et al. (2012) regarding the results of the word identification task. Altogether, these influential studies demonstrated that amusia is not specific to non-tone language speakers and, as previously shown, is not a music-specific disorder either.

Being interested in the *categorical perception* of lexical tones, Jiang, Hamm, Lim, Kirk and Yang (2012) studied the identification and discrimination of tones by generating continua of pitch patterns in 11 steps, ranging from a high-level tone to a mid-rising tone in one case, and in the other case from a high-level tone to a high-falling tone. In addition to the natural speech stimuli, non-linguistic pitch analogues were created. A classification task showed that amusics had shifted classification boundaries compared to controls and experienced a specific problem with classifying rising or falling pitches. The results of the discrimination task supported the view that amusics are impaired in lexical tone processing because their performances did not improve when the two stimuli crossed the classification boundary, which held true for both speech and non-linguistic pitch analogues.

Wang and Peng (2014) wanted to identify whether a deficit in pitch or phonological processing underlies the impairment found for lexical tone processing. Testing Mandarin amusics, the authors added familiarity as a potential factor to their research design by using fine-grained tone contrasts in Cantonese consonant-vowel combinations that were either similar or dissimilar to the Mandarin counterparts. Familiarity played a role when natural Cantonese level tones needed to be discriminated. Controls only performed better in the familiar condition, whereas in the unfamiliar condition controls and amusics performed similarly, indicating that the phonological deficit is the driving factor explaining amusics' performance. Amusics were also able to correctly imitate the Cantonese level tones (see section 2 for similar reports). This study also emphasizes that segmental and suprasegmental processing are closely intertwined in speech processing.

Motivated by the idea that there may be subgroups of amusics who are either impaired or unimpaired in their speech processing abilities (Nan et al., 2010; Patel et al., 2008; Yang, Feng, Huang, Zhang, & Nan, 2014), Huang, Liu, Dong and Nan (2015) studied categorical perception of lexical tones in three groups (controls, *pure amusics* and *amusics with lexical tone agnosia*) and compared their performances in a tone identification and discrimination task. Amusics with tone agnosia performed previously worse on a lexical tone identification and discrimination task than controls and pure amusics. For this study, the authors created a set of stimuli based on the vowel /a/ by covering a continuum of different frequency contours, ranging from rising to level tone, with a varying onset frequency and a fixed offset frequency. The results indicated that controls and pure amusics performed similarly well, and that only amusics with tone agnosia were impaired in categorical perception. The sample size was very small, but the data suggest that there are subsystems of pitch processing that are not shared in music and speech, which clearly reinvigorates the discussion about *modularity* (i.e., domain-specificity). The same research group also demonstrated that only amusics with tone agnosia were impaired in pitch contour processing (Huang, Nan, Dong, & Liu, 2015).

Neurophysiological evidence has recently corroborated this finding. Nan, Huang, Wang, Liu and Dong (2016) used EEG to record *mismatch negativities* (MMNs) in response to changes in lexical tones in a sequence of stimuli. The MMN is an event-related potential that occurs in response to an odd stimulus in a sequence of stimuli (Näätänen & Alho, 1995). Amusics with tone agnosia had reduced MMN responses in comparison to pure amusics and controls. Furthermore, the authors demonstrated that there was a positive association between the neural responses and the behavioral measures, showing that the MMN is a well-suited objective measure of performance. Future research will have to meet the challenge of determining whether the differentiation into pure amusics and amusics with tone agnosia is justified, and if so, to what degree genetic or environmental factors can explain the existence of these subgroups. It is plausible to assume that this debate will profit from our growing understanding of the underlying pitch processing deficit in amusia, in both tone and non-tone language speakers.

Research on lexical tone processing may also reveal insights into basic questions of pitch processing by investigating which aspects of pitch processing are impaired and how amusics compensate for them. In an elaborate experiment, Bones and Wong (2017) recently reported that amusics may use *temporal-envelope pitch cues* to process lexical tones. These are pitch cues that are inherent in the temporal envelope of the high-numbered unresolved harmonics. The authors used chimera stimuli in which ambiguous words contained pitch cues in the temporal fine-structure and temporal envelope. Amusics were more likely than controls to base their judgments of words on envelope cues, suggesting that amusics rely on a secondary mechanism of pitch processing.

4.1.2 *Speech intonation*

In the literature on linguistic prosody processing in tone language speakers, there seems to be a general agreement that amusics show an impairment in laboratory conditions, which is in line with previous studies involving non-tone language speakers (see section 3.2). Jiang, Hamm, Lim, Kirk and Yang (2010) were the first to demonstrate that Mandarin-speaking amusics are impaired in melodic contour processing as well as in speech intonation processing. By using discrimination and identification tasks, they showed that amusics performed worse than controls in differentiating between statements and questions in natural speech (based on two-syllable verb-object constructions whose pitch pattern of the final syllable was manipulated) and also in conditions with non-linguistic pitch-analogues. The data did not reveal subgroups of amusics. Liu et al. (2012) employed longer speech stimuli (statements and questions) that varied naturally in duration, intensity and pitch. The authors hypothesized that amusics should be able to differentiate between statements and questions by using acoustic cues other than pitch, which was indeed the case. This finding may explain why amusics generally do not report difficulties in speech perception in their daily lives.

Jiang, Hamm, Kim et al. (2012) studied the cognitive processing of linguistic prosody during listening to short discourses using EEG. In these discourses, a question (speaker A) was followed by a yes/no answer and a sentence consisting of two clauses (speaker B), of which the second clause was either a statement or question. Each discourse was recorded

twice, once with the correct and once with the incorrect intonation at the end of the discourse (last syllable). This enabled the authors to have congruent and incongruent pairings between semantic content and prosody. Amusics performed worse than controls in a speech comprehension task, and the neurophysiological data revealed that the P600 and N100 effects differentiating between congruent and incongruent intonation in controls were not present in amusics. Among other things, the P600 effect can occur in the context of a syntax-prosody mismatch (Eckstein & Friederici, 2005), whereas the N100 effect has also been associated with intonation expectation (Näätänen & Picton, 1987). Therefore, the amusic brain seems to be impaired in processing the (in)congruency between semantic meaning and intonation.

Relatively little is understood about whether the pitch processing deficit underlying the impairment in intonation processing can be overcome by drawing on other linguistic information. In an ERP study, Lu, Ho, Liu, Wu and Thompson (2015) thus investigated whether the emotional valence of words can compensate for impaired intonation processing (statements vs. questions) in amusics. They were motivated by previous reports that emotional linguistic information can facilitate stimulus processing, but the authors did not find a positive effect of emotion. Amusics showed impaired performance in the intonation-matching task as well as a reduced N2 response to incongruent intonation pairs. The N2 response has previously been found to be larger in conflict than in non-conflict trials (Nieuwenhuis, Yeung, Van Den Wildenberg, & Ridderinkhof, 2003). Nevertheless, Lu et al.'s data indicated that early auditory processing is intact in amusics because the N1 response was similar in amusics and controls.

Speech intelligibility in noisy conditions was the center of interest in a study by Liu, Jiang, Wang, Xu and Patel (2015). Their stimuli comprised news-like sentences spoken in Mandarin, and the sentences' pitch contour was either natural or flattened. There were four conditions of babble noise and a quiet control condition. Participants were asked to listen to the sentences and to write down what they understood on a piece of paper. Amusics (young, highly-educated adults) were impaired in speech comprehension in all conditions regardless of the sentence type (natural or flattened). Moreover, the authors reported that this deficit among amusics was not related to their pitch processing deficit, which is in line

with recent findings suggesting that amusics may be impaired in other aspects of auditory processing besides pitch processing (Whiteford & Oxenham, 2017). Liu et al. (2015) speculated that amusics may also be impaired in segmental processing, which may be relevant for the debate surrounding the rapid auditory processing hypothesis in amusia which has already been discussed in relation to non-tone language speakers (Albouy et al., 2016) and other neurodevelopmental disorders.

4.2 **Evidence from Cantonese speakers with congenital amusia**

Replication of results should be at the core of any empirical research field. Liu et al. (2016) recently replicated findings previously reported for Western (English and French) and Mandarin-speaking amusics in Cantonese-speaking amusics. Cantonese is characterized by six tones and thus exhibits a more complex tone system than Mandarin. Liu et al. employed a large set of tests, measuring pitch thresholds, lexical tone perception and production as well as singing ability. In brief, their results indicated that amusics showed severe impairments in music perception and production, mild impairments in speech perception and intact speech production. Therefore, this study nicely corroborates previous accounts and calls for similar studies involving other languages.

Since some evidence has accumulated that amusia may be more than a domain-general pitch processing deficit (Lehmann et al., 2015; Liu et al., 2015; Whiteford & Oxenham, 2017), Zhang, Shao and Huang (2017) investigated frequency processing beyond pitch processing. To be specific, they examined frequency/spectral processing in the context of segmental processing and the perception of vowels. Spectral frequency peaks (*formants*), in particular the first and second formants, determine the difference between vowels. Sound continua in three frequency-based stimulus types (lexical tone, pure tone and vowel) and one temporal stimulus type (voice onset time) were employed. The authors reported that amusics were impaired in the discrimination, but not in the identification, of all three frequency-based stimuli types. Amusics were unimpaired in the processing of temporal information. They concluded that the data suggest that amusics are impaired in phonological processing of speech sounds as well as in basic auditory pitch processing of pure tones,

which clearly motivates further studies on how this disorder manifests itself in different auditory contexts.

To summarize, considerable research attention has been devoted to the study of speech intonation and lexical tone in amusia in tone language speakers during the last few years, including the employment of unique paradigms (Liu et al., 2015; Lu et al., 2015) that could be applied to the study of Western language speakers. In general, the prosodic impairment in tone language speakers with amusia seems to be similar to the one observed in non-tone language speakers, which suggests a culture-independent impairment. The next steps will probably include the study of affective prosody perception and production to be able to make similar claims regarding that aspect of speech processing.

5 CONCLUSION

In the last 15 years, research on the nature of amusia has made significant progress, which has led to the current notion that amusia involves several cognitive deficits related to pitch processing, namely those regarding pitch change detection, pitch direction discrimination as well as short-term memory for pitch. Importantly, future research will have to clarify whether other basic perceptual/cognitive deficits, going beyond pitch processing, need to be included in the characterization of amusia, and further, how these deficits overlap with other developmental learning disorders (Peretz, 2016).

In this light, research on speech processing in congenital amusia has considerably changed our view about this auditory neurodevelopmental disorder. Although amusia is mostly conceived of as a musical disorder, it is now generally accepted that individuals with amusia show a wide range of deficits in speech processing in laboratory conditions due to a domain-general impairment in pitch processing. Thus, the reported deficits regarding phonology, prosody and syntax are pertinent to our understanding of how music and speech are processed in the brain and support speculations about a common origin of music and language. This opens a door for further studies exploring cognitive and affective deficits in amusia across domains.

A representative body of research involving both tone and non-tone language speakers has dealt with speech perception and production, comprising a wide range of tasks and stimulus types as well as behavioral and neurophysiological measures. Only such a comprehensive approach involving researchers from different fields (linguists, music psychologists and neuroscientists) has made it possible to arrive at the current state of knowledge about amusia. Consequently, it is my fervent hope that research on amusia will remain an interdisciplinary playground hereafter.

Future research will have to meet the challenge of replicating the present results in language speakers other than English, French, Mandarin and Cantonese. This would necessitate that more research groups become interested in studying amusia, and ideally, that research groups collaborate and conduct the same experiments in cohorts from different cultures. Such an approach will also clarify whether subgroups of amusics exist, and if so, whether they are language-specific.

ACKNOWLEDGEMENTS

I am very grateful to Fang Liu, Bruno Gingras and an anonymous reviewer for helpful comments, which have greatly strengthened the chapter.

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II

Language Development

The attainment of independence from the mother in primate infants and its implications for the evolution of cooperative breeding in hominins

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ABSTRACT The infant process of attaining independence from the mother is directly related to the course of lactation and timing in resumption of cycling for mothers, which affect female reproductive rates. Understanding infant development patterns and variations across primates can allow us to evaluate their fitness implications and inform comparative life history models of hominoids. Here, factors leading to inter- and intra-species differences in development and lactation will be evaluated and contextualized relative to sources of life history and socio-ecological variation. Literature on maternal investment through lactation and on infant nutritional development in the *Primate* order will then be reviewed. Finally, the concept of alternative behavioral and nutritional perspectives on weaning will be introduced to emphasize that physiological and social needs within the mother-offspring relationship are mitigated, together and separately, to support primate infants in their attainment of independence. A layered perspective that distinguishes between social and physiological mother-infant relationships may be important to consider in evolutionary models aimed at understanding the appearance of cooperative breeding in hominins, as it puts extant nonhuman primates in a position more similar to the human pattern than previously anticipated.

This perspective can help us to more accurately determine the evolutionary steps leading to the unique life history traits of contemporary humans.

KEYWORDS cooperative breeding, infant development, mother-infant relationship, parental investment, primate life history, weaning

1 INTRODUCTION

Infancy is one of the most dangerous periods of a primate's life, and this is assumed to be partly because infants are unable to meet nutritional requirements independently (Janson & van Schaik, 1993). Mortality risks are highest during this time, as infants are vulnerable to the negative health effects of inadequate nutritional intake (Altmann & Alberts, 2005; Sellen, 2007). To reach feeding independence, primate infants transition through three developmental stages that are distinguished by two major life history markers: 1) the first ingestion of solid food marks the end of the exclusive suckling stage and beginning of transitional feeding (or complementary feeding in humans), and 2) the last nutritive nursing bout (with milk transfer) marks the end of *weaning*, and effectively ends infancy (Bădescu, Katzenberg, Watts, & Sellen, 2016a; Sellen, 2007, 2009). The rates at which primate infants go through the process of attaining feeding independence from the mother often varies by species according to differences in life history patterns, physiology and socioecology (Kennedy, 2005; Lee, 1997; Sellen, 2006). Moreover, infant development can differ considerably between and within populations of the same species. Variations in feeding development have been noted in the great apes (e.g., chimpanzees, *Pan troglodytes*: Bădescu et al., 2016a; Bădescu, Watts, Katzenberg, & Sellen, 2016b; Fahy et al., 2014; mountain gorillas, *Gorilla beringei*: Eckardt, Fawcett, & Fletcher, 2016), although to a lesser extent than in hominins. Contemporary humans seem to be adapted for greater flexibility in lactation, infant feeding and care. For example, infants may be weaned anytime from birth (no breastfeeding when maternal milk is substituted for infant formula) to several years after birth (Kennedy, 2005; Sellen, 2006), and no other extant primate species can sustain the demands of early infant growth with no breastfeeding whatsoever (Ken-

nedy, 2005; Sellen, 2006, 2009). Inter-specific variation suggests that numerous traits associated with infant development and growth in several primate species can show a degree of plasticity that may directly respond to differing social and environmental pressures (Lee & Kappeler, 2003).

The process of attaining independence from the mother is directly related to maternal reproductive parameters that affect female reproductive rates and growth of populations (Lee, 2012). Therefore, understanding the general patterns, while also highlighting the extent of variation in the development of extant primates, can help us to evaluate the fitness consequences of different developmental and parental investment strategies, and inform comparative evolutionary models that aim to delineate the evolutionary trajectories of early life history parameters across hominids (Hawkes, 2014; Hawkes, O'Connell, Blurton Jones, Alvarez, & Charnov, 1998; Hrdy, 2009; Kennedy, 2005).

In this chapter, factors leading to inter- and intra-species variation in development will be evaluated. The focus will be on the process of infant nutritional development, from complete dependence on maternal milk to nutritional independence. This is the time when primate infants are unequivocally connected to their mothers and other caregivers by access to food and care to meet basic needs. Thus, the attainment of feeding independence arguably forms the functional basis of an individual's overall growth and development during infancy. Firstly, patterns of infant growth, development and maternal lactation will be contextualized relative to sources of life history and socioecological variation. Secondly, what we know about the exclusive suckling stage of nutritional development in primates including maternal lactation and maternal milk, will be summarized. Thirdly, the transitional feeding stage of development will be described, and the ways by which primate infants develop the knowledge and ability to forage independently will be evaluated. Fourthly, the weaning process will be discussed – the theoretical and methodological challenges in measuring and describing weaning in wild primates, the variation in weaning across the primate order and hypotheses of mother-offspring weaning conflict. In this section, the distinction between physiological weaning separate from behavioral weaning in nonhuman primates will be introduced. Finally, the behavioral versus nutritional mother-infant relationship and the implications of this distinction to the

emergence of cooperative breeding in *Homo* during the Pleistocene will be discussed.

2 **LIFE HISTORY VARIATION, SOCIOECOLOGY AND DEVELOPMENT**

Mammalian life histories are comprised of parameters associated with rates of development and reproduction, such as the typical lengths of gestation and inter-birth intervals, age at first reproduction, life span, number and weight of offspring at birth, size and age at weaning and postnatal growth rates (Zimmermann & Radespiel, 2007). The scheduling and durations of nutritional development stages (i.e., exclusive suckling, transitional feeding, weaning) affect the lactational physiology of mothers, which mediate maternal trade-offs between investment in current offspring versus future reproduction, number versus quality of offspring, and influence the inter-birth intervals of females (Charnov, 1991; Charnov & Berrigan, 1993; Pusey, 2012; Sellen, 2006, 2009; van Noordwijk, 2012). Although primates generally exhibit slow life histories compared to most other mammals, showing low rates of birth, growth, mortality and long life spans, significant variation does exist within the primate order (Zimmermann & Radespiel, 2007). Several hypotheses that highlight inter-species differences in body size, diet, and social systems have been used to explain primate life history variation (Lee & Kappeler, 2003; Zimmermann & Radespiel, 2007). Large primates, like great apes, give birth to fewer offspring that have relatively slower rates of development, and reach sexual maturity relatively later than small primates like strepsirrhines (including lemurs, lorises and bushbabies, Lee & Kappeler, 2003; Zimmermann & Radespiel, 2007). The life histories of larger primates are therefore relatively slower than those of smaller primates, illustrating how body mass is a major predictor of life history parameters (Lee & Kappeler, 2003; Zimmermann & Radespiel, 2007). Maternal and neonatal body mass are correlated with weaning age, as mothers typically wean infants when they are roughly one-third of maternal body weight (Lee, 1997; Majluf & Gordon, 1991). While species of similar size are expected to have similar weaning ages, this is not always

the case (Lee et al., 1991). Differences in suckling patterns and in the nutritional quality of maternal milk produced can lead to differential rates of infant development, which can result in variation in the length of infant dependency and weaning age (Lee, 1997, 2012).

Inter-species differences in diet explain some of the life history variation exhibited by similarly-sized primates (Lee & Kappeler, 2003). Compared to *frugivores*, who predominantly eat fruit, and *omnivores*, who eat a variety of plant and animal sources, *folivores* may be less likely to risk starvation because they benefit from higher food availability, as their main food source, leaves, are spatially and temporally more abundant than fruit or prey (Lee & Kappeler, 2003). Since species at risk of starvation often exhibit slower infant growth rates (Altmann & Alberts, 2005; Janson & van Schaik, 1993; Leigh, 1994; Nowell & Fletcher, 2007; Wich et al., 2007), frugivores and omnivores generally have slower infant development than folivores of similar body mass, and this has been shown using multi-species comparative analyses (Leigh, 1994).

Variation in social systems may lead to life history variation among similarly sized species (Lee & Kappeler, 2003). Primates displaying *alloparenting* (i.e., infant care by individuals other than the mother) often exhibit faster postnatal growth rates and earlier weaning ages than species lacking alloparenting (Mitani & Watts, 1997; Ross & MacLarnon, 2000; van Noordwijk, 2012). Alloparenting may increase maternal foraging efficiency, enabling mothers to obtain the energy needed to support rapid infant growth and earlier weaning (Borries, Lu, Ossi-Lupo, Larney, & Koenig, 2011; Lee, 1997; Maestripieri, 1994; Tardif, 1994; van Noordwijk, 2012). Additionally, as infants spend more time away from their mothers during alloparenting, infant nursing rates and durations often decrease (Bădescu et al., 2016b; Fairbanks, 1990). A reduction in suckling stimulus releases mothers from hormonal inhibition, enabling them to return to estrus (i.e., become fertile) sooner than if alloparenting did not occur (Lee, 1997). Thus, in species with alloparenting, mothers have shorter inter-birth intervals and infants are weaned earlier. In humans, infants are provisioned extensively by alloparents, and mothers may also rely heavily on food provisioning by relatives and other group members during lactation (Hawkes, 2014; Hawkes et al., 1998; Kramer, 2010; Kramer & Otarola-Castillo, 2015; Piperata, 2009).

3 EXCLUSIVE SUCKLING, LACTATION AND MATERNAL MILK

Apart from human infants, who may be bottle-fed infant formula rather than breastfed, primate infants rely completely on maternal milk that is accessed through suckling during nursing (Nicolson, 1987; Sellen, 2007; see Figure 1). Patchy data on infant feeding across species indicate that the duration of exclusive suckling, and the age at which transitional feeding begins, is typically shorter than six months (e.g., black lemur, *Eulemur macaco*: 6 weeks, see Harrington, 1978; blue monkey, *Cercopithecus mitis*: 5 weeks, see Forster & Cords, 2002; patas monkey, *Erythrocebus patas*: 7 weeks, see Chism, 1986; yellow baboon, *Papio cynocephalus*: 5 months, see Altmann, 1980; Hanuman langur, *Semnopithecus entellus*: 3 months, see Rajpurohit & Mohnot, 1991; mountain gorilla: 6 to 8 months, see Watts, 1985; lowland gorilla, *G. gorilla*: 6 months, see Nowell & Fletcher, 2008; chimpanzee: 3 to 5 months, see Bădescu et al., 2016a; van de Rijt-Plooij & Plooij, 1987; human, *Homo sapiens*: 6 months recommended, see World Health Organization, 2001, but Reilly and Wells, 2007, suggest 3 months may be optimal), with the exception of the orangutan (*Pongo pygmaeus*), which can nurse exclusively for one year (van Noordwijk & van Schaik, 2005).

The exclusive suckling stage is critical for overall infant development, as this is when growth rates tend to be highest (Fairbanks, 2000; Lavenex, Banta Lavenex, & Amaral, 2007). Some primate infants can attain up to 70 percent of their adult body size within the first few months of postnatal development (e.g., black-and-white ruffed lemur, *Varecia variegata*: Pereira, Klepper, & Simons, 1987). Variation in the quantity and composition of maternal milk produced can influence infant growth and development rates (e.g., common marmoset, *Callithrix jacchus*: Tardif, Power, Oftedal, Power, & Layne, 2001; baboon, different species of *Papio*: Roberts, Cole, & Coward, 1985). In rhesus macaques (*Macaca mulatta*), the quantity of milk infants ingest can affect their ability to cope with environmental stressors later in life (Hinde & Capitanio, 2010). Time spent suckling and the amount of milk transferred to infants can vary throughout the course of lactation and infant development, depending on several factors of the mother-infant dyad (Hinde & Milligan, 2011). These may include maternal health condition (Hinde, 2007a; Hinde, Power, & Oftedal, 2009; Prentice & Prentice, 1995; Roberts et al., 1985; Sellen,



Figure 1. 2-year-old chimpanzee infant, Kozena, engaged in a nursing bout while her mother, Penelope, simultaneously grooms her at Ngogo, Kibale National Park, Uganda (photographed by Eva M. Luef).

2007; Tardif et al., 2001), reproductive experience (Hinde, 2009; Hinde et al., 2009) and the quality of milk produced (Gomendio, 1989; Hinde, 2009; Tanaka, 1997; Tilden & Oftedal, 1997; Whittier, Milligan, Nutter, Cranfield, & Power, 2011), as well as infant sex (Gomendio, 1990; Hinde, 2007b, 2009; Quinlan, Quinlan, & Flinn, 2005; Tanaka, 1997), hunger (Cameron, 1998; de Passillé & Rushen, 2006), age and nursing efficiency (Drewett & Woolridge, 1979). Nursing efficiency increases with age as infants develop the ability to coordinate suckling rate with swallowing and respiration, and consequently, while the time spent suckling can remain constant, the amount of milk transfer can actually increase as infants grow (Cameron, 1998).

While the quality of maternal milk shows little intra-specific variation, it can differ greatly across species (Oftedal, 2012; Oftedal & Iverson, 1995; Sellen, 2007). In some mammals, mothers produce energetically rich milk with a high fat content to support rapid development over a shorter time frame (e.g., hooded seal, *Cystophora cristata*: Bowen, Oftedal, & Boness, 1985). Relative to most mammals, primates produce di-

lute and low-energy milk, which enables mothers to support frequent nursing while minimizing maternal energetic costs of milk production (Hinde & Milligan, 2011). Variation in milk composition does exist among different primates. Strepsirrhines, and especially genera where infants are left unattended during prolonged periods of maternal absence (i.e., *infant parking*), and therefore nurse infrequently, tend to produce richer milk relative to other primates (Tilden & Oftedal, 1997).

The duration of lactation is influenced by infant nursing patterns, as mothers are often unable to reproduce again until their dependent offspring are weaned (Lee et al., 1991). This is the result of mechanical stimulation of the nipple that leads to the release of the hormone *prolactin*, which inhibits ovulation (i.e., *lactational amenorrhea*). Lactational amenorrhea may not be as clear-cut, as mothers in some primates (including *H. sapiens* and species of *Pan*, *Colobus*, *Semnopithecus* and *Macaca*) can continue to lactate and nurse their current offspring at low rates while resuming ovarian cycling, estrus, and even into their next pregnancy (Borries et al., 2011; Ellison, 1995; Pusey, 1983; Tanaka, 1992).

4 **TRANSITIONAL FEEDING**

Prior to the cessation of exclusive suckling and the beginning of *transitional feeding*, infants engage in exploratory foraging behaviors that include mouthing and handling of food objects. In blue monkeys, exploratory foraging can occur as early as four days after birth (Forster & Cords, 2002), whereas mountain gorilla infants may not engage in exploratory foraging behaviors until four months of age (Watts, 1985). While human infants are fed selected complementary foods during much of transitional feeding (Sellen, 2007), nonhuman primate infants acquire ecological competence through a combination of genetic and learned components (King, 1999). The mechanisms by which primate infants learn what transitional foods to ingest, and how to process them, vary depending on the species. In some primates, mothers may share food with their infants by permitting them to take some of their food (initiated by the infants, e.g., Temminck's red colobus, *Procolobus badius temminckii*: Starin, 2006; golden lion tamarin, *Leontopithecus rosalia*: Lefebvre, 1985; chimpanzee:

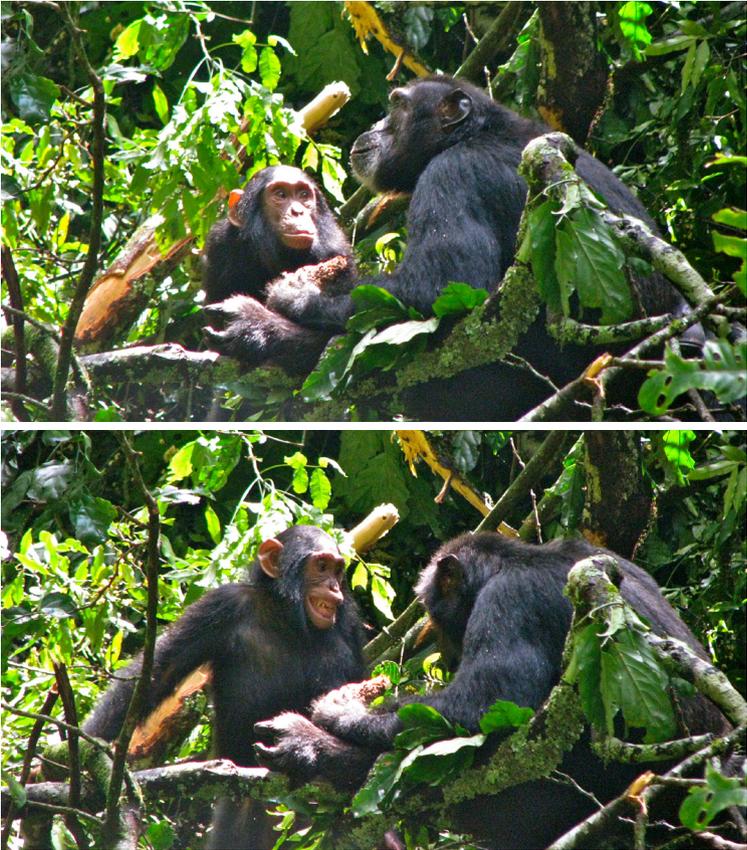


Figure 2. Older weanling, Gus, staring at (top) – and begging for honey from (below) – adult male, Bartok, at Ngogo, Kibale National Park, Uganda. Gus obtained left-over parts of the honey comb discarded by Bartok (photographed by author).

Bădescu, 2017, Silk, 1978, Ueno & Matsuzawa, 2004; capuchin, *Cebus* spp.: Fragaszy & Bard, 1997). While this type of food sharing occurs to some degree across the primate order, the active feeding of adult foods by mothers and other conspecifics to infants is rare and may only occur regularly in cooperative breeding primates, in which alloparenting and active provisioning is compulsory (i.e., humans: Sellen, 2006, 2007; spe-

cies in the family *Callitrichidae*: Brown, Almond, & van Bergen, 2004). Food sharing with infants encourages independent foraging (Silk, 1978), which can potentially lead to earlier weaning in primates (Lefebvre, 1985).

The predominant mechanisms by which most primate infants acquire information on transitional foods appear to be through trial-and-error, imitation and observational learning (e.g., mantled howler monkey, *Alouatta palliata*: King, 1999; mountain gorilla, chimpanzee, orangutan: Byrne, 1999, van Noordwijk & van Schaik, 2005). Infants may pay close attention to – and peer at – individuals feeding, and they may also ingest food items dropped by other individuals or be permitted to directly take food from others (Goldstone et al., 2016; Kopp & Liebal, 2016; Nicolson, 1987; van Noordwijk & van Schaik, 2005; Watts, 1985; see Figures 2a and 2b). The exact duration of the transitional feeding stage in many primates is not known, however, it typically lasts until the end of the weaning process and is thus quite long in species that give birth to single offspring that show a prolonged period of dependence on care-givers (Hayssen, 1993; Sellen, 2007). Therefore, while maternal food sharing and observational learning may encourage independent feeding, neither results in immediate nutritional independence.

5 WEANING

Weaning is generally a gradual and often lengthy process but can also be abrupt in some mammals (e.g., hooded seal: Bowen et al., 1985). Definitions of weaning can vary according to whether the focus is on infant development or maternal reproduction (Lee, 1997) and also depend on the academic discipline. For instance, human biologists define weaning as the final period of time when maternal milk provisioning is terminated (Sellen, 2009), whereas primatologists and archaeologists usually define weaning from the time the contribution of maternal milk in the diet of infants begins to decrease, to the last suckling bout with milk transfer (Bădescu et al., 2016a; Borries, Lu, Ossi-Lupo, Larney, & Koenig, 2014; Kennedy, 2005; Lee, 1997). Here, we defer to the latter definition more commonly used in primatology.

Determining the beginning and end of weaning, and thus the exact duration of the weaning process, is difficult to calculate from observations of wild primate infants. To demarcate the onset of weaning, studies have relied on a number of observable correlates, including the first intake of solid food, beginning in the decline of nursing rates, or time when maternal nursing rejections became repetitive (Borries et al., 2014; Martin, 1984; Nicolson, 1982). Inconsistent definitions of weaning onset across studies have led to unclear information on when the weaning process tends to begin for most species (Borries et al., 2014). For example, depending on the type of definition used, the weaning onset of chimpanzee infants ranges from 5 months to 2 years of age (Bădescu et al., 2016a; Clark, 1977; van de Rijt-Plooij & Plooij, 1987). An infant who has successfully completed the weaning process is able to digest adult foods and forage independently, even in the face of food supply fluctuations (van Noordwijk, 2012). The completion of weaning is usually behaviorally determined when the last nutritive nursing bout occurs, but observing this directly in the field is difficult. While weaning is often not complete until the birth of subsequent offspring (Chism, 1986; Nicolson, 1987; Pusey, 1983; Rajpurohit & Mohnot, 1991; Watts, 1991), in some primates, weanlings may continue to nurse, and mothers may tolerate this, even after the birth of a new sibling (e.g., orangutan: van Noordwijk & van Schaik, 2005). The age of weaning completion varies across primate species (e.g., gray mouse lemur, *Microcebus murinus*: 1 month; ring-tailed lemur, *Lemur catta*: 3.5 months; mantled howler monkey: 1.8 years; crab-eating macaque, *Macaca fascicularis*: 1.2 years; black colobus, *Colobus satanas*: 1.3 years; lar gibbon, *Hylobates lar*: 2 years, orangutan: 7 years; lowland gorilla: 2.8 to 4.6 years; chimpanzee: 4 to 5 years, see Alvarez, 2000; Bădescu et al., 2016a; Nowell & Fletcher, 2007; Watts, 1991). While data from human hunter-gatherers suggest a mean weaning age of 2.8 years, weaning ages of human infants range from birth (no breastfeeding) to several years (with extremes of 15 years, see Alvarez, 2000; Marlowe, 2010; Sellen, 2001). Weaning in humans can be gradual, or abrupt, and can occur to infants ranging in size from small to large (Sellen, 2007).

Most investigations of weaning in wild nonhuman primates use proxies of continued nursing behavior, such as the time spent by infants on the nipple or in ventral body contact, to identify the age at which infants are weaned and evaluate the termination of the mother-infant relation-

ship (e.g., grivet, *Chlorocebus aethiops*: Lee, 1987; chimpanzee: Clark, 1977, van Lawick-Goodall, 1967; gorilla: Nowell & Fletcher, 2007, Stewart, 1988; orangutan: van Noordwijk & van Schaik, 2005). However, nipple contacts without milk transfer do occur in some primates, and this may fulfill a social or affiliative function for infants, as opposed to a nutritive function (i.e., *comfort nursing*, Martin, 1984; see, e.g., rhesus macaque, *Macaca mulatta*: Harlow & Harlow, 1965; chimpanzee: Bădescu et al., 2016a; Hanuman langur: Rajpurohit & Mohnot, 1991). On the other hand, infants may appear completely weaned from daytime observations but they may continue to nurse nutritively at night when observations are not normally conducted. For example, Reitsema (2012) used feeding observations and fecal stable carbon and nitrogen isotope ratios to evaluate dietary intake in a captive François langur infant (*Trachypithecus francoisi*), and revealed that milk constituted a small portion of the infant's diet even after the age when observational data indicated weaning was complete. This study showed that while primate infants can behave as weaned juveniles through self-foraging of adult foods and without nursing or ventral contact with the mother during the day, they can continue to rely nutritionally on milk beyond this stage, probably through nighttime suckling. In wild *P. troglodytes* at Ngogo, Uganda, the same method of fecal stable isotope ratios was used to evaluate the relative contributions of maternal milk to solid foods in infant diets at different ages (Bădescu, 2017; Bădescu et al., 2016a; Bădescu et al., 2016b). Individuals showed comfort nursing, without milk transfer, for up to two years after lactation had ended and physiological weaning was complete (Bădescu, 2017; Bădescu et al., 2016a). In this case, the offspring behaved as infants through continued nipple contacts with their mothers, but were no longer obtaining maternal milk and were nutritionally independent.

5.1 Weaning conflict

Maternal suckling rejections during the weaning process can be aggressive (e.g., hitting, biting, pushing, cuffing) or passive (e.g., mother obstructs access to nipple by changing position of arms or body; avoiding infant before they can attempt to access the nipple), which can lead to infant distress ranging from mild infant vocalizations and fear grins to prolonged temper tantrums (Nicolson, 1987; e.g., ring-tailed lemur:

Macedonia, 1993; patas monkey: Chism, 1986; Hanuman langur: Rajpurohit & Mohnot, 1991; lowland gorilla: Nowell & Fletcher, 2007). Three major hypotheses associated with the amount of parental investment (Trivers, 1974), timing of investment (Altmann, 1980) and honest signaling of nutritional need (Bateson, 1994; Wells, 2003) can explain mother-infant weaning interactions. Maternal rejections and infant distress are often outcomes of what is typically known as the *weaning conflict* between mothers and infants over access to maternal investment through lactation effort (Trivers, 1974). The production of maternal milk to energetically support a growing infant is an expensive form of maternal investment due to its energetic and reproductive costs (Lee, 1984). Conflict arises when infants become too large for mothers to energetically support via lactation, and to reduce the energetic burden on mothers, it becomes more beneficial for infants to feed independently (Trivers, 1974). Mothers can subsequently invest in the next offspring and enhance their reproductive success. However, while mothers may try to encourage independent feeding by rejecting nursing, infants may persist in their attempts to make nipple contact. While the weaning conflict hypothesis (Trivers, 1974) is traditionally accepted, some primate studies do not fully support it (Altmann, 1980; Barrett, Dunbar, & Dunbar, 1995; Chism, 1986; Nowell & Fletcher, 2007).

Conflict over the inappropriate timing of nursing, rather than over investment itself, can also lead to weaning conflict behaviors (e.g., gelada, *Theropithecus gelada*: Barrett et al., 1995). Over time, nursing behaviors of growing infants may impede the ability of mothers to fulfill their daily activities and nursing attempts made during inappropriate times (e.g., foraging, traveling) may be rejected so that infants learn to nurse when it is not a hindrance to maternal activities (Altmann, 1980). The weaning conflict and *timing over investment* hypotheses are not necessarily mutually exclusive, as mothers could initially change nursing patterns and later reduce the amount of investment (Barrett et al., 1995).

Another hypothesis suggests that mother-infant interactions typically associated with the weaning conflict may be a means for mothers to monitor their infants' energetic needs (Bateson, 1994; Wells, 2003). Mothers may reject infant nursing attempts but continue to monitor infant behavior, so that if infants show an honest energetic need through persistent distress and suckling attempts, they will permit infants to

suckle. In a population of geladas for example, weaning conflict behaviors only occur during times of low food availability, however, nursing rates actually increase, as mothers allow infants to nurse more during these times (Barrett, Henzi, & Lycett, 2006). Thus, in periods of low food availability, infant distress likely portrays an *honest signal* of inadequate nutritional intake, as weanlings are unable to meet their energetic needs through independent foraging (Barrett et al., 2006). A similar pattern of mothers monitoring infant distress to gauge honest nutritional need for maternal milk may also occur in wild lowland gorillas (Nowell & Fletcher, 2007).

A few factors can make it difficult to measure weaning conflict between mothers and infants. Firstly, the reasons for weaning conflict can be difficult to determine because nursing rejections can be coupled with maternal rejections in contexts other than nursing, such as over solicitations to be carried, groomed, in close proximity, or if the weanling wants access to food that the mother is eating (MacDonald, 2011). The ambiguity in the contexts of maternal rejections makes it challenging to establish whether infants are distressed over denied access to maternal milk or due to lack of maternal proximity, or another aspect of maternal care (MacDonald, 2011). Secondly, in addition to rejections, mothers in some species may initiate play with weanlings when they seek nipple contact (e.g., chimpanzee: Goodall, 1986; orangutan: van Noordwijk & van Schaik, 2005), and this may distract infants from pursuing nursing. Lastly, in the absence of an outright weaning conflict, infants may wean themselves when maternal milk becomes insufficient to nourish their growing body size and energy needs, which leads them to an adult food-based diet (e.g., lowland gorilla: Nowell & Fletcher, 2007; chimpanzee: Bădescu, 2017; human: Fouts, Hewlett, & Lamb, 2005).

6 THE SOCIAL VERSUS PHYSIOLOGICAL MOTHER-INFANT RELATIONSHIP AND ITS IMPLICATIONS FOR EVOLUTIONARY ANTHROPOLOGY

In preceding sections of this chapter, the mother-infant relationship, as it is often described in primatology, was reviewed within the parame-

ters of *parent-offspring conflict theory* introduced by Trivers (1974). The parent-offspring conflict paradigm operates mainly on the basis of a push-and-pull in the mother-infant relationship, as it focuses on mothers managing limited investment, mainly through lactation effort for current offspring, and on infants maximizing their own access to limited maternal resources, primarily milk. Evolutionary anthropological studies that rely on parent-offspring conflict theory often implicitly confound the social and physiological facets of the relationship between mothers and their offspring. This can be problematic when hypotheses are founded on expectations of how mother-infant relationships should be exhibited over time; different assessments may represent only some facets of the mother-infant relationship that may not completely or accurately depict its progression. Several studies featured in this chapter (e.g., Bădescu et al., 2016a; Harlow & Harlow, 1965; Martin, 1984; Rajpurohit & Mohnot, 1991; Reitsema, 2012) point to the notion that nutritional and behavioral relationships between nonhuman primate mothers and infants can develop separately from one another despite considerable overlap in ontogeny (Borries et al., 2014). Offspring may achieve nutritional independence before it is beneficial for the mother-infant behavioral relationship to end (Bădescu, 2017; Bădescu et al., 2016a; Rajpurohit & Mohnot, 1991; van Noordwijk & van Schaik, 2005). That is, there can be a need for weaned offspring to continue making ventral and nipple contacts, and their mothers may allow or even encourage these behaviors for some time after lactation ends (I. Bădescu, personal observation in chimpanzees at Ngogo 2013–2014). Alternatively, infants may reach behavioral and social independence from the mother during daytime interactions before they fully reach dietary independence, and milk may continue to fulfill nutritional and immunological needs for offspring even after the mother-infant behavioral relationship ends. This notion is supported by data showing that offspring who are seemingly weaned due to a lack of day-time suckling and ventral contact may continue depending on maternal milk to a low degree via night-time suckling, or even fall back on milk when food availability decreases (Barrett et al., 1995; Nowell & Fletcher, 2007; Reitsema, 2012; Smith, Austin, Hinde, Vogel, & Arora, 2017). These studies point to a need for wild primate research to more explicitly distinguish between the progressions of social and physiological mother-infant relationships, and to account for potentially distinct

nutritional and behavioral weaning processes. In addition, weaning conflict between mothers and offspring could be absent in primates where mothers maintain a steady level of investment through lactation effort over several years as infants effectively wean themselves during the prolonged transition to independent feeding (e.g., chimpanzee: Bădescu, 2017; human: Fouts et al., 2005).

A layered perspective on mother-offspring relationships in nonhuman primates may be important to consider in evolutionary models of parental investment and infant development, as it puts extant nonhuman primates in a more similar position to the human pattern than previously anticipated. Like humans, where infants are weaned relatively early off maternal milk but continue to require extensive support from parents and alloparents, nonhuman primates also show that nutritional and behavioral needs within the mother-infant relationship are mitigated together and separately, to support infants in their attainment of complete independence (Hrdy, 2009; Sellen, 2006, 2009). Moreover, social interactions through alloparenting in several nonhuman primate species can assist with the transition of infants away from maternal dependence (Bădescu et al., 2016b; Mitani & Watts, 1997; Ross & MacLarnon, 2000; van Noordwijk, 2012). Using the extant nonhuman primate data as a proxy, we can thus imagine a hominoid ancestor who may have exhibited similar features. What needs to be better understood are the progressive changes that occurred in the infant care and development patterns of successive hominoid species that eventually led to the cooperative breeding system of *Homo* in the Pleistocene (Kramer & Otarola-Castillo, 2015). Humans are arguably cooperative breeders, given the existence of the long childhood stage and our universally high rates of alloparenting that includes regular provisioning of infants and mothers with complementary foods, especially by siblings, grandmothers and fathers (Hawkes et al., 1998; Hrdy, 2009; Kramer, 2005, 2010; Kramer & Otarola-Castillo, 2015; Lee, 2012; Sellen, 2006). With the exception of the family *Callitrichidae* that evolved through convergent forces a system of cooperative breeding comparable to *H. sapiens*, this combined suite of adaptive characteristics makes humans unique among extant primates, and raises ultimate questions about when and how these features appeared in our lineage (Hawkes et al., 1998; Hrdy, 2009; Kramer, 2010).

The transition from more ape-like hominids, like *Australopithecus*, to the *Homo* genera was probably a seminal stage of important changes in the mother-infant relationship (Matsuzawa, 2006). With the distinction between behavioral and nutritional components of the mother-infant relationship likely already present, we would expect to see an emergence of features during the *Australopithecus* to *Homo* transition that would have made it possible to further widen the division between infant feeding and infant socio-emotional needs, which could have ultimately allowed for the life history traits characteristic of later *Homo*, such as a lengthening in the period of dependence on caregivers but shortening of infant nutritional dependence on maternal milk (Hawkes, 2014; Hrdy, 2005; Hrdy, 2009; Matsuzawa, 2006; Sellen, 2006). Fossil evidence from the *Australopithecus* to *Homo* transition points to a suite of general changes, including increasing brain volume, appearance of tool manufacturing, and likely appearance of more complex gestural and vocal communication, division of labor, and greater cooperation among group members, including potentially relying more on kin for alloparenting (Hrdy, 2009; Matsuzawa, 2006). During this transition, we may also have seen a decrease in the time that mothers and infants spent in direct ventral body contact; infants were either held by alloparents or left on their own, as they would now have been able to sit upright in a supine posture (Matsuzawa, 2006). The emergence of infant crying, making direct eye contact, and changes in the development of neonate cognition would have allowed infants to monitor and behaviorally engage their mothers and other caregivers during the prolonged period of dependence (Hawkes, 2014; Hrdy, 2005; Hrdy, 2009; Matsuzawa, 2006). Combined with the shift toward bipedalism already present, these changes may have presented situations in which mothers were regularly not in direct physical contact with their infants, which could have facilitated the need for *baby talk* or *motherese*: melodic, sing-song vocal communication used by mothers and other caregivers to draw infants' attention and to soothe them when they are not in direct maternal body contact (Falk, 2004; see also Filippi and Gingras in this volume). Social relationships of mothers and alloparents with infants during the transition to *Homo* would likely have been characterized by a combination of mutual gazing, manual-gestural signs during face-to-face communication and vocal exchanges at various levels of proximity (Falk, 2004; Hrdy, 2005; Matsuzawa, 2006). Some have

even pointed to these important changes in modes of communication between infants with their mothers and others as one of the stepping stones facilitating the transition to language in *Homo* (Falk, 2004).

For later *Homo*, important changes in the feeding patterns of infants and young children would have contributed to changing the nutritional physiology of weanlings, and consequently, the lactational physiology of mothers. Notably, the provisioning of young by caregivers with high-energy, easily digestible complementary foods would have played a crucial role in quickening weaning, shortening the lactation period of mothers, and in allowing females to invest in a subsequent infant long before present offspring reached complete independence (Sellen, 2006, 2007, 2009). The gradual appearance of these combined adaptive features formed part of the evolutionary backbone of the unique life history traits that appeared in Paleolithic hominins; namely, early weaning but relatively low infant mortality, short birth spacings, and increased female fecundity (Hawkes et al., 1998; Kennedy, 2005; Kramer, 2010; Kramer & Otárola-Castillo, 2015; Lee, 2012).

7 CONCLUSION

Rearing of young offspring played an important role in our evolutionary past. The shift toward shared infant care, including shared infant feeding through complementary foods given to infants by alloparents, added another prosocial motivation that allowed our species to transition from the more individualistic behavioral phenotypes likely present in ape-like hominids to the *shared intentionality* that is characteristic of later *Homo* (Burkart et al., 2014; Hrdy, 2009). The appearance of obligate cooperative breeding in our species therefore went hand-in-hand with our hyper-cooperation, increasing sociality and collaboration, and evolution of cognition enabling more complex modes of communication, including language and instructed learning (Burkart et al., 2014). That being said, humans are also characterized by considerable variability and flexibility in our strategies of infant and young child care, both within and between populations (Sellen, 2006, 2009). To help delineate the evolutionary forces responsible for the variable patterns of infant feeding and care

shown by ancient and contemporary humans, we need to understand the key differences and similarities between human and nonhuman primate infant feeding, care, and development.

Future studies in nonhuman primates should account for the possibility that the typical weaning conflict expected of mothers and their offspring, particularly over maternal milk, may not be apparent or visually exhibited. In addition, interpretations of mother-infant relationships should more explicitly evaluate the different facets associated with the social and physiological implications of development, weaning and attainment of independence in early life. The relationship of infants with their mothers was the focus in this chapter. However, fathers, older siblings, grandparents, aunts and even unrelated individuals often play crucial roles in the process of attaining independence in human and non-human primates. The expressions of infant relationships outside of maternal care, and the individual roles they played in the evolutionary histories of primate species, continue to deserve further detailed attention (Hawkes et al., 1998; Kramer & Otarola-Castillo, 2015; Mitani & Watts, 1997; Ross & MacLarnon, 2000).

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Nod, nod, ignore: An exploratory observational study on the relation between parental mobile media use and parental responsiveness towards young children

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ABSTRACT There are concerns that contemporary caregivers are so absorbed by their mobile devices that it hampers their responsiveness to their children. Recent ethnographic work suggests that these concerns are warranted. Scholarly work on this issue is scarce, however, and systematic observations of the phenomenon are lacking. This chapter presents an exploratory study in which caregiver-child dyads were systematically observed to assess whether the tendency to respond and the timeliness, strength and emotionality of caregivers' responses to children's bids for attention are negatively affected by phone engagement (Hypothesis 1). Additionally, we investigated whether the relation of phone engagement to caregivers' responsiveness is different than the relation of other distracting activities that caregivers might engage in when caring for a child (Hypothesis 2). We observed caregivers and children between the ages of zero and five in Dutch consultation bureaus and playgrounds. Drawing from observations gathered from 25 caregiver-child dyads, the results show that the likelihood to respond, the time-

liness and the strength of caregivers' responses are each negatively affected by phone use. In addition, phone use appeared to be more engaging and therefore affected responsiveness more strongly than being engaged in other distractive activities. Given the importance of parental responsiveness for child and language development, these findings indicate an urgent need for further research on the issue and how it can be addressed.

KEYWORDS absent presence, absorption, child development, mobile media, mobile phone, parental responsiveness, phubbing

1 INTRODUCTION

Parental responsiveness refers to the contingency and sensitivity of parental verbal and non-verbal response to child behavior during child-parent interaction (Ainsworth, 1969; Baumrind, 1978; Feldman, 2007). There is broad consensus that parental responsiveness is crucial for child development (Darling & Steinberg, 1993). Parental smartphone use, however, is putting parental responsiveness to the test. Media authority Sherry Turkle (2012) has noticed that children compete with smartphones for parental attention. A recent poll among six thousand 6- to 12-year-olds (AVGtechnologies, 2015) confirms this: 54 percent said parents spend too much time on their phones, and 32% feel unimportant when parents are using them. Moreover, a handful of qualitative observation studies suggests that caregivers can become so absorbed by their phones that they ignore their children's bids for attention (Hiniker, Sobel, Suh, Sung, & Lee, 2015; Radesky et al., 2014).

Systematic observations are currently lacking in this field of research, and studies focusing on very young children are scarce. Hence, the first contribution of this chapter is to add to the base of knowledge by reporting the results of an exploratory observational study in which we used a systematic observation method to observe the impact of smartphone use on parental responsiveness towards small children.

Lower parental responsiveness may be observed not only when caregivers use their phone, but also when they are engaged in other non-child-related activities that caregivers encounter or select while

caring for their children (e.g., reading a newspaper, eating, social interaction). A second contribution of this study is that we examine how phone use compares to other distracting activities in terms of impact on parental responsiveness.

A third objective of the study, which we only describe briefly for the sake of completeness, is to examine the profiles of the caregivers who were more involved with their mobile phone during the interaction.

2 THEORETICAL FRAMEWORK

2.1 Parental responsiveness

The first objective of this study is to examine whether parental phone use is related to parental responsiveness towards young children. Parental responsiveness is crucial, particularly in the early years of life when important cognitive and socio-emotional developmental processes take place (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008; Bowlby, 1988; McGillion et al., 2013). Parental responsiveness supports the young child in his/her active involvement with the environment, for example when parents respond contingently to the child's focus of interest (Landry, Smith, Swank, Assel, & Vellet, 2001). Such contingent responses contribute to child language acquisition (Tamis-LeMonda, Bornstein, & Baumwell, 2001), as does joint attention. In particular, following the child's lead encourages language learning (Tomasello & Farrar, 1986; Yu & Ballard, 2007). Language acquisition is of great concern to scientists and society as a delayed or impoverished language acquisition can have negative effects, for instance on academic achievements (e.g., Kastner, May, & Hildman, 2001). The *30 million word gap* (Hart & Risley, 1992) found between children from families with lower and higher socio-economic status, for example, has become a specter in academic and public discourse.

Socio-emotionally, parental responsiveness is important because it supports a young child's need to feel nurtured. When parents provide care in a nurturing, contingent responsive way, this facilitates the child's socialization by promoting predictability and trust in the reasonableness of parental demands (Maccoby & Martin, 1983). Moreover, responsive

parenting stimulates the development of a secure attachment style in the child (Bowlby, 1988) and contributes to the development of the child's regulatory capabilities (Dozier, Meade, & Bernard, 2014).

Although there appears to be a general agreement among caregivers, practitioners and researchers in Western societies that responsiveness during early childhood is a crucial ingredient for children's cognitive and socio-emotional development, parents sometimes struggle to put responsiveness into practice. For instance, parents may be preoccupied with other tasks and chores, or may experience the (early) parenthood period as boring (Wall, 2010). It is during these instances that mobile media enter the picture, as they enable parents to multitask their parenting activity with other – perhaps more exciting or urgent – digital activities.

2.2 **Parental mobile media use during child care: Building on earlier work**

The extant empirical work on the impact of parental phone use on responsiveness is limited, but nonetheless provides a compelling argument for further examining this issue. In an observation study in U.S. fast-food restaurants, Radesky and colleagues (2014) found that 16 out of 55 observed caregivers were absorbed by their screens during the meal. Qualitative observations of the caregivers' and children's behavior showed that phone-using caregivers responded to their children's bids for attention in a non-contingent manner (e.g., ignoring the child). Also, when a response was given to the child, it was oftentimes found to be in a non-supportive manner (e.g., responding with a harsh voice, or even physically pushing the child away in an attempt to be left alone).

In a second study that we know on the topic, Hiniker and colleagues (2015) collected data from 466 caregivers in a playground setting. Part of their study involved observations of 111 caregivers. Fifty-nine per cent of those caregivers used their phone while attending to their child(ren) playing in the playground. The researchers found that only half of these phone users responded promptly to a child's interruption of their ongoing activity, compared to 90% of non-phone-users.

The studies by Radesky et al. (2014) and Hiniker et al. (2015) provide preliminary evidence that concerns over the impact of parental phone use on parental responsiveness are warranted. A limitation of both stud-

ies, however, is that the children in these studies varied considerably in terms of their age. Indeed, both studies were aimed at observing caregivers of children who the observers believed to be between 0 and 10 years old. However, caring for a 10-year-old child is in many respects different from caring for a (very) young child, and momentary lacks of parental responsiveness likely have a different effect on the child depending on the phase of the developmental process. Socio-cognitive and socio-emotional developments, such as language acquisition and attachment, which seem to require immediate responsiveness, are developmental tasks anchored in infancy and early childhood (e.g., Bowlby, 1988; Erikson, 1959; Friedmann & Rusou, 2015). Thus, our current study focuses on this age period.

Both Hiniker et al. (2015) and Radesky et al. (2014) based their studies on field notes. As noted by the authors, this is a valid approach to first explorations of a topic, for example to identify main themes. However, it is difficult to include precise measures of frequencies and durations of behaviors using field notes only. Radesky and colleagues, for example, occasionally include time estimates, but the precision of these is unknown (e.g., “She [the child] doesn’t seem able to make it work, so she starts to make whining vocalizations ... a minute later caregiver notices the child is having difficulty”, p. e848). Hiniker et al. observed the duration of phone use of a subgroup of caregivers involved in their study, but it is unclear whether this subgroup overlaps with the sample observed to assess responsiveness.

In addition, in both studies the instances of relevant behavior lacked a systematic definition and operationalization, making it difficult for the reader to understand exactly what behaviors were observed and coded/noted. For example, Hiniker and colleagues seem to have focused on children’s bids for attention in the sense of children’s intentional attempts to “interrupt or gain the attention” (p. 732) of the adult (e.g., calling out “Mom, look!”). Children’s bids for attention, however, may also be subtler and easier to miss. A child might, for example, seek eye contact with the caregiver without making any sound or movement. Also, some child behavior, such as the child that cries out because he/she hurts him- or herself, may not be an *intentional* bid for attention, but may bid attention anyhow. Particularly when examining very young children, these subtle

and unintentional behaviors seem relevant to the topic of responsiveness and the developmental correlates that we discuss here.

In short, while the ethnographic work done by Hiniker et al. and Radesky et al. is extremely valuable because it provides a rich description of a new phenomenon, it lacks a *systematic assessment*, which is relevant if we want to quantify an overall relation between phone use behavior and parental responsiveness. The first objective of this study is to add to the extant body of research on the relation of parental phone use to parental responsiveness, focusing on caregivers of children during the first years of life by using a systematic observational method.

We define *children's bids for attention* as all intentional and unintentional behaviors (including sounds, eye gaze and movement) expressed by the child that might solicit a response from the caregiver. We hypothesize that caregivers will be less responsive to these bids when they are engaged with a mobile device. We assess responsiveness by focusing on whether or not a response was given and three aspects of the responses. The first aspect is *strength*: a weak response is one in which the caregiver shows awareness of the child's bid for attention, whereas a strong response is one in which the caregiver actually interacts with the child. Another aspect is the *timeliness* of the response. Ideally, a response is contingent on the child's bid, meaning that it follows immediately after the child's bid. We examine this second element of responsiveness by checking whether the response is timely or not (yes/no). In terms of *positive emotionality*, a positive emotion can be expressed in the response (e.g., by smiling). Aspects that were not included because the negative poles were not observed were negative emotionality and valence of the response – a caregiver may reject the child, for example when the caregiver negates (“Don't throw that ball at me”), or may acknowledge/encourage the child (“Yes, that is a nice ball. Take it.”).

We expect to find the following results in our examination of caregivers' responsiveness:

H1: Caregivers' responses to their children's bids for attention occur (a) less frequently, (b) with a lesser strength, (c) in a less timely manner and (d) with less positive emotions when caregivers are engaged with a mobile device than when they are not. Finally, (e) children also have to make greater efforts to gain their caregivers' attention when caregivers are engaged with a mobile device than when they are not.

Both Hiniker et al. (2015) and Radesky et al. (2014) noted that there are differences in the degree to which caregivers are absorbed by their phones, and that this degree of absorption seems to affect responsiveness negatively. We examine whether we find support for this relation by investigating the following research question:

RQ1: Is there a negative linear relation between the degree of caregivers' absorption in phone use and their responsiveness to their children's bids for attention?

2.3 **Mobile devices versus other non-child-related activities?**

Caregivers can be involved in several different activities that might reduce their responsiveness to their children's bids for attention: they may be folding clothes, reading a magazine, preparing dinner, eating or drinking something, etc. A pertinent question that needs to be asked is whether phone use is qualitatively different from these latter activities (see Radesky et al., 2014).

There is reason to assume that the use of mobile communication technologies is different from the former activities. Hiniker et al.'s (2015) study revealed that most caregivers who used their phone were using it to access interactive social media applications, such as email and mobile messengers. These kinds of interactive social media applications induce a strong immersion of the caregiver into the activity. Communication applications differ from other sources of diversion (such as newspapers or the radio) in that they are dialogical rather than monological (Gergen, 2002). Media with a monological presence (i.e., one-way communication or broadcast media) provide information or stimulation to the user, but they can easily be ignored or moved to the background. Media with a dialogical presence, on the other hand, facilitate a flow of interactions that bring the user into a state of "absent presence" (p. 227): a state of physical presence, but mental absence. This leads to our second hypothesis:

H2: Caregivers are less responsive when they are engaged with their mobile phones than when they are involved in other activities.

2.4 **Caregiver predispositions: Fear of missing out, habitual phone use and problematic phone dependency**

Studies on phone use in the presence of (adult) others suggest that there are certain predispositions that may make people more likely to use their phone in the presence of others. Three such predispositions are having a higher fear-of-missing-out (FOMO; Przybylski, Murayama, DeHaan, & Gladwell, 2013), having a stronger phone checking habit (Oulasvirta, Rattenbury, Ma, & Raita, 2012) and a more problematic dependency on the mobile phone (Billieux, Maurage, Lopez-Fernandez, Kuss, & Griffiths, 2015). Thus, a second, exploratory research question guiding this study is whether caregivers who use phones during the observation report these predispositions more strongly.

RQ2: Do caregivers who used phones during the observation period report a greater fear-of-missing-out, habitual phone use and problematic phone dependency?

3 **METHODS**

3.1 **Procedure**

The research was conducted in two types of public places in the Netherlands: at one playground and two different child health centers. In these child health centers, children's caregivers are invited for check-ups and vaccination at regular intervals.

When caregivers with children of the appropriate age entered the playground/child health center, the study was briefly introduced to them. The caregivers were then asked to participate, and, in case they agreed, briefed more thoroughly and asked for a written informed consent. A unique ID number was assigned to the dyads. Caregivers were not fully informed of the objective of the study during the briefing to avoid alterations in their mobile phone usage. They were informed, however, that the study concerned caregiver-child interactions.

After consent was obtained the observations took place. Caregiver-infant dyads were observed for a maximum of ten minutes and 25 seconds (see coding procedure below). When the observations had ended, the

participants were asked to fill out an anonymous questionnaire. Finally, participants were debriefed, and the full purpose of the study was revealed. The ethics committee of the authors' faculty approved the study (REC #2017/11).

3.2 Participants and sampling

The participants of this study were an opportunity sample of caregiver-child dyads, with the children aged zero to five years. In all cases, the dyads needed to adhere to two criteria in order to be eligible for participation: (1) the child had to have an age between zero and five years, and (2) the adult caregiver had to be one of the child's primary caregivers (defined as being the legal guardian of the child).

Of the 25 dyads, nine participated on a playground and the other 16 dyads participated while having an appointment at the child health center. The gender ratios are shown in Table 1, and the children's birth ranks in Table 2. The children who participated were on average 26.3 months old ($SD = 18.1$), with 13 of them below 2.5 years, and 12 above. The caregivers (all of them the children's parents) had a mean age of 36 years ($SD = 4.4$). The highest education of most caregivers appeared to be higher vocational education (50%) followed by higher academic education (31%).

Table 1: Gender ratio of the caregiver-child dyads

Caregiver	Child		Total
	Son	Daughter	
Father	1	5	6
Mother	10	9	19
Total	11	14	25

Table 2: *Children's birth rank*

Older siblings	Younger siblings		Total
	No	Yes	
No	11	2	13
Yes	10	2	12
Total	21	4	25

3.3 Materials

The data were gathered via observations and a questionnaire. The observations provided information on the caregivers' phone use and their responsiveness to the children. The questionnaire was used to gather socio-demographic background information and self-report measures of the caregivers' fear-of-missing-out, habitual phone use and problematic phone use.

3.3.1 Observations

Observations were made according to a time sampling procedure that consisted of 25 timeslots. In each timeslot, the dyad was observed for 10 seconds followed by 15 seconds for noting the observed behaviors (see Abels et al., 2005, for a similar procedure). The observations were done by two trained observers (co-authors TVT and HVM), one focusing on the caregivers' behavior, the other on the child's bids for attention and the caregivers' responses. The intervals were coordinated using a mobile application called "Interval Timer" which gave a beep after every interval. Both observers listened to a recording (via one pair of earphones) that instructed them when to start and stop observing.

Coders were trained with video-recorded mother-child interactions. Intercoder reliability was established on observations of three dyads on the playground and was above Cohen's Kappa of .91 for each reported behavioral domain (caregivers' responsiveness = .918, children's bids for attention = .945 and non-child-related activities = .974).

3.3.2 *Observations of the caregivers' behaviors*

We coded a set of caregivers' activities that were either directed to the child, or non-child-related. *Child-directed* activities (e.g., talking, playing with objects, care) were coded but not reported here. The second category of caregivers' activities that were observed were *non-child-related activities*, which included all other activities a caregiver could perform while being in the presence of the child. These activities included phone manipulation, talking on the phone, reading, eating/drinking, talking to somebody else, listening to something while wearing earphones and other, which was then specified. The activities were coded using three levels of absorption into the activity: *passive*, *occasional* and *exclusive* (coded 1, 2 and 3). *Passive* was generally coded if an object was held but no active engagement with it was observable, for instance holding a coffee cup (passive drinking) or simply holding a mobile phone without looking or interacting with it (passive phone manipulation). *Occasional* was coded if a caregiver was involved in the activity part of the time, for example glancing at the phone occasionally or taking an occasional sip from a coffee cup. *Exclusive* was coded in cases in which the caregiver seemed completely focused on the non-child-related activity, for instance by constantly manipulating their mobile phone. Exclusive did not exclude the possibility of being aware of the child and his/her activities through different modalities (e.g., drinking coffee while looking at the child; looking at the mobile phone while listening) or occasionally glancing at the child.

3.3.3 *Observations of the child's bids for attention and the caregivers' response*

The second observer focused specifically on whether the child asked for the caregivers' attention. The child's action was coded as a bid whether or not the *intention* of bidding attention was observed. The rationale for this operationalization was that a caregiver's response would likely not depend on whether or not the child's action was an intentional bid for attention, which is anyhow difficult to assess, particularly in some behavioral modalities and among very young children. A distinction was made between different types of bids for attention considering, among other things, the caregiver's sense the bid is aimed at or the modality in which

it is produced: gaze (visual), other visual attention seeking (e.g., waving, jumping up and down), auditory (e.g., talking, banging toys), touch or taking object.

The second observer additionally coded the (absence) of the caregiver's response to the child's bids for attention in terms of the *degree*, *timeliness* and *emotion* of each response. The *degree* of the response refers to whether the parent responded to the child's bid, and, if so, whether the response could be categorized as a rejection or acknowledgement. We operationalized degree as a compound of two components: the *valence* of the reaction and the reaction *strength*. It was measured using five categories: "explicitly rejecting the bid", "softly rejecting the bid", "no response", "showing awareness of the bid but no action", and finally "acknowledging the bid by responding and/or interacting with the child". In the current study, however, no negative valences (i.e., rejections) were registered. Hence, the *degree* measure had only three values (no response, a positive awareness response, and a positive acknowledging/interactive response). Based on this measure, we computed two new variables: a *response* variable, indicating whether a response had been given or not, and, if yes, a *strength* variable, indicating whether that response was weak or strong. *Timeliness* was also a binary measure: when the caregiver responded, we coded whether that response was given instantly (coded intuitively, in coder training we observed that this was generally within 1–2 seconds after the bid) or with a delay. If the caregiver showed any *emotions* during the response, these were coded as either positive or negative; if no code was assigned, this implied the caregiver displayed a neutral emotion. We did not register negatively valenced emotions. Hence, the emotion variable was also binary in nature.

To summarize: For the statistical analyses, four dichotomous variables concerning caregivers' responsiveness were created to represent the caregivers' behavior:

1. *Responses*: whether (1) or not (0) a caregiver responded in any way to a child's bid
2. *Reaction strength*: awareness (0) or response/interaction (1)
3. *Timeliness*: whether the reaction was timely (1) or delayed (0)
4. *Emotionality*: whether the reaction had a positive emotional tone (1) or was neutral (0)

To give an example, when a child was waving at the caregiver, this was coded as a *direct bid for attention targeted at the caregiver's visual modality*. When the caregiver responded immediately by waving back and laughing, this was coded as a *response* that was *timely, strong* (i.e., an acknowledging/interaction response) and *emotional*. In contrast, making noises while playing was coded as an *indirect bid for attention aimed at the auditory modality* of the caregiver, and when the caregiver responded after four seconds by glancing at the child, this was coded as a *response* that was *not timely, weak* and *without emotion*.

3.4 Statistical analysis

To test whether caregivers' responses to children's bids for attention occur less (H1a), are weaker (H1b), less timely (H1c), and less likely to be expressed with positive emotions (H1d) when caregivers are using phones than when they are not, we performed logistic regression analyses with caregiver phone use during the interval (yes/no) as the predictor variable, and the former outcomes as the dependent variables. We examined research question 2, which asked whether the degree of the caregiver's involvement with the phone mattered, by repeating the former analyses but with the caregiver's level of phone involvement (none, passive, occasional and exclusive) as the predictor variable.

Children's bids for attention may differ in the extent to which they are successful in eliciting a response. It is likely that a bid that involves multiple modalities (e.g., simultaneously waving, shouting and looking at the caregiver), draws more attention, and is thus more likely to elicit a (timely, strong, positive) response from the caregiver than a bid that involves only one modality (e.g., waving only). We thus expect the number of modalities in which bids are expressed to predict the occurrence, strength, timeliness and emotionality of caregivers' responses. The caregiver's phone use, however, may moderate this relation: it may be the case that, when phones are present, more modalities are needed to elicit a (timely, strong, positive) response from the caregiver. For example, 'waving + shouting' may not be enough to elicit a response when the caregiver is using a phone, whereas it may be enough when the caregiver is not using a phone. To test this hypothesis (H1e), we performed stepwise logistic regressions with the number of modalities in which children bid for at-

tention, phone use (yes/no), and their interaction term as predictor variables and the occurrence, strength, timeliness and emotionality of the response as outcome variables.

Hypothesis 2 states that caregivers are less responsive when they are engaged with their mobile phones than when they are involved in other activities. To test this hypothesis, we compared the predictive strength of logistic regression models that use caregivers' level of involvement with the phone as the predictor with models that use involvement in all other non-child related activities combined as a predictor. To that end, we first produced the models using involvement in all other non-child related activities combined as a predictor. These models were then compared descriptively to the models produced for hypothesis 1. Finally, to directly test whether there are additional effects of phone use over and above the level of non-child related activities, a stepwise regression was performed with both the level of involvement in non-child related activities and phone use (yes/no) as the predictor variable and the occurrence, strength, timeliness and emotionality of the response as outcome variables.

In a separate section we briefly summarized the answer to research question 2, using independent samples t-tests to compare caregivers who used phones at least once during the observation with those who did not in terms of their fear-of-missing-out, habitual phone use and problematic phone use.

4 RESULTS

4.1 Descriptives

In total, 25 caregiver-child dyads participated in the study. An average of 22.9 observations were made per dyad (range 12–25). This resulted into a total of 572 observed intervals. In 67% of the observations ($n = 384$), the child showed a bid for attention directed at the caregiver. An overview of the frequencies in which children bided attention in each modality is given in Table 3.

Table 3: Overview of the modalities used by children to draw attention from their caregiver

Modality used to draw attention	Occurrences		
	Total by modality	<i>M</i> %*	<i>SD</i> *
Visual by moving	321	56.60	20.69
Auditory	197	33.67	19.71
Visual by eye gaze	134	22.57	18.05
Taking an object	129	22.72	25.12
Touching	55	9.91	12.36
Total nr of intervals containing a bid**	384	68.19	19.23

Note. *Numbers are based on % of occurrences per participant; **Total number (nr) of observations in which a child bided attention in at least one of the modalities mentioned

As for the caregivers' responses given to the children's bids, in almost all cases a response was given: in only 8% ($n = 46$) of the observed intervals was a child's bid *not* followed by a response. Out of the intervals in which a response was given, in most the caregiver was not engaged in any non-child-related activities (47%). The caregiver was passively holding a phone in 11 of the 572 observed intervals (1.9%). The caregiver was actively involved with the phone (scrolling, reading, typing) in 37 (6.4%) of the observed intervals. None of the caregivers used their phone during the first four observed intervals, and once caregivers started using their phones they continued doing so at least until the end of the observation. Interestingly, 75% of the mobile media use and all of the *exclusive* media use occurred during observations on the playground. Table 4 gives an overview of which activities caregivers were involved in when responding to their children' bids for attention.

Table 4: Overview of the caregivers' activities and responses given to children's bids

Activity	Response				Timeliness	
	Overall occurrence	%*	Total	%*	Total	%*
Without distractions	266	46.5	159	47.0	155	48.3
While looking around	106	18.5	63	18.6	62	19.3
With a second child	71	12.4	43	12.7	39	12.1
With other distractions	62	10.8	42	12.4	42	13.1
While talking	61	10.7	23	6.8	17	5.3
With mobile media	48	8.4	7	2.1	5	1.6
While reading	4	0.7	1	0.3	1	0.3
Talking on phone	0	0	0	0	0	0
Total	572		338		321	

Note. *Sums are above 100% because non-child-related activities were not mutually exclusive but could occur at the same time.

4.2 Is mobile media use related to lower caregiver responsiveness?

Hypothesis 1 stated that caregivers' responses to children's bids for attention occur less (H1a), are weaker (H1b), less timely (H1c), and less likely to be expressed with positive emotions (H1d) when caregivers are using phones than when they are not. To examine these hypotheses, we performed four logistic regression analyses with the *occurrence*, *timeliness*, *reaction strength* and *emotionality* of caregivers' responses in each interval as the dependent variables and whether or not the caregivers were engaged with their phones (1 = yes, 0 = no) in these intervals as the independent variable.

Logistic regression analysis produces a X^2 -value, which informs the reader about the goodness-of-fit of the model. The value can be used to compare the predictive strength of different models. The Wald statistic and its associated significance level indicate for each predictor in the analysis if it significantly predicts the outcome measure. The odds ratio (OR) informs about the size of the effect by indicating how the odds of a particular outcome change with each 1-unit increase in the independent

variable. Finally, the R^2 -values express model fit in terms of explained deviance.

The statistics are reported in Table 5, which shows that overall responsiveness, timeliness of the response and strength of the response were negatively predicted by caregivers' engagement with their phone. In other words, hypotheses 1a, 1b and 1c were supported: the odds of the caregiver responding to the child's bid for attention ($OR = 0.09$), the odds of responding timely to the bid ($OR = 0.04$), and the odds of responding by interacting rather than showing mere awareness ($OR = 0.17$) were significantly lower in intervals in which the caregiver was using a phone than in intervals in which the caregiver was not using a phone. No relation was found with the emotionality of the response (H1d was not supported).

Table 5: Caregivers' responsiveness during phone engagement and non-engagement intervals

	No phone (<i>n</i> =365)		Phone (<i>n</i> =24)		X^2	β	$SE\beta$	Wald	C&S R^2	N R^2	<i>p</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>							
	Response	.92	.28	.50							
Timeliness	.95	.23	.42	.51	23.07	-3.20	0.63	25.53	.06	.16	<.001
Strength	.66	.47	.25	.45	8.3	-1.78	0.68	6.94	.02	.03	.008
Emotionality	.03	.18	.00	.000	0.79	-17.82	11602.71	0.00	<.01	.01	.999

Note. C&S = Cox & Snell; N = Nagelkerke

Hypothesis 1e stated that the relation between number of modalities in which children bid for attention and the likelihood of eliciting a (strong, timely, emotionally positive) response from the caregiver in an interval is moderated by whether the caregiver uses a phone in that interval: when a phone is used, more modalities are necessary to elicit a (strong, timely, emotionally positive) response than when a phone is not used.

For the analysis we created a sum score of bids for attention across all categories (eye gaze + visual + auditory + touch + takes object) for each interval. In 51% of the observed intervals bids, more than one modality

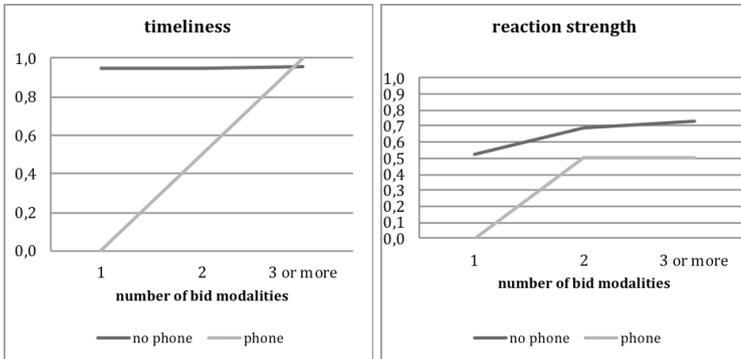


Figure 1: Responsiveness (*timeliness*: left, *reaction strength*: right) in relation to the number of modalities in which the child bids for attention for intervals with and without phone use.

occurred (i.e., 76% of the bids were multi-modal). Even though a maximum of five types of bids was possible, the observed maximum number of types of bids in any interval was four. The variable was skewed, with only one interval showing four modalities. Hence, we merged three and four modalities into one value, thus resulting in a *number of modalities*-variable with values ranging from one to three for the calculation.

We conducted four stepwise logistic regressions to test whether the *occurrence*, *strength*, *timeliness* and *emotionality* of caregivers' responses were predicted by the *number of children's types of bids for attention* (3 levels), *caregivers' engagement* with their phones (yes = 1, 0 = no), and the interaction between these two terms in an interval, respectively. The first term entered into the model was the interaction, followed by caregivers' phone use and finally, the number of bids.

The results showed that the number of bids was related only to the strength of the caregivers' reactions ($X^2 = 18.29$, $\beta = 0.45$, $SE = 0.16$, Wald = 7.56, *Cox & Snell* $R^2 = .05$, *Nagelkerke* $R^2 = .07$, $p = .006$): the odds of a caregiver responding more strongly to the child's bid were significantly higher in intervals in which the child's bid for attention involved more modalities ($OR = 1.56$). While the interactions were not significant for any of the aspects of caregivers' responses, it seems that descriptively the sum of bids and phone use interact for timeliness and reaction strength

(see Figure 1). Caregivers who did not use their phones almost always reacted in a timely way, no matter how many bids there were in the interval. For caregivers who used their phones, timeliness increased with the number of bids addressed at them. For reaction strength, both phone users and non-users showed an increase in reaction strength when more than one bid was addressed at them, but the increase seems more dramatic in intervals with phone usage.

Our first research question stated that the degree of involvement with the phone might matter, as a more exclusive involvement with the phone might make caregivers less responsive. We coded to what extent the caregiver was involved with the phone (0 = no use, 1 = passive, 2 = occasional, 3 = exclusive). A third set of logistic regression analyses was conducted to see whether an increase in involvement with the phone is related to a decrease in responsiveness. This seems to be the case for whether or not caregivers showed a response ($OR = 0.32$) and the timeliness ($OR = 0.15$) and strength ($OR = 0.32$) of the response. An increase in phone involvement was not related to the emotionality of the caregiver's response. Table 6 shows an overview of the results.

Table 6: *Engagement levels with the phone and responsiveness to children's bids for attention*

	Engagement level with the phone							
	None		Passive		Occasional		Exclusive	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Response	.92	.28	.50	.55	.73	.47	.14	.38
Timeliness	.95	.23	1	.00	.25	.46	0	
Strength	.66	.47	.67	.58	.13	.35	0	
Emotionality	.03	.18	0	.00	0	.00	0	
	X^2		β	<i>SE</i> β	Wald	C&S R^2	N R^2	<i>p</i>
Response	27.3		-1.11	0.22	26.89	.07	.14	<.001
Timeliness	28.3		-1.9	0.38	24.40	.08	.19	<.001
Strength	10.8		-1.2	0.43	7.32	.03	.04	.007
Emotionality	0.8		-15.5	7289.5	0.00	<.01	.01	.998

Note. C&S = Cox & Snell; N = Nagelkerke

4.3 **Does mobile media use affect caregivers' responsiveness more strongly than engaging in other non-child-related activities?**

The second hypothesis concerned the engagement with the mobile phone as compared to other activities. This can be construed as two separate questions:

- A. If caregivers are engaged in phone use, is their engagement with the phone more intense than when they are engaged with other activities?
- B. Does the same degree of engagement in different activities have a different relation to responsiveness if a mobile phone is involved?

For each activity that was coded, we registered whether the engagement with the activity was passive, occasional or exclusive. A first exploration showed that parents were less frequently engaged with their phones than that they were engaged in other activities. However, when the phone was used, the engagement with this activity was most frequently exclusive while the most common engagement level for the other activities was occasional [$X^2(2, n = 306) = 26.77, p < .001$, comparing the relative occurrence of phone use over the different engagement level categories with the relative occurrence of other activities (summed) across these same engagement level categories, see Figure 2]. For example, of all intervals with phone use, 48% were exclusive, whereas of all intervals with other non-child related activities, only 14% were exclusive.

While this result shows that parents display proportionately more exclusive engagement with their mobile phones than they display exclusive engagement with other non-child-related activities, a question that remains is whether – at the same level of engagement – mobile phone use reduces responsiveness to children's bids for attention more than engagement in other activities. To test how much the occurrence, strength, timeliness and emotionality of a response is reduced by the caregiver's engagement in other non-child-related activities, we repeated the logistic regression analyses performed to test H1, respective to RQ1, but with whether or not a caregiver is engaged in a non-child-related activity (cf. H1), respective to how absorbed the caregiver was in the activity (cf. RQ1) as the predictor variables. The results are displayed in Tables

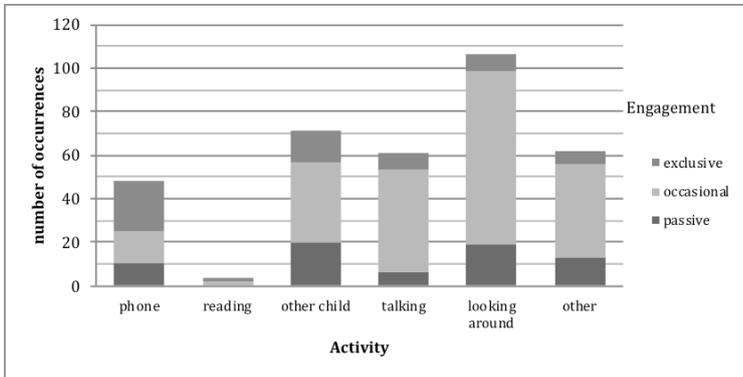


Figure 2: Parental engagement level during phone use and other activities.

7 and 8. Comparing X^2 -values with the analyses concerning hypothesis 1 (see Tables 5 and 6), it seems that the occurrence and strength of the caregiver's response are better predicted by overall non-child-related activity than phone use; timeliness of the response, however, shows higher X^2 -values for phone use.

Table 7: Caregivers' responsiveness during non-child related activity engagement and non-engagement intervals

	No other activity (n = 179)		Other activity (n = 185)		X^2	β	SE β	Wald	C&S R^2	NR 2	p
	M	SD	M	SD							
Response	.97	.15	.86	.35	18.70	-1.97	0.54	12.89	.05	.12	<.001
Timeliness	.98	.15	.91	.28	7.26	-1.42	0.58	6.01	.02	.06	.007
Strength	.77	.42	.55	.50	17.80	-1.00	0.24	17.20	.05	.07	<.001
Emotionality	.05	.21	.02	.14	1.85	-0.89	0.69	1.67	<.01	.02	.197

Note. C&S = Cox & Snell; N = Nagelkerke

Table 8: Engagement levels with non-child-related activities and responsiveness to children's bids for attention

	Engagement level with the phone							
	None		Passive		Occasional		Exclusive	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Response	.98	.15	.94	.25	.89	.32	.55	.51
Timeliness	.98	.15	.93	.26	.92	.27	.73	.51
Strength	.77	.42	.55	.51	.56	.50	.33	.50
Emotionality	.05	.21	0	.00	.03	.16	.00	.00
		X^2	β	<i>SE</i> β	Wald	C&S R^2	N R^2	<i>p</i>
Response		30.09	-1.1	0.24	21.99	.08	.18	<.001
Timeliness		9.46	-0.76	0.26	8.41	.03	.08	.004
Strength		17.60	-0.50	0.12	17.13	.05	.07	<.001
Emotionality		1.37	-0.39	0.35	1.23	<.01	.02	.267

Note. C&S = Cox & Snell; N = Nagelkerke

To answer the question of whether phone use adds a distraction above non-child-related activities, we performed four stepwise logistic regressions to see whether the occurrence, strength, timeliness and emotionality of caregivers' responses in an interval are predicted by the caregiver's engagement level in a non-child-related activity in that interval, whether or not they were using their phone in the interval, and the interaction of these two variables. In the stepwise regressions the interaction was entered first, followed by phone use and finally engagement level. The results are displayed in Table 9.

Table 9: *Engagement levels with non-child related activities, phone use and responsiveness to children's bids for attention (depicting only variables included in model)*

	X ²	β	SE β	Wald	C&S R ²	NR ²	p
Response Step 1	31.02				.08	.16	<.001
non-child activity* phone		-1.16	0.21	30.87			<.001
Response Step 2	31.47				.15	.30	<.001
non-child activity* phone		-0.74	0.23	10.73			.001
non-child activity		-1.14	0.24				<.001
Timeliness Step 1	26.60				.07	.18	<.001
non-child activity* phone		-1.76	0.35	24.97			<.001
Timeliness Step 2	9.92				.10	.25	
non-child activity* phone		-1.47	0.36	16.47			<.001
non-child activity		-0.78	0.26	8.78			.003
Strength Step 1	22.32				.05	.07	<.001
non-child activity		-0.54	0.12	21.46			<.001
Strength Step 2	4.62				.08	.10	.032
non-child activity* phone		-0.74	0.38	3.70			.055
non-child activity		-0.50	0.12	17.21			<.001
Emotionality	no variables included in model						

Note. C&S = Cox & Snell; N = Nagelkerke

As seen in the analyses above, the results indicate that higher degrees of engagement in non-child-related activities were related to fewer responses overall ($OR = 0.32$) and that these responses were weaker ($OR = 0.46$) and less timely ($OR = 0.61$). In short, being more exclusively engaged with non-phone related activities significantly hampered these aspects of responsiveness.

For response and timeliness, there was also a significant interaction with phone use. This means that an equal level of engagement in non-child-related activities was related to more ($OR = 0.48$) and more timely responses ($OR = 0.23$) if the phone was not used than when it was used (see Figure 3).

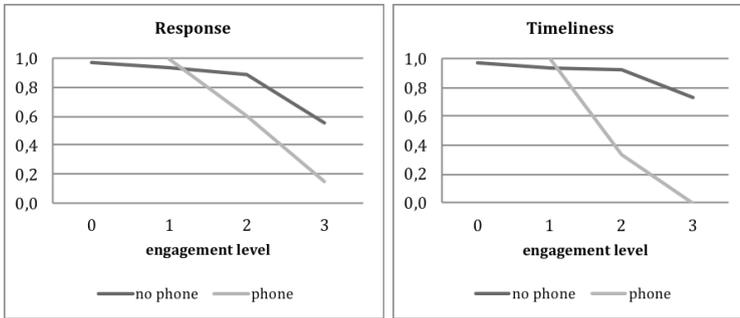


Figure 3: Responsiveness (*response*: left, *timeliness*: right) in relation to the intensity of engagement for intervals with a phone and intervals with no phone but involvement in other activities.

4.4 Observed phone use and caregivers' self-reported fear-of-missing-out, habitual phone use and problematic phone dependency

Finally, our second research question asked whether caregivers who used phones during the observation period reported a greater fear-of-missing-out, habitual phone use and problematic phone dependency. We examined this research question via independent samples t-tests, in which the caregiver served as the unit of analysis. We assessed FOMO with Przybylski et al.'s (2013) 10-item *FOMO scale* ($\alpha = .75$; $M = 2.24$, $SD = 0.73$; 7-point Likert scale). The difference in FOMO between caregivers who used a phone ($M = 2.24$, $SD = 0.73$) and those who did not ($M = 2.23$, $SD = 0.75$) was not significant, $t(23) = -0.025$, $p = .980$. We assessed habitual phone use with an adapted, 7-item version of the *Self-Report Habit Index* (Verplanken & Orbell, 2003; $\alpha = .92$; $M = 3.85$, $SD = 1.44$; 7-point Likert scale). The phone use habit of caregivers who used a phone during the observation ($M = 4.33$, $SD = 1.24$) did not significantly differ from the phone use of caregivers who did not use a phone ($M = 3.66$, $SD = 1.50$; $t(23) = -1.045$, $p = .307$). Finally, we assessed problematic phone use using a 6-item, adapted version of the *Smartphone Addiction Scale* (Karadağ et al., 2015; $\alpha = .61$; $M = 1.88$, $SD = 0.49$; 5-point Likert scale). Caregivers who used a phone did not report significantly higher addiction levels

($M = 2.03$, $SD = 0.51$) than those who did not ($M = 1.82$, $SD = 0.48$; $t(23) = -0.950$, $p = .352$).

5 DISCUSSION

This study aimed to examine (1) whether caregivers' mobile phone use is related to less responsiveness towards their small children, and (2) whether phone use is more distracting than being engaged in other non-child-related activities. With respect to the first aim, the results suggest that phone use lowers caregivers' responsiveness: in intervals in which the caregivers used phones, caregivers were less likely to respond to children's bids for attention, and when they responded, their responses were weaker and less timely. These findings support hypotheses 1a, 1b and 1c. Caregivers' phone engagement did not predict the emotionality of the response (H1d was not supported). We performed an analysis to examine if the intensity of the engagement with the phone mattered (RQ1). It did: in intervals in which caregivers were more absorbed by their phone use, responses were less likely to occur and were less timely than in intervals in which caregivers were less absorbed by their phone use.

We also tested whether children have to make greater efforts to gain their caregivers' attention when they are engaged with a mobile device (H1e). We found no support for this hypothesis. When examining the descriptives, however, the data show a trend of lowered responsiveness that manifests itself mainly in response to subtler bids for attention. That is, in intervals in which caregivers did not use a mobile phone, responses to the children's bids for attention were approximately equally strong and timely regardless of whether the child produced a bid using one or multiple modalities. In intervals in which parents were involved with their phones, however, a bid in a single modality was not likely to receive a timely or interactive response by the caregiver. If children produced at least two bids in an interval in which the caregiver used a phone, they still seemed to receive a less timely and weaker response than in intervals in which children produced at least two bids, but the caregiver did not use a phone. It would be interesting to examine further if the responsiveness of phone-using parents reaches a plateau at two or three bids, or

whether additional responsiveness can be achieved through additional bids by the children. Overall, our study thus shows that mobile media use is associated with decreased responsiveness, and further, suggests that children must work harder to get their parents' attention when mobile phones are involved in a social context.

It is important to remark that, overall, phone use was not commonly observed during the observations on the playground and almost never in the child health center. However, if the phone was used, the caregivers' involvement was most often *exclusive*, while the involvement with other non-child-related was most often *occasional*. This implies that phone use may have a different quality compared to other non-child-related activities. To examine our second research question, we compared if non-child-related activities involving the phone affected responsiveness differently than activities not involving the phone if they were of the same engagement level. The results show that when parents are engaged in other, non-child directed activities, such as talking to another person, reading a magazine or eating, their responsiveness is also hampered. In fact, the models for non-child directed activities predicted more of the variance in the occurrence and strength of responsiveness than the models for phone use; however, phone use appeared to have a greater impact on the timeliness of responses than being engaged in another activity, and when taking the intensity of the behaviors into account (i.e., passive, occasional and exclusive engagement), we found that – at an equal level of engagement – engagement in non-child-related activities was related to more, and more timely responses than engagement with the phone. All in all, these latter findings indicate that a moral panic about the phone's impact on responsiveness is unwarranted; parental phone use is part of a myriad of behaviors that caregivers engage in while caring for a child. Nonetheless, phone use appears to be a more absorbing activity than other activities and seems to affect specific aspects of responsiveness, such as timeliness, more strongly and may therefore also negatively affect types of child developments that rely on timely responses.

An additional exploratory research question (RQ2) asked whether caregivers who observed to use a phone while caring for a child would report a greater fear of missing out, habitual phone use and problematic phone dependency than caregivers who we did not observe using a phone. We found no statistical differences between the groups. It is im-

portant to note, however, that the sample size was small, and that we grouped caregivers on the basis of a (very) short observation period. A valid assessment of the former research question requires at least a longer observation period among a larger set of caregiver-child dyads. Moreover, it is important to point out the limitations of self-reports. Particularly when assessing frequent, yet irregular behaviors such as phone use, self-report data are known to be biased (e.g., Vanden Abeele, Beulens, & Roe, 2013).

In all, the results suggest that when caregivers use mobile media they are less responsive to children's bids for attention. From our current data, however, we cannot rule out a reversed causal interpretation, namely that caregivers who use mobile media are less responsive to their children's bids for attention to start out with, and their use of the phone is a behavioral manifestation of their non-responsiveness, rather than its cause. However, recent experimental studies have linked mobile phone use to still-face situations, indicating that phone usage has an extreme effect on the interaction even when it is not the caregiver's choice to use it (see Bohr, Khourouchvili, & Lau, 2017; Kildare & Middlemiss, 2017; Myruski, et al., 2017). This study lends indirect support to the notion that mobile media use hampers responsiveness.

While this interpretation needs further validation in future studies (for instance, with longer observation periods that capture longer episodes in which caregivers abstain from using their phone), we assume that mobile media use distracts parents who might otherwise be equally attuned to their children's bids for attention as those who were not observed using their mobile phone¹. Interestingly, this seems to be true even if the phone is only used passively (at least for the frequency of responses a child receives, see Table 6). This may be due to a preoccupation with the phone even if it is not in use at the observed moment. This phenomenon has been observed before; Przybylski and Weinstein (2012) found, for example, that the mere presence of a phone during a conversation lowers interactional outcomes such as perceived closeness to the

¹ This interpretation may be strengthened by the absence of any differences between answers of phone users and non-phone users to the "Brief Attachment Screening Questionnaire" (Bakermans-Kranenburg, Willemsen-Swinkels, & Van Ijzendoorn, 2003).

conversation partner, presumably because cognitive attention is directed to the present phone rather than to the interaction partner.

Our results suggest that urgent or intense attempts (operationalized here by a high number of different bids produced in an interval) to gain the caregiver's attention on the part of the child are more successful when a phone is used by the caregiver than subtle bids for attention. That probably means that, although anecdotal evidence exists that small children may be physically endangered by their caregivers' phone use, this seems to be an exception. This corresponds to an observation of Hiniker et al. (2015) who reported that phone use on the playground most often occurred after the child was in a secure environment, typically on a baby swing. On the other hand, more subtle exchanges that may be important to the child's socio-cognitive and socio-emotional development may go unnoticed when the caregivers are using mobile media. However, as our findings show, this appears to also be true when caregivers are involved in other non-child-related activities. It is normal and oftentimes necessary for caregivers to be involved in other activities such as cooking meals, doing the laundry or cleaning at least part of the time. The mobile phone is a new development, but its dangers probably lie more in its addictiveness and the amount of time caregivers potentially spend using it than in mobile phone use per se.

Theories emphasizing the importance of exclusive attention and immediate responsiveness to children build mainly on WEIRD (Western, Educated, Industrialized, Rich and Democratic; Henrich, Heine, & Norenzayan, 2010) cultural communities. Many other cultural communities have other ways of interacting with their infants. For instance, caregiver-infant play is not a universally valued or practiced activity (Lancy, 2007) and emphasized socialization goals are often not in the cognitive and linguistic domains. Guatemalan Mayan toddlers and mothers, for example, attend to several events at one time more frequently than their Euro-American counterparts living in the USA (Chavajay & Rogoff, 1999). Children are also expected to learn by observation rather than through direct instruction by their caregivers (Morelli, Rogoff, & Angelillo, 2003; Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003). Language acquisition is also rooted in cultural practices (Schieffelin & Ochs, 1986), with only particular infants participating in labeling routines typical of WEIRD communities while many others rely to

a much larger extent on overheard speech (see Hoff, 2006) that is not dependent on responsiveness to children's signals. Contingent reactions to infants' bids may even be related to developments that are not seen as positive universally (Keller, Kärtner, Borke, Yovsi, & Kleis, 2005). These cultural differences may imply that interactions with a mobile phone while taking care of a child may have different effects on children in different communities. For instance, caregivers used to attending to several events at the same time may find it easier to keep track of their children's bids for attention even when they are using their mobile phone. However, this is an open question for further research.

There are additional limitations of our study that provide suggestions for future research. Most importantly, our sample size was rather small, and in particular, the number of participants who used mobile media was low and the observation time limited (mainly because the time spent in the waiting room was rather short). Given the small number of phone users in our sample and the overall exploratory nature of our study, we did not calculate intrapersonal comparisons between situations in which the phone was used and in which the phone was not used. We performed our analyses at the interval level, without accounting for the nested nature of the data. It is possible that interactions of phone users differ systematically from non-users even in situations that do not involve the phone. For instance, these caregivers may not be as attentive to their children's bids or there are fewer bids, which the caregivers take as an opportunity to use their phone. The tendencies we see descriptively (i.e., the tendency that higher engagement with mobile media is related to a larger decrease in responsiveness, the tendency that phone engagement is related to a larger reduction in responsiveness than other activities with the same intensity) may reach significance in a replication study with more participants. Future studies should thus apply multilevel modeling to simultaneously assess relations at the interval and caregiver-child dyad level.

Not all of the observations were complete; the number of observed intervals ranged from a minimum of 12 to the maximum number of 25 intervals. In the four observations that lasted 12–17 intervals, we did not observe caregivers manipulating a phone. In two of the four observations that lasted between 21 and 23 intervals, however, the caregiver manipulated a mobile phone. Although there does not seem to be a very clear pattern concerning the onset of phone use (although nobody used it during

the first four observed intervals), parents who started using the phone continued doing so until the end of the observation. Hence, it is possible that we have missed out on some phone use intervals in the observations that finished early. Unfortunately, there are too few observations involving a phone to say whether prolonged phone use was related to different interaction patterns than brief phone use. In any case, it seems relevant to carry out longer observations in future research.

It is obvious that there are developmental differences in the nature of children's bids for attention. For instance, in the course of development children gradually learn to communicate through gestures and words (e.g., Fenson et al., 1994). Parents' responses may reflect the nature of their children's bids, which may partly explain why mobile phone use may manifest itself differently depending on the child's age. Given the limited sample size of our study, we did not focus on the question of how the age of the child is related to the association between mobile phone use and responsiveness. Descriptively, however, our findings suggest that caregivers who use their phone seem to have children who are older, and caregivers of younger children appear less intensely involved with the phone (age in months and phone involvement correlated significantly). It is possible that caregivers of older children are confident that their children will find ways to communicate effectively with them even if they are involved (more intensely) with their phones. It would be relevant for future studies to zoom in further on this question.

In contrast to the other studies on this topic (Hiniker et al., 2015; Radesky et al., 2014), we obtained informed consent from our participants before observing them. This had the advantage that we could assess precise background information and ask participants to fill out questionnaires on the children's development and their own mobile media use. However, we noted several times that when caregivers were approached and asked to participate, their mobile phone use changed (i.e., they put away a phone they were previously using). For approximately half of the participants a question concerning this was added to the questionnaires, but all except one claimed that their mobile media use had been typical during the observation. Particularly the absence of mobile phones at the child health centers seems noteworthy. This may be an effect of trying to present oneself as a good parent. However, we were told that some parents even use their phone while they are inside the examination room

with the doctor/health care professional. The influence of the location of observation needs to be studied further, maybe also taking into consideration more private settings (e.g., families' homes).

6 CONCLUSION

Our present study is among the first to systematically assess how typical and common parental use of mobile media is in young children's lives. Its findings show support for the hypothesis that mobile media use is negatively associated with parental responsiveness to young children's bids for attention. Future research can build upon the findings reported in this paper, by trying to link parental phone use qualitatively and quantitatively to developmental outcomes, such as attachment or language development. It may address, for example, whether children intensify their bids when parents are involved in their phones, or whether they just give up and stop addressing them. In addition, future work may look more closely at children's and parents' emotionality and how the valence of their responses change over time, for instance whether they get annoyed, and if so, under which circumstances. The current research findings suggest that the relation between parental mobile media use and responsiveness is complex. Nevertheless, we believe our study provides a valuable starting point from which this complexity can be examined further.

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Episodic and phenomenal aspects of chaotic itinerancy in language development

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ABSTRACT Chaotic itinerancy was proposed by Kaneko and Tsuda in order to explain the neurodynamics of cognitive processes. Annemarie Peltzer-Karpf applied this concept fruitfully to language development, thus accounting for the cycle she observed in first (L1) and second (L2) language acquisition, from an initial quasi-stable state of pre-speech behavior over intermediate states of rule-extraction and high variability, to a final steady state of large internal coupling strength. Chaotic itinerancy is an attractive model for language development as it can account for (1) stability and plasticity, (2) synchronized-desynchronized behavior and (3) multistability. In this chapter, I point out episodic and phenomenal aspects of chaotic itinerancy. Firstly, language development occurs in a spatio-temporal context as the infant/child interacts with her external – physical and social – environment. Her language experience shapes internal brain circuits resulting from repeated patterns of neural activity. Secondly, language development has an experiential quality unique to each infant/child, depending on her individual history. This is for her – but also for her caregivers – “what it is like” to acquire language. Through self-organization, self-similar linguistic patterns emerge which are embedded within each other on various time-scales (micro-, meso-, and macro-). Through this concept of multiple nesting, traditionally opposite accounts, such as

acquisition (*nature*) and learning (*nurture*), can be integrated into an overarching *nonlinear dynamic systems* (NDS) account of language development. Annemarie Peltzer-Karpf pioneered and advanced this research agenda decisively throughout the itinerancy of her academic life and inspired many to join her on this journey.

KEYWORDS chaotic itinerancy, episodic memory, nonlinear dynamic systems theory (NDST), language development, phenomenal, self-organization

1 INTRODUCTION

The dynamic hypothesis in cognitive science (van Gelder, 1998), psychology (Guastello, Koopmans, & Pincus, 2009) and linguistics (de Bot & Larsen-Freeman, 2011) has profoundly changed our way of conceiving language and cognition, shifting away from static states and computations that define how to change between these states towards on-going dynamical processes within an organism embedded in its environment. However, *Nonlinear Dynamic Systems Theory* (NDST) with its mathematical origin is a hard reading for scholars coming from philosophy, psychology, linguistics, and similar disciplines in the social sciences and humanities. The technical meaning of important concepts of NDST (*self-organization, chaos, bifurcation*) is difficult to map onto corresponding concepts in these disciplines. As Kampis (2004, p. 585) put it: “They are hopelessly far from anything in which the philosopher or psychologist is interested” (but see the playful yet serious attempt of van Geert, 2008). No easier is it to map these (barely understood) concepts onto (higher-order cognitive) phenomena that would instantiate them in these disciplines. However, NDST can be applied fruitfully to various domains. It “can contribute to new and improved theories and reveal commonalities in dynamical structure among phenomena that might not have been compared or connected otherwise” (Guastello & Liebovitch, 2009, p. 36).

But where to start? What is true for hiking is also true for science in this respect: it is good to have a guide at your side who knows the territory, who can show you the way, and who can prevent you from falling off of precipices. My guide and senior companion in the territory of

NDST was (and still is) Annemarie Peltzer-Karpf. Through Annemarie I learned what to look for in my domain – language acquisition – that would provide concrete evidence for some of these magical concepts that seemed so abstract and intangible yet so intriguing and deeply meaningful to me as a developmentalist: *self-organization, self-similarity, fractals, chaos, attractors, oscillations, bifurcation, multistability, complexity, emergence*, to name just the most important. What is the phenomenology of these dynamical systems concepts in language acquisition? What does self-organization look like in language acquisition? What does a fractal look like in language acquisition? When I read her book *Selbstorganisationsprozesse in der sprachlichen Ontogenese: Erst- und Fremdsprache(n)* (Karpf, 1990) during the preparation of my PhD dissertation (Hohenberger, 2002/2011), preliminary answers to these questions began to form in my mind.

In the remainder of this essay, I will highlight important concepts of a nonlinear dynamic systems approach to language development, which Annemarie introduced to the literature originally (most famously *chaotic itinerancy*), and discuss their episodic and phenomenal aspects. Finally, I will argue that in virtue of the fractal character of language – its nested spatio-temporal frames in development – NDST is capable of resolving the nature-nurture controversy in language development.

2 **EXPERIENCE-DEPENDENT DEVELOPMENT – VARIATION AND SELECTION – PLASTICITY**

(Language) development can be understood as a “directed process of change toward or unfolding of a mature state [...], implying increasing complexity in terms of a system that differentiates [...] and at the same time integrates” (van Geert, 2009, p. 248). Particularly salient are the results of differentiation of the complex language system in the course of ontogeny, as when the lexicon and morphology begin to split up (yet remain coupled). Annemarie showed through correlational data that the beginning of this decoupling takes place in concert with a phase of overproduction in L1 and L2 language acquisition (Karpf, 1990; Peltzer-Karpf, 2006). Word formation becomes excessive and word forma-

tion rules and structural constraints are easily overridden. Legendary are Annemarie's examples of morphological diverse forms pouring out of the cornucopia of German L1 learners' productions (Karpf, 1990, p. 189), such as: "karoliert, karomustig, karomusterig, gekariert, gekaro, gekart, gekarot, gekarost, karomelt" [adjectives denoting 'kariert' (checkered)] or "Schönichkeit, Schönerung, Verschönung" [nouns denoting 'Schönheit' (beauty)].

Likewise, L2 learners of German delight us with a wide variety of adjectival derivations, for example of the target word 'bewölkt' (cloudy): "wolknisch, wölklich, wolkerisch, wolkelig, bewolkt" (Peltzer-Karpf, 2006, p. 245). But how could we make this abundance more visible and at the same time more intelligible? NDST lives from rendering temporal processes spatially. Since Poincaré's invention of "qualitative or geometric theory of dynamical systems" (Beer, 2000, p. 93) we have a plethora of visual devices available that show the states of a system over time in a single spatial chart: return maps, vector fields, flow diagrams, phase portraits, bifurcation diagrams, parameter charts, etc. As developmentalists, we would like to retain the temporal flow somehow. Waddington's *epigenetic landscapes* with their *chreodes* (pathways of change) are another good way of picturing diversity during epigenesis (Waddington, 1957). Annemarie's manifolds of "karo" (Karpf, 1990, p. 189), pooled over the entire sample of German L1 learners, might look like what is depicted in Figure 1.

In each of these little valleys or *chreodes* of this canyon landscape, one morphological form *rolls down* the epigenetic course. Each of them has its own fate, and in fact, they will all die out (become flat), converging onto the single rule-conform derivation 'kariert' finally rolling in a deeply carved out valley (not depicted in this landscape). However, these alternatives are not to be disrespected as frank errors or mere noise. They are all covered by the Darwinian principle of variation and selection, here extended to epigenesis. At some point in development, these variants or *mutants* are produced from within the dynamical system (note that the children could not have heard any of these forms) from which a selection is made subsequently, depending on the constraints of the related linguistic system. In the end, only the target form which is best adapted to the language environment survives.

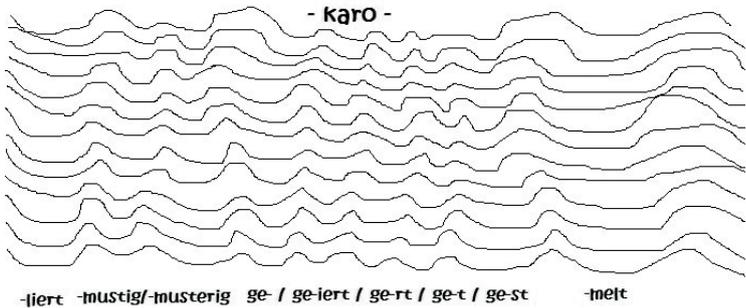


Figure 1. Pooled epigenetic morphological landscape of German L1 learners of the adjective 'kariert' (checked).

The role of experience is to shape the form of this landscape, which is an intuitive visual depiction of learning processes in the brain. Here, Annemarie relied on Singer and colleagues' model of *experience-dependent development* or *activity-dependent self-organization* (Singer, 1987, 1990). This principle explains the ongoing interaction between internal states of the dynamical system – here, language – and the environment in which it is embedded and with which it exchanges energy. Dynamical systems are open systems poised at the edge of chaos (Kauffman, 1993; Peltzer-Karpf, 2012, p. 65). They dissipate (expend) energy from inside-out and thus create order far away from (thermo-dynamic) equilibrium (Prigogine, 1977; for a more comprehensive list of attributes of dynamical systems see de Bot & Larsen-Freeman, 2011; van Gelder, 1998, among others). Order formation can be spontaneous; however, it is greatly eased under formational constraints of the environment – here, the ambient language. The role of the environment is to provide the carrying capacity for the infant's/child's growth process and to constrain it at the same time. That is, while the primary linguistic data is the *feeding trough* of experience for the child's growing lexicon and grammar, the linguistic rules instantiated in that specific input that she is exposed to, her particular native language(s), guide the child towards this/these particular lexicon(s) and grammar(s) and not to others. The metaphor of *carving out a sculpture* from a crude rock based on experience is highly appropriate here. This sculpture is a mental object, though, a *body of knowl-*

edge of language. The process through which this sculpture emerges is self-organized, meaning there is no blueprint of a fully determined innate grammar of language that merely unfolds in time through a maturational process; however, domain-general and -specific initial conditions are assumed.

Universal Grammar (UG) can be thought of as an *initial attractor network* (Peltzer-Karpf, 2012, pp. 67-68) that starts the protracted series of iterative mappings of concrete speech tokens onto linguistic representations which become more and more target-like. In these self-organizing developmental processes, maturation and experience play complementary roles (Peltzer-Karpf, 2012). Self-organization can be considered as the mechanism of change in a growth model of language development (van Geert, 1993, 2008, 2009). The motor of this change can be seen in the *gradient of discrepancy* (Tschacher, Dauwalder, & Haken, 2003) between the child's and the target language system, which is extinguished during the course of development. While at the beginning the discrepancy is maximal, the child consumes it during ontogeny through linguistically interacting with her caregivers and others. This interaction is the indispensable and powerful motor of change. It is seemingly asymmetric in the beginning with the caregiver instigating proto-conversation, and one may even consider it irrational to some extent: why would you talk to anyone who cannot understand you? Yet, caregivers' (counter-)intuitions are perfectly right. While infants do not understand the linguistic meaning of what is said to them, they respond to the prosody of their caregiver's address adequately. In Fernald's (1989) words: "The melody is the message". Here is where usage-based, situated approaches contribute fruitful insights to our conception of language development (see, e.g., Behrens, 2009; Lieven, 2016; Tomasello, 2003, 2015). According to this approach, the meaning of an utterance lies in its use and is construed by virtue of general cognitive skills prior to language, namely joint attention and intention-reading (Tomasello, 2015). Extracting linguistic meaning and structure is then a corollary of the interaction between infant and caregiver with its many facets – cognitive, emotional, bodily and contextual. From a usage-based, situated perspective, pre- and even non-linguistic creatures, such as infants and non-human animals, may not yet be able to decontextualize; however, they can understand meaning if it is contextualized and allows for perception of affordances such that

they can respond to their partner adequately (Froese, Ikegami, & Beaton, 2012).

Language is embedded three times over: in the brain, in the body and in the environment (e.g., Beer, 2000; de Bot & Larsen-Freeman, 2011, among others). In terms of the first – *embrainment* – language development is a result of continuous self-organizational processes in the brain. Events do not flow smoothly during language growth, though. There are surges of growth due to neural plasticity exhibiting increased levels of variability, as we have seen in the introductory examples above. They correlate with phases of synaptic exuberance and subsequent *pruning*, that is cutting back unnecessary synaptic connections and superfluous neurons, resulting in experience-dependent differentiation (Changeux & Dehaene, 1989; Peltzer-Karpf, 2012). Neural plasticity shows specific time-stamps for the various components of grammar – phonology, morphology, syntax – and for the various parts of the brain – sensorimotor, parietal and temporal, as well as prefrontal cortex (Thompson & Nelson, 2001).

Recently, the role and interplay of maturational-biological and experience-dependent factors in neural plasticity has been revisited by Werker and Hensch (2015). They suggest a mechanistic model explaining the onset and closure of *critical periods* (CPs) in speech development in which a balance of excitatory and inhibitory processes in pyramidal cells defines the onset and *molecular brakes* the closure of CPs. In the same vein, Fischer (2008) points out that, generally, cognitive growth in individual children proceeds through cycles of jumps and drops. This pattern of scalloping is natural and reflects adaptive plasticity at macro- and micro-levels, respectively. According to Fischer, “cortical growth spurts reflect the emergence of new skill levels” (2008, p. 137). The *vocabulary spurt* at around 18 months and the *syntactic spurt* later in the second year of life are cases in point (Hohenberger & Peltzer-Karpf, 2009; van Geert, 1993). Such spurts occur when a critical mass of items (here: lexical entries) has been accumulated which makes it more efficient to handle them at a higher level of complexity. Otherwise, the growing lexicon may turn chaotic. In the case of the vocabulary spurt, the lexicon *phonologizes* (Levelt, 1998); in the case of the syntactic spurt, the lexicon *syntacticizes*. In NDST terms, a bifurcation between the lexicon and grammar (phonology, morphology and syntax) occurs, leaving the child with a mental

lexicon and rules of how to combine words as well as their constituents (phonemes, morphemes). In return, the onset of syntax allows more lexical entries to be handled and thus increases the *carrying capacity* of the lexicon (van Geert, 1993). Such feedback loops are typical in dynamic systems and may give rise to growth patterns that even look like Piagetian stages (van Geert, 1998). In terms of architecture, linguistic structures become *recursive* over the course of language development, that is self-similar structures are nested within each other, allowing the conveyance of increasingly complex thoughts (see also Murphy in this volume). The human cognitive and language system is so rich with tree-like, recursive structures that Fitch (2014) speaks of *dendrophilia* in humans.

3 CHAOTIC ITINERANCY

The notion of attractors provides a useful dynamical interpretation of (intermediate) stable representational states through which the infant and child processes and produces language. However, what exactly is the process by which children are guided towards these attractors only to leave them again, heading towards new attractors replete with yet more knowledge of language? Annemarie espoused an elegant mechanism originally discovered by Ideda, Kaneko and Tsuda independently between 1989 and 1991 (Kaneko & Tsuda, 2003; Tsuda, 2001, 2015): *chaotic itinerancy* (CI). CI comprises a set of quasi-attractors and dynamical trajectories between them (see the intuitive landscape in Figure 2).

The dynamical system itinerates through the state space which has regions of high dimensionality (*chaos, disorder*) and regions of low dimensionality (*ordered states, (quasi-) attractors*). Higher-dimensional inlet trajectories lead into a quasi-attractor of low dimensionality which can be left again through outlet trajectories into higher-dimensional space. The neighborhood of these quasi-attractors has been called *attractor ruins* because as the quasi-attractors become unstable over time, they dissolve into their neighborhood. The advantage of chaotic itinerancy is that it can describe and explain crucial features of dynamical development, namely the *stability-plasticity dilemma* (how a system can maintain and increase order and yet remain flexible); cycles of synchro-

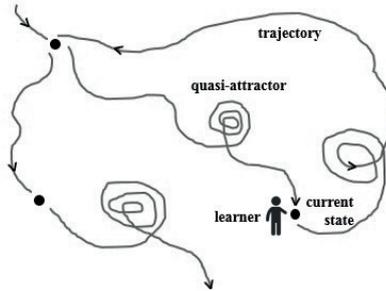


Figure 2. Schematic drawing of chaotic itinerancy, closely adapted from Tsuda (2001, Figure 4, p. 799): overall state space comprising regions of low dimensionality (quasi-attractors surrounded by attractor ruins) connected by regions of high dimensionality (trajectories) through which a learner itinerates (current state).

nized-desynchronized behavior (either between interacting agents or between sub-components of the system, such as lexicon and syntax); and multistability (the system has more than one state in which it can dwell, see Kelso, 2012). Annemarie interpreted Kaneko and Tsuda's mathematical model in terms of the developmental cycle leading from (1) an initial quasi-stable state including pre-speech behavior and dominated by unanalyzed holistic chunks, over (2) intermediate states characterized by rule-extraction, over-generalization and high variability among clusters to (3) a final steady state with coherent clusters and large internal coupling strength (Hohenberger & Peltzer-Karpf, 2009; Karpf, 1993; Peltzer-Karpf, 2006).

4 THE EPISODIC NATURE OF CHAOTIC ITINERANCY

Chaotic itinerancy has been claimed to pertain to, among other things, *episodic memory* (Tsuda, 2015), which is memory of *what-where-when*. In episodic memory, not only the content of what has been experienced is retained but also the context, that is where and when the memory had been formed (Tulving, 2002). The procedural and experiential aspect of episodic memory is mental time travel, defined as the conscious re-living

of some previously experienced episode (Suddendorf & Corballis, 2007). Itinerancy with its wandering nature, stopping at various attractors and moving to the next one through a chaotic state space seems to be a suitable framework for episodic memory, indeed. In the following, I will focus on the episodic nature of itinerancy more generally by considering the process itself.

The developmental process itself is a series of episodes in the life of the infant and child as she interacts with her environment, moving literally through space and time. These real-life episodes leave episodic traces in the brain: each encounter with a word, each parsing of some phrase, and each utterance of the child changes the brain – in terms of its physical and physiological structure, in terms of its processing procedures and also in terms of its (representational) content. Language thus develops in parallel in terms of the episodic nature of life events and corresponding brain events. For a long time, researchers in the generative tradition have not been interested in nor appreciated the spatio-temporal context of *learning episodes* in infant and child language development. They were rather focused on the outcome: knowledge of language (Chomsky, 1986). How exactly they arrived at this state was not considered important. The many different pathways were *equifinal* – they eventually all reached the same (or a very similar) steady state, namely the target language system. However, when development is taken serious, individual pathways to language (Karmiloff & Karmiloff-Smith, 2001) can be considered as concrete instantiations of episodic itinerancy. Similarly, usage-based, emergentist and situated approaches (Behrens, 2009; Lieven, 2016; Tomasello, 2015) equating usage with development (de Bot & Larsen-Freeman, 2011), capture the spatio-temporal embeddedness of the language learning infant and child naturally.

A researcher who took the episodic nature of language learning literally is Deb Roy. He and his team tracked the language development of his son for over five years in the house of the family (see Kamenetz, 2011). For this purpose, they had cameras with microphones installed in each room and recorded more than 90,000 hours of interaction of the boy with the various family members, the nanny and visitors, capturing exactly *where* and *when* and in *which linguistic context* he would utter his first and subsequent words and phrases (Roy, Frank, DeCamp, Miller, & Roy, 2015). They tracked where in the house this vocabulary *resides* and

when, during the day, this vocabulary is used. Through this high-density data collection technique, they kept an objective record of the episodic context of the lexical development of Roy's son. They could, for example, identify how, over six months, the proto-word *gaga* turned into *water*. The three-fold contextual distinctiveness (*where, when, in which context*) predicted the emergence and spatio-temporal distribution of word production, for instance, the word *water* appears mostly in the kitchen but the word *fish* in the child's room (see Roy et al., 2015, Figure 3, p. 12666). Roy and his team could predict the *birth of a word* through their episodic tracking system (Roy et al., 2014, 2015). His son's brain keeps a similar record, at the same time, namely it encodes and processes these words at different places and in temporal order, through repeated patterns of neural activation in brain circuits, thus imprinting the words into the brain spatio-temporally. This unique longitudinal study takes seriously and operationalizes the episodic nature of chaotic itinerancy and shows what concrete behavior appears at various points during the protracted course of language development.

5 THE PHENOMENAL NATURE OF CHAOTIC ITINERANCY

In philosophy, the phenomenological tradition is concerned with the *intentional* character of experience, that is the fact that all experience is about something. Besides perceptual content, *phenomenology* is concerned with spatial and temporal aspects of experience, i.e., it takes serious our situatedness in the world (Gallagher & Zahavi, 2012). Similar issues have been raised in episodic cognition, as pointed out above. Phenomenologists ask *what it is like* to have a certain experience (Nagel, 1974), and they focus on the subjective level of experience from a first person perspective, as opposed to the objective, physiological brain processes underlying experience from a third person perspective. The latter can be reduced to a physical basis, the former cannot.

An NDST of language development yields an abstract (ideally mathematical) description accessible from a third person perspective. Yet, the non-linear equation governing the dynamic process comprises as many trajectories as there are individual observations. The boundaries of this

equation form an episodic and phenomenal *envelope* around them. In other words, this mathematical description remains connected to concrete cognitive processes – observable at the levels of behavior and the brain. The individual life and language history of any observed infant and child makes her productions unique and non-reversible. These phenomenal properties correspond to the episodic nature of chaotic itinerancy.

Language development manifests itself in each child in an inter-individually distinct – and sometimes very funny – way, for example, in the form of “gekarot”, “karoliert” or “karomustig”, to come back to Annemarie’s amusing morphology examples mentioned above (Karpf, 1990, p. 189). These examples yield evidence of *what it is like* for a child to acquire language. However, the child does not consciously experience her language development and is not (necessarily) aware that she produces these words. In this respect, Tulving’s (2002) criterion of *autonoesis* for episodic cognition (i.e., being aware that an experience has happened or is happening to oneself) is not fulfilled. Yet, I want to reassert that language development is episodic and phenomenal for the infant and child herself, however, with *autonoesis* being outsourced to the social partners of the child and becoming *heteronoesis*. This is because other people around the child are aware of the belongingness of her productions to her and likewise experience her language development episodically, phenomenally and sympathetically. Together, as a coupled system, they form an extended observer-experiencer unit (Vrobel, 2011) – a phenomenologically complete and competent double-agent: the child brings the (production) data to the table and the caregiver/researcher the awareness. It is through this *coupling* that the child’s lack of *autonoesis* – her episodic unawareness – is compensated and preserved as *heteronoesis* in her adult interlocutors. Through the protracted interaction with her caregivers, this gulf is closed more and more until the child experiences herself as the agent of her own language productions.

Stewart and Cohen (1997) term this property of continuing interacting dynamical systems *complicity*. In *complicity* both systems realize levels of complexity which they could not have reached without each other. In the case of language development, it seems to be an asymmetric interaction since it is the infant who is mostly in charge of extinguishing the existing *gradient of discrepancy* (Tschacher et al., 2003) and is approaching and finally reaching the target state; however, the infant’s caregivers are

also changed. They may engage in a novel speech register (child-directed speech) and temporarily adapt to the infant's current communicative needs. In Deb Roy's project, caregivers at around the time of the *birth of a word* would repeat back that word to the boy in its isolated form or in short sentences only, thus adapting to his current needs to focus on the word form, while the word appeared in more complex sentence contexts before and after this critical moment. Both partners in the process shape each other's behavior *complicitly*.

In terms of Kaneko and Tsuda's chaotic itinerancy and Deb Roy's high-density data project, the conceptualization of dynamical trajectories in space and time are similar, be it in the abstract mathematical realm, in the brain of the learner, or in the house where he is living. They can be thought of as episodic wandering in space and time, along with the phenomenal quality of *what it is like* to learn language (and *what it is like* to observe language learning). Dynamical patterns can characterize either modality equally well – abstract modeling, internal processes in the brain and external processes in the environment.

6 **RESOLVING THE NATURE-NURTURE CONTROVERSY DYNAMICALLY**

During my linguistic studies, I was aware of the great controversy between rationalism/nativism on the one hand and behaviorism/connectionism on the other hand, that is, the *nature-nurture debate*. This debate can be exemplified by the (almost complementary distribution of the) use of two highly related terms in two opposing camps – *generativists* and *connectionists*. These two terms are *acquisition* and *learning*. Generativists on the one hand use the term of acquisition, meaning the fast, relatively error-free, and easy course of attaining knowledge of language by an infant equipped with an innate Universal Grammar (*nature*). Researchers working within the connectionist and usage-based framework rather prefer to speak of learning in the sense of change in behavior based on experience (*nurture*). Dynamicists tend to prefer *development* over *acquisition* (de Bot & Larsen-Freeman, 2011). For my part, I was used to speaking in nativist terms of *language acquisition* and not in con-

nectionist terms of *language learning* (Lindner & Hohenberger, 2009). However, I was even more impressed by how others, above all, Annemarie, defied this controversy and endorsed instead a paradigm that seemed to cut across concepts of either camp and was able to integrate them. It promised a *synthesis* of what I had only known as incommensurable *thesis* and *antithesis* before. This promise was more exciting and productive for me than frankly declaring the debate as unproductive (Fitch, 2012). One notion in particular was suitable for a possible convergence between nativism and connectionism: fractal (time) scales. *Fractals*, informally speaking, are self-similar spatial or temporal structures at various scales of magnitude (for a formal definition, see Liebovitch, 1998, p. 62). Growth processes in dynamical systems typically self-organize into fractal patterns. During language development, we can observe formation of syllables, words, phrases, clauses, complex embedded clauses, all the way up to discourse. Crucially, all these units can supposedly be described with the same (tree(-like)) structure or the same structural process (recursive binary branching) (Fitch, 2014).

When we look at developmental processes over time, we see self-organization at three broad time-scales: (1) the macro-scale of evolution/phylogeny, (2) the meso-scale of ontogeny and the (3) micro-scale of microgeny (Schweiger & Brown, 2000). These time-scales can be tracked for the development of the human brain as well as for the mental capacity of the human language faculty. Biology and self-organization work in concert during evolution. According to Kauffman (1993), self-organization creates and preselects certain patterns on which natural selection then acts (see also de Boer, 2012). Considering the phylogeny of language, the same dynamical principles apply as in ontogeny (Luef & Peltzer-Karpf, 2013). This process is best observable in ontogeny, where infants and children come up with a variety of self-generated candidate structures, which are then selectively stabilized through the comparison with the target language (Karpf, 1990, 1993). At any moment in the microgeny of vocabulary growth, but in particular at critical bifurcation points where sub-systems decouple, can such mutants arise (see the multitude of “karo-” variants above).

In development, these three time-scales are nested within each other (van Geert, 2008): the infant’s concrete moment-to-moment processing and production of language (microgeny) is nested within her overall lan-

guage development (ontogeny) which is nested within the global evolution of language (phylogeny). The speed at which growth processes take place at these levels is dramatically different: fast at the micro-level; medium at the meso-level and slow at the macro-level. The first words (or signs if one believes that human language started out as a sign language, see Corballis, 2003) at the evolutionary level were certainly learned slowly and effortfully. They could not be *acquired* because there was no innate structure there yet (at least no domain-specific language structure, albeit a similar structure for action, see Steele, Ferrari, & Fogassi, 2012). Hence, language was first *learned*, in a piecemeal fashion. However, subsequent generations, who inherited both genetically and culturally the propensity to use language for communicative purposes, already had some structure to build on further. Since the linguistic output of each generation was fed (back) to each new generation, self-organization could proceed steadily and iteratively converge on stable patterns of linguistic structures. Over time these structures conformed to tree-like structures which are most efficient for organizing information hierarchically and producing it sequentially. Early learning and later acquisition just demarcate different points in the overall nested developmental growth process. Therefore, it is no contradiction that language looks innate, i.e., is *acquired* on the ontogenetic level but looks *learned* at (least at early) phylogenetic/evolutionary levels (for a similar example of how different the same process can appear depending on what time-scale you look at it, see van Geert, 2008, p. 184).

Metaphorically speaking, when you say that language is a *prêt-à-porter* dress for the child which she can readily take off from the clothes rail and don smoothly, you still have to explain how that ready-made dress came to hang there (how it was *tailored*). Deacon (1997) gave a famous answer to this question claiming that the evolving language – the dress – itself had to adapt to the cognitive system of the human – the wearer of the dress. Kirby and colleagues (e.g., Kirby et al., 2014) provided the mechanism of this process – *serial learning*, which is the iterative transmission (and improving) of language from one generation to the next – until the dress fitted its wearer seemingly perfectly. The fast and smooth donning of the dress in ontogeny then looks like language was inherited – although it might have been a slow trial-and-error process with lots of waste in the beginning. The dispute whether language is innate (the

dress is *prêt-à-porter*) or learned (the dress is *tailored*) can thus be overcome and resolved by relegating these alternative pathways of gaining knowledge to different time-scales. Since these processes are embedded into each other in a self-similar way over time (Vrobel, 2011), they are available throughout the entire development. Various forms of learning (statistical, distributional, etc.) and acquisition processes co-exist and interact in a modern infant's developmental pathway to language. As dynamicists, we enjoy greater theoretical freedom because we can readily acknowledge various forms of knowledge acquisition and their complex interplay during language ontogeny.

Coming back to the episodic and phenomenal aspects of (chaotic) itinerancy, we can conceive of self-organizational processes at all time-scales. As our ancestors wandered around in the savannah, using utterances from which words emerged to name objects, activities and qualities of their surrounding and putting them together syntactically, they experienced language in concrete space and time, in the context of their living environment. At the same time, self-organization crafted brain circuits reflecting this episodic itinerancy in the form of spatio-temporal patterns of neural activity. At the level of ontogeny, the modern infant experiences the same parallelism. The episodic and phenomenal nature of this itinerancy thus pertains to all temporal and spatial scales – to mental language structures, physical brain-structures supporting language, as well as to environmental structures providing the context of language development.

7 CONCLUSION

Chaotic itinerancy, according to Kaneko and Tsuda, is a suitable framework for observing cognitive neurodynamics through the looking-glass of a mathematical attractor model. Annemarie first applied it to language development. Here, I pointed out episodic and phenomenal aspects of itinerancy and the significance of nested time-scales in language development. Annemarie's expertise in the area of self-organization in language development and her fruitful recruitment of dynamical concepts for the explanation of L1 and L2 acquisition as well as in typical and ex-

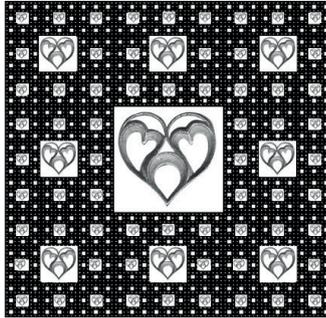


Figure 3. "Liebe Annemarie! Ich 'karoliere' Dir von ganzem Herzen zu Deiner Pensionierung!" — Annette

ceptional language development (Peltzer-Karpf, 2002) was, and still is, a great source of inspiration for me.

Annemarie, if you had not been there at the right time in the right place in my own academic life, I would not have proceeded in my own studies as I did, and may not have found the proper entry to the *basin of attraction* of NDST. Thank you for accepting me as an itinerant companion over the past decades and hopefully in future decades as well! Without you, language development would have felt and appeared differently to me – certainly less “karoliert”!

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Interfaces (traveling oscillations) + Recursion (delta-theta code) = Language

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ABSTRACT Formulating a minimalist model for language, Gärtner and Sauerland (2007) collected a series of papers exploring the possibility that the recursive generative component plus the conceptual and articulatory interfaces provide the essential components of the system. This was summarized as 'Interfaces + Recursion = Language'. Over the past decennium a range of linking hypotheses have been drawn up to better ground this architecture within the brain. In the realms of cognitive and systems neuroscience, the search for the neural code across a number of domains has seen a marked transition from the analysis of individual spike timings to larger patterns of synchronization. This chapter argues that the language sciences should embrace these systems-level developments, with recent findings concerning the scope of possible oscillatory synchronization in the human brain revealing the existence of traveling/migrating oscillations, adding further impetus to reject the typical stasis found in cartographic neurolinguistics models. After exploring empirically-motivated revisions to the neural code for hierarchical phrase structure, it is discussed how this code could provide a new perspective on language disorders, fluid intelligence and language acquisition.

KEYWORDS delta, gamma, language disorders, neural oscillations, weakly coupled oscillators

1 INTRODUCTION

This chapter will be concerned with the neural implementation of the generative component of language. Specifically, it will discuss the potential neural oscillations have for providing an explanatory link between linguistics and the brain sciences. *Neural oscillations* are rhythmic fluctuations of spiking activity within neural clusters, and in recent developments in cognitive neuroscience it has been argued that synchrony of these oscillations in distinct clusters can shape input gain and assist information transfer (Akam & Kullmann, 2010; Muller et al., 2018). Oscillations reflect synchronized fluctuations in neuronal excitability and are categorized by frequency: delta (δ : ~0.5–4 Hz), theta (θ : ~4–8 Hz), alpha (α : ~8–12 Hz), beta (β : ~12–30 Hz) and gamma (γ : ~30–100 Hz) (see Meyer, 2017).

With respect to particular language-neurobiology linking hypotheses, I will here be assuming the framework for phrase structure generation in Murphy (2016a-c), involving, at a minimum, $\{\delta(\theta)\}$ phase-amplitude coupling (with the notation denoting the amplitude of θ being phase-locked to δ) to construct multiple sets of linguistic syntactic and semantic features, with distinct β and γ sources also being embedded within θ for, respectively, syntactic prediction and conceptual binding. This provides a specific neural code for *recursive hierarchical phrase structure* (reapplying the set-forming operation to its own output), with α being involved in the early stages of binding (Pina et al., 2018) to synchronize distant cross-cortical γ sites needed for the ' $\{\theta(\gamma)\}$ code' of working memory and to modulate attentional resources. True recursion defines its output value in terms of the values of all of its previous applications, grounded in the initial application (Lobina, 2017), and this self-referential quality of recursion can be implemented via repeated nestings of θ within successive δ rhythms. The $\{\theta(\gamma)\}$ code is a generic mechanism utilized for visual, auditory, somatosensory and even vibrotactile working memory (von Lautz et al., 2017), and is also involved in inter-regional communication (Solomon et al., 2017), and so it is likely recruited by the language system. θ - γ phase-phase coupling in the human hippocampus has also been shown to be involved in multi-item working memory maintenance (Chaieb et al., 2015), and different cognitive domains may construct representational stacks via different types of couplings. Given the rich inter-

faces between language and other cognitive and perceptual domains, it is likely that language processing is implemented via a range of cross-frequency couplings. Although there is accumulating empirical support for this model (Segaert et al., 2018, provide empirical support for the present claims about α being involved in phrasal chunking) and its computational basis (Zaccarella et al., 2017, provide neuroanatomical support for assuming a core, elementary phrase-structure building operation), recent research opens up the possibility for expansion and refinement.

I would like to note here that any particular linguistic theory which assumes elementary combinatorics for syntax in conjunction with some form of cyclically generated hierarchical phrase structure is compatible with the model to follow, and there is nothing (as yet) in principle which should restrict our focus to *generative/minimalist models* – not least because neurobiological theories do not yet have the explanatory power to adjudicate between different computational theories. Hierarchical dependencies are not exclusive to generative theories, and there is potential scope for linking hypotheses between neurobiology and any number of linguistic theories (e.g., Categorical Grammars, Dependency Grammars, Usage-Based grammars). The minimalist framework assumed here is motivated primarily by the architecture formulated by the Gärtner and Sauerland (2007) equation mentioned above, which is particularly useful for integrating distinct neurobiological processes into a unified theory of the dynamics of language comprehension.

2 TRAVELING OSCILLATIONS

Building on a large body of work into the nature of oscillations (Kopell et al., 2014; Le Van Quyen & Bragin, 2007; Patten et al., 2012), Zhang et al. (2017) present novel insights into a relatively new mechanism for large-scale neural coordination in the form of *traveling oscillations* which cycle cross-cortically at a speed of ~0.27–0.75 metres per second. These form spatially coherent waves that move across the cortex. In purely physical terms, a traveling wave is a disturbance traveling through a medium such as water, air or a cellular network. Instead of involving precise zero-lag synchrony (involving perfect temporal alignment between synchro-

nized oscillations), Zhang et al. show how a range of phase offsets can be achieved (whereby the phase of multiple oscillations differs), producing traveling waves of various shapes such as plane, radial and spiral waves. The propagation of traveling oscillations was found in 96% of neurosurgical patients (through electro-corticography) and was consistent with good performance on the Sternberg working memory task (Sternberg, 1969). Zhang et al. (2017, p. 3) conclude that “human behaviour is supported by ... traveling waves”. These waves have recently been implicated in multiple sensory, motor and cognitive systems, and Muller et al. (2018, p. 1) recently speculated that “travelling waves may serve a variety of functions, from long-term memory consolidation to processing of dynamic visual stimuli”. Summarizing recent literature, Muller et al. (2018, p. 8) suggest that hippocampal CA1 traveling waves in the θ band exhibit a particular computational role (“Patterning pyramidal spiking from small to large place fields in each theta cycle”) which can be contrasted with the putative role of traveling fast γ waves in the same region (“Patterning spiking in either direction of the dorsoventral axis in hippocampus”). More broadly, it seems clear that traveling waves serve to organize spike timing along a particular behaviorally relevant axis.

It is clear from Muller et al. (2018; see their Table 1) that only visual, sensorimotor, motor, hippocampal and macroscopic computational principles of traveling waves can be proposed with any certainty, with the development of large-scale, high-precision recording technologies being able to expand current understanding. What precisely constitutes the range and influence of traveling waves over the rest of cognition is a topic for future study, and Muller et al.’s project should readily be expanded to language processing such that neurolinguists should investigate the computational role of traveling waves across various *language regions*. For now, we can begin to sketch possible directions and explanations for these discoveries.

Zhang et al. (2017) discovered what they define as traveling *theta and alpha oscillations*, yet their analysis reveals that the full range of migrating waves stretched from 2–15Hz, therefore implicating mid- δ . Mid- δ is involved in phrasal chunking, though not sentential chunking (which low- δ seems responsible for). This could potentially lead to a refined neural code for language processing: δ waves cycle across the cortex, building up the syntactic representation phrase-by-phrase and being en-

dogenuously reset by a newly constructed phrase, either traveling to parts of the cortex responsible for storing the required semantic representations or being coupled to traveling θ waves which perform the same function. The second option seems more likely, given what is known about where δ seems to be localized during language comprehension (Ding et al., 2016). The limitations of semantic processing could be derived either from the physical limitations placed on the speed of traveling cycles as they move from station to station ($\sim 0.25\text{--}0.75$ m/s) or the width of the propagating waves (median: $\sim 2.4\text{--}4.8$ cm) which might limit the range of conceptual structures manipulated.

As discussed elsewhere (Murphy & Benítez-Burraco, 2017a), the brain was re-shaped in our lineage via *globularization*, through which our braincase adopted a more globular shape, and so I would like to hypothesize that this granted oscillations the ability to travel across new areas of the cortex and subcortex whilst also being coupled to a number of other regions. This would have opened up new interfaces for conceptual representations, and in combination with the present neural code would also have derived Gärtner and Sauerland's (2007) equation *Interfaces + Recursion = Language*. Further, Zhang et al.'s findings support a model of traveling waves as a network of *weakly coupled oscillators* (WCO), according to which the traveling wave is a result of phase coupling. According to the WCO model, oscillators are arranged in a linear array and are weakly coupled with their neighbors. The model also assumes that there is a spatial gradient in intrinsic frequency across the oscillators. Since the traveling wave is assumed to be the result of phase coupling, these assumptions conspire to yield the prediction – fulfilled by Zhang et al.'s (2017) data – that faster waves would travel in the direction of slower waves. The language model assumed here (see also Murphy, 2015) complements these findings, since Zhang et al. found that waves typically travelled in a posterior-to-anterior direction. It is assumed here that elementary syntactic combinatorics involves a parahippocampal and cortico-basal ganglia-thalamo-cortical loop (concatenation and semantic conjunction) which is later coupled with left inferior frontal regions such as BA 44 and BA 45 which act as crucial memory buffers for the maintenance of hierarchically organized syntactic objects.

Both this model and the WCO traveling wave model predict posterior-to-anterior directionality as the language system proceeds from se-

lecting linguistic features (parahippocampal, thalamic and basal ganglia regions), to combining them (anterior temporal regions), to attributing to them a labelled identity (cortico-basal ganglia-thalamo-cortical loop), and finally to storing them in working memory (left inferior frontal regions, in particular pars opercularis). This directionality also notably correlates with the rhythms hypothesized to be responsible for these operations, with faster γ and β rhythms in posterior and central regions being coupled with slower central θ and α rhythms, which in turn travel towards slow left inferior frontal δ regions they are coupled with. While faster γ and β rhythms have currently not been shown to migrate, we can assume that this reinforces the neuroanatomically fixed nature of conceptual representations as being stored in typically resilient neural clusters (= *representations*), which can nevertheless be coupled to slower, traveling rhythms (= *computations*).

More pertinently, Zhang et al. (2017, p. 13) conclude that “[w]hen phase coupling is absent, there are no traveling waves because intrinsic oscillation frequencies differ between electrodes”. This suggests a strong degree of co-dependence between the phenomenon of cross-frequency coupling and traveling waves. If certain findings reviewed in Murphy (2016c) are accurate – in particular, the finding of human-specific phase coupling diversity, hypothesized here to have occurred due to cranial reshaping – then the language system likely evolved as a direct outcome of a broader range of oscillatory migration routes which resulted from new inter-regional phase couplings. One of language’s hallmark characteristics of breaking modular boundaries and combining representations from distinct domains to be stored cyclically in an expanded memory buffer (or phonological loop; Aboitiz, 2017), would arise immediately from this – as would the language system’s ability to interface with conceptual and articulatory apparatuses. Though I have explored elsewhere how the core oscillatory architecture of δ - θ - γ interactions can generate phrase structure building (e.g., Murphy, 2016c), the work of deriving the mechanism of syntactic combinatorics was previously left simply to phase-amplitude coupling. We can now add to this basic mechanism the understanding that language-relevant representations can be accessed cross-cortically through a process of posterior-to-anterior wave propagation.

Concerning the topic of what type of grammatical representations are manipulated by the brain, Greenhill et al. (2017) used a *Dirichlet process mixture model* (a probability distribution whose range is itself a set of probability distributions) to explore the rates of change in lexical and grammatical data from 81 Austronesian languages, showing that while many features change rapidly there exists “a core of grammatical and lexical features that are highly stable” (2017, p. e8822), and hence are strong candidates for being central components in the dynamics of language evolution. These stable features include inclusive vs. exclusive distinctions, gender distinctions, the existence of tense auxiliaries, prepositions, clause chaining and the presence of animacy features on the noun/class gender system (see Dataset S2 in Greenhill et al., 2017). Recent work has revealed that different cortical regions appear responsible for storing distinct representational formats, with γ rhythms in the ventrolateral prefrontal cortex signaling low-level, stimulus-based category abstraction (e.g., dog) and β rhythms in the dorsolateral prefrontal cortex signaling high-level, rule-based category abstraction (e.g., animal, Wutz et al., 2018). A slight reorganization in the shape of the prefrontal cortex (of the kind discussed in Neubauer et al., 2018) may have permitted the brains of anatomically modern humans to generate oscillatory migrations and phrase synchronizations such that these two major ontological representational bases could interact more efficiently, potentially allowing the generation of a greater number and broader range of low-level categories to be stored within a given high-level node.

Since the poster-to-anterior propagations documented in the literature are involved in *feedforward processes*, it is possible that instances of anterior-to-posterior migration (a phenomenon documented in Zhang et al., 2017, and which was extremely rare compared to the reverse migration pattern) have a distinct functional role such as supporting feedback or top-down processes. It would be of interest to explore in future work whether δ waves propagate in an anterior-to-posterior direction at particular points of syntactic processing, perhaps accessing distinct loops of a memory buffer stretching from pars opercularis to posterior regions of Broca’s area as the number of syntactic labels/nodes increases. Moreover, these findings should encourage neurolinguists to reconsider some core assumptions considering event-related potentials, which might (under the present framework) result from traveling waves transiently

organizing at a given timepoint and phase (see also Murphy, 2015, for connections between oscillations and event-related potentials).

If δ rhythms are shown to migrate during phrase-structure building, it would be possible to attribute particular computational roles to these oscillations in the way Muller et al. (2018) have done for spatial navigation. For instance, traveling δ waves could be responsible for patterning spiking from single- to multi-unit lexical structures in each δ cycle.

In my view, these observations speak against the idea that linguistic computation is based on *regional stasis* (e.g., the claim in Friederici et al., 2017, that BA 44 and its temporal dorsal pathway constitutes the basis of natural language syntax) and is rather implemented via a cortical circuit even more dynamic than previously assumed (for perspective: Zhang et al., 2015, discovered for the first time traveling θ waves, but only throughout the human hippocampus; see also Patten et al., 2012). Indeed, Muller et al. (2018, p. 12) note that “the existence of stimulus-evoked traveling waves in the sensory cortex presents a challenge to the orderly topographic arrangement of selectivity first described by Hubel and Wiesel at the trial-averaged level”. Likewise, the existence of weakly coupled traveling oscillators presents quite a dramatic challenge to the language sciences, and it has been my intention here to sketch out possible directions for reconciling the cortical language circuit with these emerging discoveries and principles.

Current neurolinguistic work on brain oscillations provides simple associative oscillation-computation models mapped to strict brain regions, as when Meyer (2017) claims that β is strictly involved in prediction, or when Ding et al. (2016) propose that δ entrainment to phrasal and sentential structures is a core feature of language comprehension, or when Bastiaansen and Hagoort (2015) claim that γ is involved in semantic unification and β is involved in processing syntactically coherent structures. All of these studies doubtless shed some light on the dynamics of the cortical language circuit, but they should be understood to be only a partial take, with the existence of traveling oscillations potentially forcing a more elaborate set of models to emerge.

It may not simply be oscillations, then, but more specifically traveling oscillations that could provide the optimal way to bridge neuroanatomy and brain dynamics, fulfilling the goal articulated succinctly in Friederici et al. (2017, p. 719) of “finding the explanatory link between the neuro-

anatomical data, the electrophysiological data, and the formal properties of human syntax”. As Zhang et al. (2017, p. 15) conclude, “individual traveling-wave cycles represent spatially discrete pulses of neural activity that correspond to distinct behavioral states”. The future task for the language sciences is to investigate how traveling waves might serve as a general mechanism for transmitting discrete pockets of neural activity in ways which map onto the functions of semantic, phonological and syntactic combinatorics. Muller et al. (2018, p. 1) document “the generality of their role in cortical processing” but their role in language processing remains unknown. Indeed, in their original discovery of traveling waves, Patten et al. (2012, p. 7) speculate that “the thalamus may exert an important influence on cortico-cortical propagation via thalamocortical re-entrant loops”, and since traveling waves appear to propagate along corticocortical fibers the role of the thalamus may be crucial (see Murphy, 2015, for the role of the thalamus in language).

3 **RETHINKING LANGUAGE DISORDERS, FLUID INTELLIGENCE AND LANGUAGE ACQUISITION**

Traveling oscillations may also be able to account for certain *language disorders* and *aphasias*, since in the literature there are often cases documenting damage to brain areas not typically seen as *language areas* (see also Luef in this volume) and yet which negatively impact language processing (Papathanasiou et al., 2012). It is possible that the migration of oscillations is disturbed by lesions and other forms of brain damage, which may serve to *block* them. Likewise, there are an even greater number of documented cases regarding the survival of key language skills after a supposedly core language region is damaged (see Ardila et al., 2016). Under the present perspective, this could simply imply that only part of the migration route was taken, impairing some representations from being accessed but nevertheless leaving much intact, or indeed that only part of the migration route was damaged. It is well known, for instance, that *Broca’s aphasia* can be caused by damage to a number of areas outside Broca’s area, such as the superior longitudinal fasciculus (see papers collected in Bastiaanse & Thompson, 2012). Lesions to the precentral gyrus,

anterior insula, and even the basal ganglia and anterior temporal lobe have been implicated in Broca's aphasia (Abutalebi & Cappa, 2008). Crucially, notice that these structures lie along the broader language circuit implicated in the model in Murphy (2016a-c), suggesting that damage to different stations of the path taken by language-relevant traveling oscillations (mediated necessarily by connecting neural streams) can result in aphasias just as severe as those resulting from damage from more classically *core* language regions. Disruption of the anterior head of the caudate and putamen results in verbal aphasias (Lieberman, 2000), which may be due not simply to damage to white matter fibers projecting from the cortex to the striatum (*à la* Nadeau & Crosson, 1997) but more specifically because oscillations responsible for constructing necessary speech signals are blocked from traveling across the full network responsible for vocal production, extending far beyond the thalamus (it should be noted that transmission speed in cortical gray matter is estimated to be approximately 1000 times slower compared to white matter, pointing us towards likely sources of linguistic computational efficiency; Kurth et al., 2017). A similar explanation might account for the various verbal communication deficits resulting from lesions to the globus pallidus (Strub, 1989). A possible way to provide some criteria of falsification for these hypotheses would be to conduct magneto-encephalographic (MEG) or electro-encephalographic (EEG) scans of participants with various aphasias alongside neurotypicals during basic semantic and syntactic processing tasks, determining whether particular oscillations migrate as a function of a linguistic manipulation and whether they do so in ways which significantly differ between these groups.

Turning briefly to another area where traveling oscillations may provide novel insights, Gağol et al. (2018) discovered that *fluid intelligence* level (*gf*), or the ability to solve novel problems via abstract reasoning regardless of prior knowledge, depends on the precise synchronization of fast rhythms to the phase of slow rhythms. In particular, $\{\delta(\gamma)\}$ phase-amplitude coupling was found to be indicative of *gf* (more precisely, low γ at $\sim 36\text{Hz}$ and δ at $\sim 3\text{Hz}$), suggesting under the model in Murphy (2016a-c) that δ coordinates the extraction of various cortical representations (Chacko et al., 2018, also showed $\{\delta(\gamma)\}$ phase-amplitude coupling to be crucial for spatial attention). No *intervening* rhythms are involved in this form of phase-amplitude coupling, unlike in linguistic computa-

tion, which involves hierarchical structures and hence coupling between δ , θ , β and γ of differing combinations. Buzsáki et al. (2013) discuss that the propagation of low frequency oscillations across the cortex is considerably faster in the human brain than in the smaller rat brain, likely explaining the origins of *gf*. Mechanical morphogenesis – or “the process through which simple mechanical forces can lead to instabilities that [contribute] to the emergence of complex shapes” (Foubet et al., 2018, p. 3) – may also play a role in the development of complex neocortical organization.

Further, the close rhythmic similarities between the oscillatory basis of fluid intelligence and language processing support the notion that the computational basis of memory and certain language processes – *Load*, *Maintain*, *Spell-Out*, *Concatenate* and so forth – is shared (with the exception of labeling and cyclicity). Billeke et al. (2017) provide related evidence from EEG that the coupling of the amplitude of slow γ ripples (90–110Hz) to the phase of cortical δ differs as a function of cognitive task, ranging from memory recall to directed attention; supporting the role of δ - γ interactions in fluid intelligence. Meyer and Gumbert (2018) also performed an auditory EEG study utilizing uniformly distributed morphosyntactic violations across natural sentences, with their results providing evidence that the synchronization of electro-physiological responses at δ to speech implicitly aligns neural excitability with syntactic information.

Duncan (2013) discusses his frontoparietal *Multiple Demand System* and regards it as the basis of fluid intelligence, with this system more broadly implicating subcortical structures like the thalamus and basal ganglia. It seems to follow from this model and the findings in Gağol et al. (2018) that $\{\delta(\gamma)\}$ coupling ranges over this frontoparietal circuit, with the general processes of fluid intelligence possibly being enhanced by elementary forms of linguistic computation involving *Search* and *Concatenate* processes. While general forms of intelligence are coordinated by $\{\delta(\gamma)\}$ coupling, more complex, hierarchical syntax arrives only through a broader range of cross-frequency couplings. This likely explains why fluid intelligence is also at risk of impairment in the event of brain lesions, with either the paths of the traveling δ waves across the frontoparietal Multiple Demand circuit either being limited, or the cortical γ clusters they are typically coupled with being unable to synchronize.

Flanagan and Goswami (2018) also present evidence that changes in the magnitude of the phase synchronization index (Δ PSI) of slow amplitude modulations in the δ - θ range accompanies both phoneme deletion and plural elicitation – basic morphophonological tasks – suggesting that sensitivity to slow rhythms in speech forms a major aspect of morphophonological knowledge.

Other recent research points us in different, potentially fruitful directions. Headley and Paré (2017) conducted a large-scale review of the oscillatory memory literature in humans. In order to account for differences in oscillatory activity in memory-relevant regions during sleep (i.e., some forms of memory are sensitive to slow-wave sleep, others to rapid eye movement sleep), they suggest that while θ rhythms seem responsible for consolidating procedural memories during sleep, the literature indicates that δ rhythms during slow-wave sleep additionally promote the consolidation of declarative memories. Given the presently proposed role of δ in phrasal – and, hence, sentential and propositional – construction and interpretation, it is possible that during sleep the language system is active in this declarative consolidation process (though likely not causally, rather recruited in the service of processing efficiency), what with the crucial role of language in the generation of facts and certain events (see Cross et al., 2018, for a related approach, and whose oscillatory architecture for language is almost identical to that in Murphy, 2016a,b). The potential role of linguistic computations in declarative consolidation is easy to square with the well-known interactions between the hippocampus and cortical δ rhythms (Hahn et al., 2006). It would be of interest for future research to examine cross-frequency coupling during declarative consolidation to examine any potential similarities with language processing.

Another potential avenue for oscillatory theories of language is to implement logical operators like NOT, AND, NAND, XOR, NOT and Neg-AND. For instance, the first could be rooted in phase asynchrony. Merging/synchronizing two oscillations might implement an AND operation, an increase in amplitude of a long-range wave relative to the stable signature of a local traveling wave might serve to represent a NOT function, the rapid de-synchronization or phase-resetting of multiple waves could execute a NOR computation, and the annihilation of two oscillations might implement a XOR logic gate. Empirically, these hypotheses would

be readily falsifiable given the use of an experimental paradigm which permitted a careful execution of these basic semantic operations, such as in a setting where participants were tasked with implementing these operations over a range of auditory, linguistic and visual objects.

Lastly, according to Wexler's (1998) *Unique Checking Constraint* (UCC), a child's linguistic system is limited to checking only one syntactic property per linguistic environment. For instance, in the clausal domain AGReement and Tense features cannot both be checked, and so only one is eliminated (producing the Optional Infinite stage of language acquisition). Since we are beginning to understand the oscillatory differences between child and adult language comprehension (Leong & Goswami, 2015), this constraint may be due to particular limitations on traveling θ oscillations across cortical areas responsible for coupling with γ pockets storing AGR-relevant and Tense-relevant features, with maturity likely providing the brain with a broader and more extensive traveling path. Recent work from Kurth et al. (2017) examined slow oscillations in sleep in a group of children ($n = 23$; 2–13 years) and showed that with increasing age, slow oscillations propagated across longer distances, with an average growth of 0.2 cm per year. The speed of the traveling waves remains unchanged across childhood, suggesting that the *interface* component of the equation in this chapter's title is subject to greater developmental changes than the core neural code for phrase structure building. Since this area of neurobiological research is a recent development, further studies of child language processing within these frameworks will be needed to elaborate on these hypotheses any further. The psycholinguistic possibilities of testing the morphology of traveling oscillations using MEG seem highly promising. An interesting question for future research concerns the relevance of traveling subcortical oscillations (e.g., parahippocampal migrations) and the morphology of traveling waves in nonhuman primates.

Dynamic studies of infant and child language processing will also be needed due to a current lack of understanding concerning the developmental characteristics of language-relevant brain rhythms. In one of the few studies exploring this topic, Schneider et al. (2016) revealed θ and β power decreases in adults at, respectively, left frontal and parietal regions and right parietal regions when participants processed ungrammatical sentences. These results were not replicated in children, despite simi-

lar abilities to detect ungrammatical constructions. The children instead displayed an N400 effect (a negative-going deflection peaking around 400 ms post-stimulus onset) at ungrammatical words while adults showed a greater P600 effect (a positive-going deflection peaking around 600 ms post-stimulus onset). Altogether, these results suggest that syntactic neurocomputational mechanisms go through various, dynamically marked developmental stages. Continuing this line of research, Leong et al. (2017) used EEG to show that infants not only entrain to the speech rhythm, but they appear better prepared for this than adults. Examining gaze directed speech in which an adult spoke to an infant, *partial directed coherence* (PDC) was computed for all pairwise connections at all EEG frequencies, with PDC being a directed measure of statistical causality (*how much does i predict j , independent of j 's history*). Leong et al. showed that phase coupling was weaker when the adult speaker shifted their gaze away during speech in θ , α and β (see also Schoch et al., 2017, who explore across-night dynamics of slow oscillations in children).

What is also needed is a more extensive investigation into the oscillatory activity of infants during complex thought, before they acquire language. Much of the language neural network is already in place (and left-lateralized) before birth (Dehaene-Lambertz, 2017), suggesting that exposure to speech is not necessary for the oscillatory basis of syntax to develop – intensifying further a central message presented here concerning the potential for a cluster of domain-general cellular and oscillatory codes to derive major components of linguistic computation.

A topic closely related to language development is the genetic basis of the oscillatory language system. This is currently an open field, but there at least seem to be clear directions available. One direction assumes that the oscillatory language system (called in previous work the *oscillome*; Murphy, 2016b) is largely genetically hard-wired. Murphy and Benítez-Burraco (2017b) provide a number of linking hypotheses between particular genes and oscillatory brain activity implicated in language, suggesting that much of the oscillome is likely genetically-directed; the set of genes implicated here is termed the *oscillogenome*. In contrast, another emerging direction is exemplified by Soloduchin and Shamir (2018). Weighing up whether the mechanisms responsible for generating and stabilizing oscillations are hard-wired or could be acquired via a learning process, they focus on the dynamics of spike timing depen-

dent plasticity and the effective coupling between two competing neuronal populations with reciprocal inhibitory connections, analyzing this via a phase-diagram of the model system that detects possible dynamic states of the network as a function of effective inhibitory couplings. They show that under a wide range of parameters, oscillatory activity can in fact emerge via an unsupervised learning process of spike timing dependent plasticity. It remains to be seen whether oscillatory activity does in fact emerge through such a learning process (since the fact that certain oscillatory features can do so does not necessitate the claim that all oscillatory features relevant to cognition emerge this way), or whether it is grounded in the genome.

4 CONCLUSION

In summary, linguistics can direct the brain sciences insofar as its insights into the universality of phrase structure building operations (or indeed rules of functional application in heuristic *Categorical Grammar*, or any number of other formulations of elementary combinatorics) inform the goals of neurobiology. The brain sciences can direct linguistics insofar as they place constraints on what possible operations neuronal assemblies and their oscillations can perform (see Badin et al., 2017, for an exploration of the notion of a neuronal assembly, which they see the defining feature of as being *one of dynamism*). While linguists should focus on making their claims about language biologically feasible, neuroscientists should conversely ensure they do not sideline the notion of computation, as stressed most forcefully by Gallistel and King (2009).

ACKNOWLEDGEMENTS

My thanks go to the editors for encouraging me to formulate the ideas presented here for this volume. This work was supported by an Economic and Social Research Council scholarship (1474910).

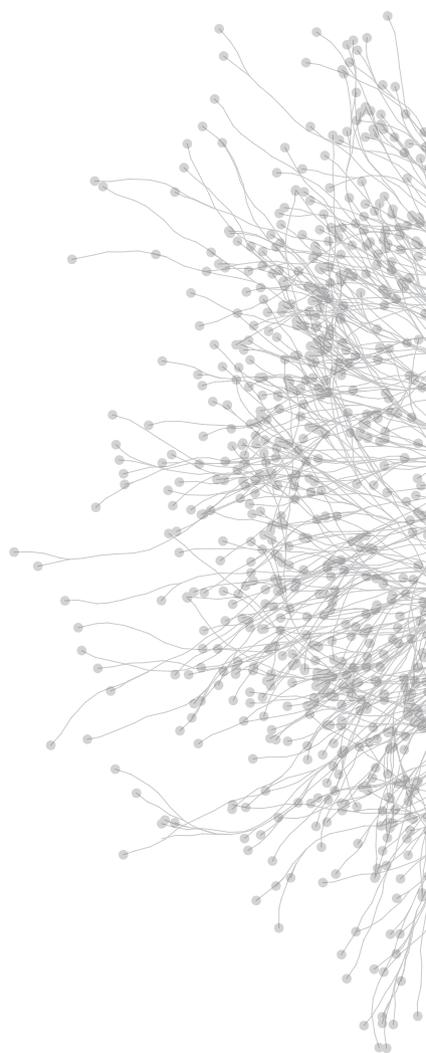
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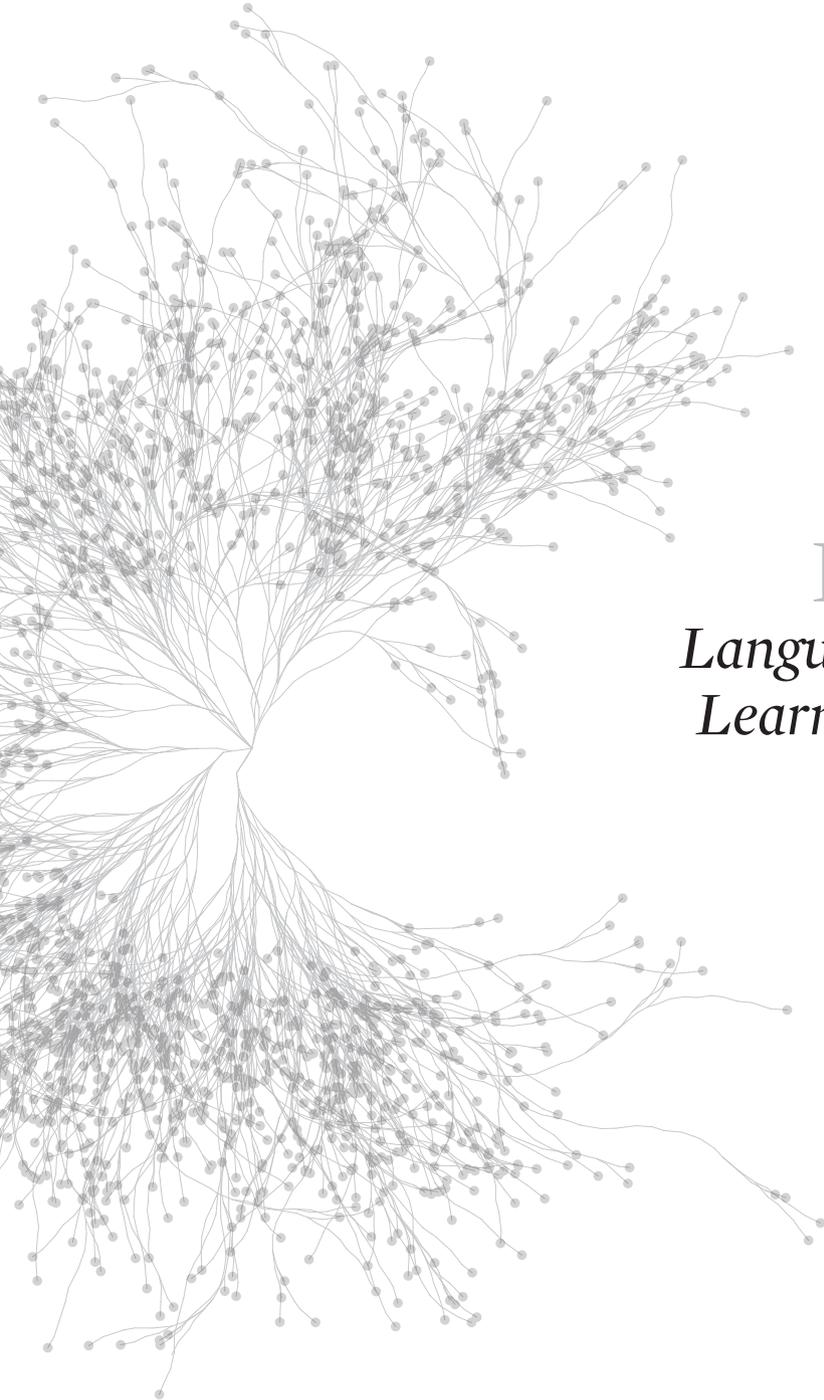
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III

Language Learning

Lessons learned from brain responses: The second language learning experience

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ABSTRACT Learning a second language (L2) is a complex process that undoubtedly involves the acquisition of a complex implicit linguistic system. Lexical entries, their features and forms, complex syntactical and phonological systems as well as rules on the pragmatic use of language have to be acquired. The acquisition process itself involves numerous sub-processes that interact at every stage of learning the second language. Learners develop sensitivity to regularities in the absence of verbalizable knowledge, which can be traced in brain responses. *Event-related potential* (ERP) responses like the P600, N400 and especially the *early left anterior negativity* (ELAN), which are produced within a few hundred milliseconds after syntactic and semantic violations, are most likely not the result of conscious thought processes. Thus, it seems that grammatical form-meaning connections, grammatical categories, chunking and statistical learning in orthography, phonology and syntax are learned implicitly. When acquiring a second language, we form recognition patterns, e.g., for the speech sounds and the grammar specific to the newly acquired language. Research has found evidence for native-like brain responses after very little exposure in classroom settings. It is still controversial which role language analytical ability (the specific ability for learning languages) plays in this process, which is often named as one of the components of language aptitude. Moreover, we still do not know how implicit linguistic systems are ac-

quired. In the following, I will take a closer look at brain responses during language processing and factors associated with second language acquisition, such as perceptibility, prosody-syntax integration, letter-sound integration and pragmatic communication ability. By shedding light on some recent developments in second language acquisition research, I will make an attempt to connect brain research to language learning and teaching.

KEYWORDS brain responses, event-related potentials, language learning, second language acquisition, theory of mind

1 LANGUAGE APTITUDE AND COGNITIVE PROCESSING

In light of modern theories on second language acquisition, which view the process of second language learning as one driven by cognitive processes also involved in other mental activities, language aptitude is seen as a complex construct that comprises cognitive and perceptual abilities that predispose individuals to learn well or rapidly (see, e.g., Doughty et al., 2010). The existence of potential connections between individual differences in language aptitude and cognitive style are usually taken into consideration as well (see also Dörnyei & Skehan, 2003). Studies investigating individual differences in cognitive abilities in relation to brain function tend to focus on the neural efficiency hypothesis. Their main aim is to explain the mechanisms underlying high cognitive skills (see, e.g., Nussbaumer, Grabner, & Stern, 2015; Prat & Just, 2011). In these studies, cognitive ability tests are used to measure mental processes in laboratory experiments, using reaction times, error rates and other indicants.

Recent research distinguishes between cognitive aptitudes for implicit and explicit learning (see, e.g., Linck et al., 2013; Morgan-Short, Steinbauer, Sanz, & Ullman, 2012). Implicit memory and implicit inductive learning ability are attributed to aptitude for implicit learning, which is characterized by the absence of conscious intention to learn and conscious attribution of any noticed change to the effects of learning. Explicit induction and rote learning are typically attributed to explicit learning aptitude. These attributions are in line with dual-process

theories of cognition that claim that individuals operate using two separate systems: a conscious, analytical, rule-governed and slower system, which is explicit, and a nonconscious, holistic, associative and faster system that is implicit (see, e.g., Epstein, 2008; Witteman, van den Bercken, Claes, & Godoy, 2009).

The two main information-processing styles proposed by dual-process theories in cognitive psychology, namely the *rational-analytical* and *experiential-intuitive cognitive style* (see Pacini & Epstein, 1999), can be related to implicit and explicit cognitive abilities. Recent research suggests that there seems to be a relationship between rational-analytical profiles and explicit aptitude, as well as between experiential-intuitive profiles and implicit aptitude (Granena, 2016). These results can be interpreted as support for the existence of qualitatively different types of cognitive processes that underlie rational-analytical and experiential-intuitive cognitive styles. Second language learners preferring an experiential-intuitive cognitive style tend to rely on intuition and holistic thinking as an approach to information processing, whereas second language learners showing a rational-analytical style have a tendency to rely on logic and analysis as an approach to information processing. In several studies, preference for an analytical cognitive style correlated positively with scores on psychometric intelligence, explicit associative learning and working memory (Kaufman et al., 2010; Pretz, Totz, & Kaufman, 2010). Studies by Woolhouse and Bayne (2000) show that subjects with a more intuitive style learn covariations in an implicit learning task more accurately.

Kepinskaa, de Roverb, Caspersa and Schillera (2017) investigated whether the neural basis of *Artificial Grammar Learning* (AGL) differs between highly and moderately skilled learners. The results of their study suggest that highly skilled learners performed better in proficiency tests than moderately skilled learners and engaged more neural resources in the right hemisphere, especially in the right angular/supramarginal gyrus, the superior frontal and middle frontal gyrus and the posterior cingulate gyrus. SLA (*second language acquisition*) research has found that learning proficiency correlates with the training-induced increases in the strength of the structural connectivity between the right inferior frontal gyrus and caudate (Hosoda, Tanaka, Nariai, Honda, & Hanakawa, 2013).

Undoubtedly, working memory and short-term memory play a crucial role in second language acquisition as well as in the processing of linguistic input. Working memory represents a control system with limits on both its storage and processing capabilities and has access to phonemically coded information. Many linguists assume that it is controlled by a rehearsal buffer which is responsible for the limited memory span and allows for the manipulation of stored information (see Mandler, 2013). Working memory enables us to navigate complex cognitive tasks such as comprehension, learning and reasoning and is involved in the development of *wh-questions* in English (see Wright, 2010). Cognitive processes involved in performing these tasks include the executive and attention control of short-term memory, which permit the interim integration, processing, disposal and retrieval of information. It is well-known that short-term memory has very limited capacity, which means that language learners can keep only a certain amount of information in their short-term memory before it disappears again, so that new information can be stored (see Juffs & Harrington, 2011; Martin & Nick, 2012; Paradis, 2004; VanPatten, 2002).

2 **EVENT-RELATED POTENTIALS: DISCOVERY OF DISSOCIABLE LEARNING ABILITIES IN ADULTS**

As we have seen in section 1, individual differences in language aptitude have been researched extensively and associated with success in second language learning. However, little research has explored how native-language processing affects second language acquisition success. This is made possible by measurements of brain responses that can help shed light on how first and second languages are neurally processed and what crucial differences exist between them from a cognitive perspective. In the following section, I will review relevant studies that address different types of brain responses to the learning of vocabulary, syntax, non-native sound contrasts and prosody. The aim of this chapter is to highlight how language proficiency impacts language cognition and what lessons can be learned for second-language teaching.

2.1 **Neuroimaging: Measuring brain responses**

Various types of neuroimaging techniques are commonly used in the psychological sciences, which can measure different indirect neuronal response types from which conclusions can be drawn as to the cerebral involvement of specific cognitive tasks, such as speech processing. Electro-physiological methods, which are able to directly measure the electric activity of nerve cells, focus on temporal aspects of brain processes and involve electrodes which are applied to the head *electro-encephalography* (EEG, see Swaab, Ledoux, Camblin, & Boudewyn, 2012). Positive (P) and negative (N) voltage deflections are measured in reaction to external or internal events (*event-related potentials*, ERPs) of which some are of particular relevance for neurolinguistics (for instance P600 or N400, see Qui et al., 2017). Magneto-encephalography (MEG), on the other hand, exploits magnetic fields that are generated by neural activity. By contrast, hemodynamic neuroimaging methods, such as fMRI (*functional magnetic resonance imaging*), detect changes in cerebral blood flow and thus allow inferences regarding the location of brain activity (Small & Burton, 2002). The introduction of a novel stimulus in a homogenous sequence of stimuli (e.g., a voiced plosive appears in a series of unvoiced plosives), leads to *Mismatch Fields* (MMF), an abrupt change in cognitive engagement which indicates that participants neurologically distinguish between new and old stimuli (Pulvermüller & Shtyrov, 2006). Taken together, neuroimaging methods are valuable tools to study how the human brain processes first and second language(s).

2.2 **Vocabulary and syntax**

Research in L2 (second language) acquisition of morphosyntax is primarily concerned with mental linguistic representations. *Acquisitionists* and cognitive linguists are interested in whether mental representations are similar in L1 and L2 ultimate realization or whether they are maturationally conditioned to be different (see Tsimpli & Dimitrakopoulou, 2007; White, 2003). Research results indicate that the ability to learn syntax and vocabulary are dissociable and thus not strictly linked. A recent study by Qi et al. (2017) demonstrates how native language and second language abilities are intertwined concerning morphosyntactical

structures. In fact, ERP measurements from native language processing can be used to make predictions about a person's success in learning an artificial language. Qui and colleagues first recorded N400 and P600 values while native speakers of English were judging the acceptability of English sentences, followed by recording them when they were learning an artificial language. Results showed a double dissociation between native-like ERP responses and their relationship to the learning of the novel, artificial syntax and vocabulary. Generally, the N400 effect is related to lexical/semantic processing (see Hagoort, Brown, & Osterhout, 1999; Kutas & Federmeier, 2011), and participants who exhibited a greater N400 effect when processing English sentences were overall more successful in learning the artificial language. The P600 effect only predicted future success in morphosyntactic but not in vocabulary learning. Qi et al.'s results suggest that neural predispositions related to native language processing can help with learning another (in this case artificial) language.

L2 research has always been interested in how speakers acquire and regulate more than one language in both production and comprehension (see Abutalebi & Green, 2007; Prior & MacWhinney, 2010; Rothman, 2015). Some components appear to be specifically related to syntactic processing in contrast to lexical-semantic processing. As noted above, syntactic violations consistently elicit P600 effects which are assumed to reflect syntactic integration (see Kaan, 2007). However, with increased proficiency, responses to morphosyntactic violations appear to become more native-like. We also find studies that observed hemispheric changes (from right to left) with increased L2 proficiency (Xiang et al., 2015). Thus, increased proficiency in a language leads to neural re-organization of linguistic processing which subsequently becomes reflected in brain activity in response to linguistic cognition.

2.3 Neural evidence for perceptibility and prosody-syntax integration

Learning a second language involves the establishment of mappings between familiar speech sounds and new phoneme categories. The phonological relatedness of the language that is learned compared to the learners' native language influences the perceived similarity but may also cause problems. For instance, language learners may face difficulties

when allophones in the native language represent phonemes in a second language, such as /d/ and /ð/ which are allophones in Spanish but different phonemes in English (see Barrios, Namyst, Lau, Feldman, & Idsardi, 2016). Learners have to overcome native language mappings in order to form new phonological relations between familiar phones. Barrios et al.'s results suggest that even for late learners, phonological relatedness may not cause persistent difficulties, at least in advanced learners. It seems as if L2 learners are able to make use of cues in the input they get to establish new mappings between familiar phones. Barrios et al. provide MEG evidence from two experiments they conducted, during which they measured sensitivity and pre-attentive processing of three listener groups (L1 English, L1 Spanish and advanced Spanish late learners of English). Spanish and English natives developed greater sensitivity for non-word pairs distinguished by phonemic contrasts than for pairs showing allophonic contrasts. However, Spanish late learners of English developed sensitivity to all contrasts, meaning they succeeded in establishing new mappings, which can be considered a very positive second language learning effect.

Ideally, second language learners should be able to develop automatic speech processing of phonetic contrasts. Unfortunately, classroom experience does not lead to linear improvements in phonetic discrimination and thus, learning a second language should be accompanied by targeted phonetic training in the L2. A useful tool for phonological practice can be mismatch fields, which are created by presenting a deviant stimulus within a series of homogenous stimuli. MMF data are used to prove automatic processing of sensory-derived information. Whenever the derivation is processed in a similar way irrespective of the physical parameters of the stimulus per se, researchers assume that automatic processing is going on. Hisagi et al. (2016) investigated second language learning effects and focused on second language vowel duration contrasts in English learners of Japanese. MMF findings suggest that targeted training of L2 phonology is necessary to allow for changes in the processing of L2 speech contrasts to happen at an automatic level.

The role of prosodic information in sentence processing is an aspect that is very often neglected in L2 instruction (however see, e.g., Anderson-Hsieh, Johnson, & Koehler, 1992; Trofimovich & Baker, 2006). Neurocognitive studies in that area are rare as well. In one of the few studies

that have been conducted, Hed (2016) tested the perception and production of the Swedish word accent-grammar association in L2 learners of Swedish using EEG. Based on findings from previous research, she started from the assumption that L1 speakers of Swedish use Swedish word accents to make predictions about linguistic segments that appear in sequential order within a word, for instance affixes. In her study, L2 learners of Swedish received special training in order to practice this accent-suffix association. In a perception test, valid and invalid accent-suffix combinations had to be discriminated and subsequently, participants were trained to use accent as suffix predictors more extensively. However, the participants did not re-process ungrammaticality and tended to rely mainly on the suffix itself. Unlike L1 speakers, the L2 learners did not yield longer response times when confronted with ungrammaticality in the post-test. Here, no P600 effect was found.

Similarly, Nickels and Steinhauer (2016) investigated prosody-syntax integration contrasting ERP data from German and Chinese learners of English. They found that L1 background and L2 proficiency influence the processing of prosody-induced *garden path effects* which are created by grammatically correct sentences that start in such a way that readers' most likely interpretation will be incorrect because they are lured into a parse that yields a clearly unintended meaning. Using such sentences, Nickels and Steinhauer provide interesting data on complex interactions between L1 background, prosodic structure and morphosyntactic processes. An important lesson from these studies is that prosody should be a focus in L2 instruction.

2.4 **Brain responses to letter-sound integration in second language reading**

Successful reading in alphabetic languages requires the correct integration of letters and sounds, and evidence from ERP studies shows that native language background has an important influence on brain responses to letter-sound integration. Yang Z. et al. (2016) found that Chinese learners of ESL (*English as a second language*), whose mother tongue has a morphosyllabic system in which each character corresponds to one syllable, have great difficulties in integrating letters and sounds in the alphabetic language English during early stages of reading. Chinese ESL

learners' ERP responses were shown to be different from those of native speakers and from those of native Korean ESL learners who acted as their control groups (Korean also uses a phonological spelling system): native Chinese speakers performed slower compared to the native Korean ESL learners. Yang Z. et al.'s findings provide a significant contribution to SLA reading research as they help to understand brain mechanisms involved in second language reading. From this, implications for the teaching of reading to speakers of non-alphabetic languages can be gathered.

Most researchers agree that reading in a foreign language is an interactive process in which L2 readers bring a unique set of past experiences, emotional and mental processes, and individual levels of cognitive development to the reading process (see, e.g., Britt, 2013; Kennedy, 2000; Koda, 2005; Snowling, 2010). Readers also apply reading strategies from their L1. Naturally, reading in a second language involves accessing the meaning of words in the new target language. In agreement with the *Revised Hierarchical Model* by Kroll and Stewart (1994), L2 learners first access the meaning of L2 words via L1 while advanced learners access meaning directly. Ma, Chen, Guo and Kroll (2017) tested this hypothesis in an ERP study with English learners of Spanish. They used a translation recognition task, in which participants were asked to judge whether English words were the correct translations of Spanish words. The researchers measured the performance of learners in a task where they had to reject distractors that were related to the translations in form or meaning when a long (750 ms) or short (300 ms) SOA (*Stimulus-Onset Asynchrony*) separated the two words. Their findings show that late learners also access the meaning of second-language words directly in comprehension, thus seemingly contradicting the Revised Hierarchical Model. When time was limited, learners showed semantic access without translation mediation. Furthermore, the study provides evidence for the fact that the meaning of an L2 word is accessed prior to the L1 translation equivalent.

Contrary to the findings of the studies mentioned above, Yang, Wang, Bailer, Cherkassky and Just (2016) claim that there is commonality in neural representations of sentences across languages. They were able to predict brain activation during Portuguese sentence comprehension using an English-based model of brain function. Their computational

models are capable of predicting *Neurally Plausible Semantic Features* (NPSFs), thematic role markers to neural activation patterns (assessed with fMRI), and activation levels in a network of brain locations. The English-based model predicted fMRI patterns for Portuguese sentences in both monolinguals and bilinguals. In addition to that, the sentences from two languages were decodable from the same set of 38 brain locations.

3 THE SOCIAL BRAIN: PRAGMATIC COMMUNICATION ABILITY AND THEORY OF MIND

In order to become proficient users of an L2, learners have to acquire the ability to use language in context. The development of some form of pragmatic communication ability goes beyond the understanding and expressing of basic word meanings and the production of grammatically correct forms. In order to become pragmatically competent speakers, learners have to be able to understand other speakers' intentions, interpret speakers' feelings and attitudes, differentiate speech act meaning, evaluate the intensity of a speaker's meaning, recognize sarcasm and joking, and be able to respond appropriately. It is quite common that pragmatic communication deficits occur at the initial stages of SLA when learners are not familiar with appropriate registers or are lacking intercultural experience.

To date, research has not yet succeeded in establishing a widely accepted standard framework for the assessment of pragmatic competence, social adjustment, social functioning and social cognition (see, e.g., Ebbstein, 2011; Fiske, 2010; Striano, 2009). Since this assessment depends on interpretative attitudes and embeddedness in cultural practices, this will continue to present a major challenge in the future. Proponents of Grice's (1957) position claim that any kind of pragmatic processing is about inferring the intentions that underlie the speaker's utterance. According to this view, pragmatic processing is associated with the derivation of both primary and secondary meanings and can be seen as a cognitive capacity that is inherently rooted within *Theory of Mind*, that is, the capacity to attribute and reason about mental states (see Premack & Woodruff, 1978). Many researchers such as Kissine (2015) criticize the alleged modularity

of pragmatic processing inherent in Grice's model and view pragmatics as being dependent on language-independent contextual factors that can, but need not, involve Theory of Mind. They see pragmatics as a language-specific metacognitive process that may unfold at an unconscious level without involving any kind of meta-representation. In support of this idea, Kissine (2015) refers to data showing that, from a very young age, children can make use of contextual cues to interpret and produce communicative behavior, even though they have not mastered a full understanding of all layers of Theory of Mind.

According to Sperber and Wilson (2002), pragmatic processing is underpinned by a specific cognitive module which is responsible for the interpretation of communicative behavior. This cognitive module is grounded within a more general Theory of Mind and has an independent developmental trajectory. Wellman, Cross and Watson (2001) proved that verbally demanding versions of first-order Theory of Mind tasks (e.g., false-belief tasks involving other people's false beliefs) prove difficult for typically-developing children below the age of four. There is consensus among researchers that children are not capable of attributing second-order mental states (e.g., understanding that a belief about another person's belief can be false) until the age of seven (see Leekam & Prior, 1994).

Pragmatic communication deficits have been documented in patients suffering from schizophrenia. Schnell et al. (2016) investigated irony comprehension and the underlying brain activity in patients with schizophrenia. Using fMRI techniques, they succeeded in revealing the brain networks involved in social cognition and non-compositional processing, which refers to the processing of meaning that cannot be inferred from the meanings of the individual words. They were able to identify an area with an integrative role, which is responsible for pragmatic meaning construction, and their results are in line with the idea of a hypothesized meta-module of pragmatic comprehension.

Pragmatic processing is guided by a scale of interpretative strategies that require different developmental stages of Theory of Mind. As outlined by Kissine (2013), *egocentric relevance* does not require any Theory of Mind since it is entirely based on egocentric considerations of accessibility, and the child is not able to understand other people's points of view; *allocentric relevance* requires at least implicit first-order Theory

of Mind, as it is based on an understanding of other people's perspectives. It is similar to egocentric relevance, but it rules out contents that are incompatible with the speaker's perspective. Essentially, the *Gricean, sophisticated interpretation* becomes available only when second-order Theory of Mind is operational.

Explicit pragmatic instruction to facilitate the development of pragmatic competence should find its way into the SLA classroom. Foreign language learners need to develop new representations of pragma-linguistic and socio-pragmatic knowledge and can be instructed on the strategies and linguistic forms by which specific pragmatic features are performed and used in different contexts (see Bardovi-Harlig, 2013). This can be done, for instance, in online learning environments where Hong et al. (2017) investigated the effect of online gaming on brain connectivity. Their results revealed that after twelve weeks of online English education, the children showed improved connectivity between Broca's area and the left frontal cortex as well as between Wernicke's area and the left parahippocampal gyrus and the right medial frontal gyrus. In addition to that, changes in the pragmatic scores correlated positively with the average peak brain activity in the left parahippocampal gyrus.

4 **CONNECTING BRAIN RESEARCH TO LANGUAGE LEARNING AND TEACHING**

This final section aims at critically assessing the current state of neuro-linguistic data on language acquisition and processing and will discuss how they might inform us with respect to developing appropriate teaching methods for the ESL classroom. Research in the area of neurolinguistics has developed dramatically over the past few years, providing us with a wealth of exciting and promising findings. In particular, the field of neuroplasticity research has produced data about the ability of the brain to structurally change in relation to input from the environment (Shaw & McEachern, 2012). The theory that the brain loses plasticity for language learning past a critical period during early childhood has been challenged, and today we know that the brain undergoes continuous change and is able to form new synapses well into adulthood (see also

Kong-Insam and Resnik in this volume). Brain structures can change in response to direct mental effort and thus language learning as a complex cognitive ability can be recommended, for example, in order to delay the onset of the Alzheimer's disease.

Our brain has to undergo cognitive adaptation processes in order to accommodate the L2. It recruits existing regions used for the L1 but can also make use of adjacent areas of the cortex. We know from neuroimaging studies that an actual structural shift takes place in the brain in response to acquiring an L2 as an adult (Mechelli et al., 2004). We can rely on declarative memory or explicit knowledge and thus SLA teachers should provide learners with strategies to tap into knowledge from their L1.

The importance of selective attention should be taken into account in ESL teaching as well since we know from brain response studies that when we pay attention to certain things, our neurons become active and strengthened, which ultimately results in an increase in our knowledge and awareness. Thus, output and input enhancement can be achieved by drawing learners' attention to what is missing in their developing systems (see Izumi, 2002). This might even motivate learners to become more active with their input processing (VanPatten, 2003). Possibilities for active interaction should be part of every language class because it has been proven that interaction promotes L2 acquisition.

Finally, it has long been known that learners need to be provided with ample opportunities to practice and repeat. From neurolinguistic findings it is known that practice is critical if newly acquired language should move from the short-term memory into the long-term memory. By performing language exercises, learners can strengthen relevant synapses and thereby improve their language skills. In receptive and productive exercises and activities, students should be exposed to routines and familiarized with conventionalized language forms to support them in the development of communicative competence in their L2 (see Rosas, 2018; Yorio, 1980). This can be achieved by activities focusing on fluency, providing respective feedback and by familiarizing students with turn-taking queues, pause fillers, set phrases and expressions that make them sound more natural to native speakers. Creating a motivating and relaxed classroom atmosphere will also help to increase their confidence and language proficiency (see Mercer, Gkonou, & Tatzl, 2016).

5 CONCLUSION

No doubt, our understanding of the developmental processes of language learning has increased enormously over the past two decades. Research has found neurolinguistic evidence for grammatical development, letter-sound integration, dissociate learning abilities and prosody-syntax integration, to name only those areas that have been addressed in this chapter. Although the nature of the mental realization of language learning processes has become more transparent, we are still a long way from fully understanding it. Much research still needs to be done in order to get a clearer picture of the factors relevant for language learning, which is a highly individual process involving a complex interweaving of psychological factors. Nevertheless, we should make use of opportunities for cross-fertilization across the disciplines of cognitive linguistics and second-language research. Ideally, we should envisage a symbiotic relationship for mutual benefit with the ultimate goal of creating linguistically and neuro-linguistically informed, evidence-based pedagogies for second language teaching.

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The effect of age in L2 ultimate attainment: Revisiting the evidence

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ABSTRACT Learning another language is challenging, and apparently even more so in adulthood. The assumption of a critical period for *second language acquisition* (SLA) based on brain maturational constraints has persisted for a very long time. This view has been challenged though, and proponents of critical periods or sensitive periods are these days most often in favor of a *plurality* thereof in the context of SLA. This means there are multiple periods rather than only one depending on the different skills (e.g., pronunciation and morphosyntax), and the ability to develop these is often assumed to be multiply determined. Drawing on previous research on the effect of age and the *nerve growth factor*, the view that “the sooner, the better” holds true in any case regarding the successful sequential attainment of another language (LX) will be challenged: neuronal plasticity is certainly ongoing at an advanced age, which means that the ability to learn another language does not end, and factors other than age might be more important regarding cortical representation. Furthermore, three premises for study designs on the age factor in SLA will be proposed, thereby stressing the need for a change of paradigm towards a holistic approach to LX users and the necessity to understand the process of LX attainment as a dynamic one. Finally, this chapter highlights the importance of emotions in (un)successful LX acquisition, which is linked to the need for a shift towards a focus on individual differences instead of universals when grappling with the complexity underlying *ultimate attainment* in an LX. All in all, it is suggested that the view on the *age of onset of acquisition* (AoA) influenc-

ing proficiency in a uniform manner might have been too simplistic as the processes underlying SLA are multifaceted and entangled.

KEYWORDS age of onset of acquisition, critical periods in SLA, individual differences, multi-competence, neuronal plasticity

1 **AGE-RELATED DIFFERENCES IN THE ATTAINMENT OF AN LX: AN INTRODUCTION**

In the context of SLA (*second language acquisition*), the relationship between *age of onset of acquisition* (AoA) and success in learning or acquiring another language has been of interest for a long time and links between the two cannot be denied (Muñoz & Singleton, 2011). However, researchers' opinions diverge regarding the nature of these links, and consequently, numerous theories with varying points of view have been developed, of which the most prominent will be dealt with and critically analyzed in this chapter.

In the past, the assumption of “the sooner, the better” regarding successful *LX attainment* (LX referring to any language acquired after one's first, see Dewaele, 2017) was mostly based on the notion that the brain of early birds differs substantially from those of late birds, making it easier for the former to catch the worm. Thus, early research on the age effect in SLA often explained differences in children's and adults' acquisition processes and attainable proficiency level in terms of biological and neurological differences, which supposedly prevent adults from attaining another language at similar levels as early acquirers. Even though there are “interesting parallels between young and older learners in the initial and intermediate stages” (Peltzer-Karpf, 2003, p. 389), children tend to outperform adults in the long run, whereas the latter tend to start off faster (Muñoz, 2006; Peltzer-Karpf, 2003). This is partly due to increased meta-linguistic awareness and advanced cognitive development in general. Despite both, adults and children, going through similar acquisition processes including comparable *interim solutions*, which means committing similar mistakes (see, e.g., Ortega, 2009; Peltzer-Karpf, 2003), the above-mentioned led to the common assumption that successful LX

attainment is a strictly age-bound event, and various approaches to *critical period hypotheses* (CPH) for SLA were proposed (see, e.g., Lenneberg, 1967; Long, 1990). The trigger for classic treatments of a CPH was Penfield's and Roberts' (1959) assumption of an early AoA being advantageous for successful LX attainment, which will be analyzed in more detail and critically examined in the following section.

In this chapter, I will propose that the view on the AoA influencing proficiency in a uniform manner might have been too simplistic and that the processes underlying SLA are much more complex than previously thought (see also Moyer, 2014), which could to some extent also explain the divergent research findings. In other words, a number of variables have an impact on the success in learning or acquiring another language, such as experience and type of input, amount of exposure and psychological factors, such as motivation. Even though previous research has shown that age is an influential variable in these processes (see also Kong-Insam in this volume), it is certainly not the only variable playing a role and not necessarily the most decisive (see also Muñoz & Singleton, 2011). Thus, the following is an attempt to review research on the age factor and underlying assumptions critically and, in doing so, evaluate if an earlier start is beneficial in any case.

2 **BIOLOGICAL AND NEUROLOGICAL APPROACHES TO A CRITICAL PERIOD FOR SLA**

For a long time, researchers have tried to understand the reasons underlying the ease and rapidity with which children acquire multiple languages. This “wonder at the child’s amazing ability to acquire language” (Cook, 1995, p. 52) compared to adults’ seemingly often having difficulty with it raised the question of whether it is at all possible to become a proficient user of an additional language when attaining it relatively late in life. “[S]tudies of the brain suggest that the timing of second language experience plays an important role” (Kuhl et al., 2016, p. 7) indeed, which led to a widely-known assumption in SLA research, namely that of a CPH.

The term *critical period* (CP) is commonly used in biology in connection with an organism's learning abilities. Thirty-five years ago, Colombo (1982, p. 261) defined it as "a time during the life span of an organism in which the organism may be affected by some exogenous influence to an extent beyond that observed at other times". This means that during a particular time in life (referred to as a critical period) an organism is most sensitive to stimuli relevant for developing a specific ability, such as attaining another language (see also Lenneberg, 1967). In case the respective stimuli are absent during the CP, the ability may either not develop fully or even not develop at all. Most importantly, sensitivity to respective stimuli will decline in a non-linear way after the critical period, a point referred to as *terminus*. Thus, all critical periods involved in the development of an organism share specific geometric features. With regard to a CP in SLA, showing the presence of an offset and flattening is crucial. Additionally, it has to be proven that the terminus itself marks the end of a correlation between age and the respective ability if there was a CPH for SLA (Van Boxtel, 2005). Bongaerts (2005) summarizes the main idea underlying all critical period hypotheses for SLA having been proposed so far. Following Birdsong (1999, 2004), researchers in favor of a CPH of some sort all claim that "age effects operate within a circumscribed period of time, bounded by an onset which marks the beginning and a terminus which marks the end of a period of heightened sensitivity to ambient language input" (Bongaerts, 2005, p. 259). Hence, those theories share the common assumption that in a certain period of life, a language may be acquired with ease whereas after the end of the so-called CP it is no longer possible to become equally proficient in all language skills.

As already mentioned, there is no agreement regarding this assumption, and the proposed offset points, especially, show great variation (Muñoz & Singleton, 2011). In 1959, the neuroscientists Penfield and Roberts suggested that a child is able to acquire multiple languages with ease until the age of nine and that children are, in general, more successful in learning an L2 (*second language*) than adults due to brain maturational constraints experienced in adulthood. Lenneberg (1967), following the two neuroscientists' ideas, also based his well-known CPH on biological factors. According to him, the critical period for SLA is marked by an AoA of two years and by the offset of the time by which brain lat-

eralization is completed. As soon as each of the two hemispheres have developed their specific functions, which coincides with puberty, an L2 cannot be attained as easily, successfully or efficiently anymore due to the rapid increase of “language-learning-blocks”, and foreign languages “have to be taught and learned through a conscious and laboured effort” (Lenneberg, 1967, p. 176). Thus, according to Lenneberg, the offset corresponds to puberty. Also, he stresses that exposure to a language is usually no longer purely naturalistic in these cases, and states furthermore that pronunciation seems to pose a major challenge to anyone starting to learn their L2 after the first decade (see also Kong-Insam in this volume).

Subsequently, Lenneberg’s (1967) assumptions were discredited and from then on, researchers have tried to test his hypothesis and have modified and developed it further based on their own findings. Long (1990), for instance, summarized research into these matters from Penfield and Roberts up until 1990 and concluded the following:

The ability to attain native-like phonological abilities in a SL begins to decline by age 6 in many individuals and to be beyond anyone beginning later than age 12, no matter how motivated they might be or how much opportunity they might have. Native-like morphology and syntax only seem to be possible for those beginning before age 15 (Long, 1990, p. 280, cited in Bongaerts, 2005, p. 259).

As can be derived from the citation above, Long (1990) differentiates between specific language skills and, therefore, different ages of offset are accredited to their attainment. Interestingly, it becomes clear that also from Long’s point of view, pronunciation seems to have a special status when learning another language and is probably the most difficult language skill to be acquired later in life.

These are only two of the many approaches to the topic that have been developed so far, and Singleton and Ryan (2004) are therefore certainly right when highlighting that it is important to avoid speaking of *the* CPH for SLA given the high number of different attempts to study this issue. Not only do these approaches vary concerning the age of offset, but there is also disagreement about the causes as well as the affected learning capacities (Bongaerts, 2005). Clearly, the view of a general “window of opportunity” (Kuhl, 2011, p. 33) of full LX glory has been

challenged and proponents of CPHs (for a summary, see, e.g., Cook & Singleton, 2014 and Singleton & Ryan, 2004) are these days most often in favor of a *plurality* thereof depending on the different skills (e.g., pronunciation and morphosyntax). Others prefer speaking of *sensitive periods* “whenever the effects of experience on the brain are unusually strong during a limited period in development” (Knudsen, 2004, p. 1412), which looks like a weaker, non-definite version of any proposed critical period (see, e.g., Kuhl, 2004).

What all these approaches have in common is the notion of biological predispositions and brain maturational changes being the key to age-related differences in *ultimate attainment* in L2 users. Consequently, most proponents of CPHs or sensitive periods argue that a decline in neuronal plasticity should be seen as the main argument for the existence of a time span in which human beings most effortlessly acquire an L2 (Bongaerts, 2005). The question of whether this assumption holds true indeed, will be critically examined in what follows.

3 AGE-RELATED DIFFERENCES IN NEURONAL PLASTICITY

Clearly, “the brain’s capacity to get organized and to reorganize itself as a reaction to internal or external changes” (Peltzer-Karpf, 2003, p. 370) varies greatly throughout the lifespan and also slows down after 13 brain growth spurts that take place until early adulthood (i.e., the age of 19/20). In this period, synaptic circuits are established and axons and dendrites form trees. These processes are far from unidirectional and linear though, as the brain also reorganizes initial inputs to become more efficient. *Neuronal plasticity* should thus be understood as dynamic processes, forming *dynamic systems*, which autonomously become more complex and generate form (see Hohenberger in this volume). Previous states are responsible for the current state and the current, again, forms the basis of future developments (Peltzer-Karpf, 2012). Until early adolescence, glucose values change and so does synaptic density. Long-range nerve fibers are developed and myelination takes place (Peltzer-Karpf, 2003). Humans experience phases of proliferation of neurons, for instance, but they also undergo phases of synaptic pruning (Lewis, 2005)

“true to the motto[s] ‘neurons that fire together wire together’” (Peltzer-Karpf, 2012, p. 67) and *use it or lose it*. These processes are essential in making humans ready for processing more complex tasks.

Critical periods are reflected on the level of brain maturation too, equaling short, system-specific time spans, in which cortical connections can be modified with ease and experiential fine-tuning is possible. As spurts are observable with regard to both language development and brain growth (Peltzer-Karpf, 2003), the assumption was made that the ability of our brains to reconfigure or change in function or shape (Li, Legault, & Litcofsky, 2014) could also be linked to a time window in which we are most ready to acquire an LX. Consequently, the question arose whether there is a stop to attaining an LX due to a decline in neuronal plasticity.

Ongoing research in the area of developmental cognitive neurosciences has clearly abandoned the long held belief that neuronal plasticity stops at a certain age and that “nervous pathways are fixed, finite and immutable” (Ramon y Cajal, 1909, cited in Peltzer-Karpf 2003, p. 371). Even if whatever humans did not use during development is lost at an advanced age, this does not automatically imply a loss of plasticity in adulthood. The mechanisms underlying the competition between connections may still be present and work on the remaining ones (Brown, Hopkins, & Keynes, 1991). Having identified the *nerve-growth factor*, Levi Montalcini also clearly rejects the idea of neuronal plasticity being restricted to young age and being finite when stating that neuronal plasticity may still be ongoing “nella fase senile” – at an advanced age (Levi Montalcini, 1998, p. 51).

The existence of neuronal plasticity among adults has a crucial effect on our understanding of LX attainment in adulthood, too. Clearly, adults’ brains differ from those with an early AoA. Therefore, keeping the neuronal circuits active is, in general, essential. Following Selkoe (1992) and Levi Montalcini (1998), Peltzer-Karpf (2003) states that despite the loss of unused neural circuits and biochemical changes throughout the lifespan, creative and cognitive capacities are still present at an advanced age. Even though infants’ brains seem to be “exquisitely poised to ‘crack the speech code’ in a way the adult brain cannot” (Kuhl, 2011, p. 36) as the neural networks differ from the latter, older L2 learners are able to compensate for age-related disadvantages, for instance, by changing existing

brain structures (Peltzer-Karpf, 2003) as well as by training neuronal circuits in the processing of specific tasks. When it comes to successful attainment of an additional language, age might be one factor, but not necessarily the most important or only factor.

The following section will critically examine the role of age effects by drawing on evidence from neuroscientific and behavioral studies focusing exemplarily on two aspects, namely pronunciation and morphosyntax. As a more thorough discussion would go beyond the scope of this chapter, these two domains were selected as they are among the most widely researched in this context. Furthermore, pronunciation is said to be the most difficult skill to attain in an LX, and the well-known study by Johnson and Newport (1989) led to much discussed controversies and galvanized linguists into investigating the morphosyntactic domain thoroughly.

4 **STUDIES CHALLENGING THE NOTION OF A CRITICAL PERIOD FOR SLA**

4.1 **Evidence from neuroscientific studies**

Non-invasive methods to study brain activity have deepened our understanding of the age factor in SLA and showed that factors other than AoA are certainly relevant in these processes. Abutalebi, Cappa and Perani (2001), having approached the topic by giving a review of PET (*positron emission tomography*) and fMRI (*functional magnetic resonance imaging*) studies (see Reitbauer in this volume for an overview of brain response measurements), for instance, come to the conclusion that “[c]onsistent results indicate that attained proficiency, and maybe language exposure, are more important than the age of acquisition as a determinant of the cerebral representation of languages in bilinguals/polyglots” (2001, p. 179).

Perani et al. (cited in Mehler & Christophe, 2000) also conducted research focusing on bilingualism and cortical representation in 1998. By comparing early Spanish-Catalan bilinguals and late Italian-English bilinguals (AoA = 10 years), they found that the cortical representations of the two respective languages were very similar in highly proficient early

and late bilinguals. As the results clearly differed from those of low-proficiency speakers, Mehler and Christophe (2000) also suggest that in bilinguals whose languages show historical, lexical and syntactic proximity, proficiency in the L2 is more decisive than AoA with regard to its cortical representation. Still, it needs to be mentioned that an AoA of ten years might have been too early to show any differences, and the different L1s might also have created too much noise in their data.

Zhang and Wang (2007) support the view that throughout the years research has shown that it is linguistic experience rather than maturational or biological constraints that changes language-related cortical responses and influences the way a language is acquired (see, e.g., Flege, 1995; Gaillard et al., 2000; Hernandez, Li, & MacWhinney, 2005; Kuhl, 2000; Yetkin, Yetkin, Haughton, & Cox, 1996). According to them, neural plasticity is still present in adulthood as long as enriched linguistic experience is given, and even new phonetic categories may be acquired by adults under certain circumstances. Thus, the results of various neuroscientific investigations “support the view that language learning is not a strictly timed developmental process with rigid cut-off points” and therefore “not an irreversible age-bound event” (Zhang & Wang 2007, p. 154; see also Bongaerts, Planken, Schils, & Van Summeren, 1997; Flege, 1995; Hakuta, Bialystok, & Wiley, 2003).

4.2 Evidence from behavioral studies

Behavioral studies investigated the effect of age in SLA in two different ways: they either tried to identify a terminus marking the end of reaching native-like proficiency¹ and, consequently, a critical period, or they tried to find exceptionally talented LX users, who started acquiring their LX after the closure of any of the proposed CHPs.

4.2.1 *Pronunciation: The hindrance to full foreign language glory?*

Soon after birth, the brain undergoes maturational changes and also specializes in sound processing of the L1 from eight months onwards, which

¹ Native-likeness refers to LX users performing on levels similar to those of native speakers in specific tasks (i.e., standard deviations from NS values).

is when the so-called *native language magnet* (Kuhl & Rivera-Gaxiola, 2008) takes over control, turning children into specialists in L1 sounds in their first year. Peltzer-Karpf (2003, p. 390) concludes that “the only hindrance to foreign language glory lies in the phonological domain”. In other words, the sooner the exposure to an LX starts, the better the pronunciation and the less a foreign accent is discernible usually applies (see also Scovel, 1988). If the AoA was the only decisive factor in ultimate attainment in an L2 and a CP existed, the correlation between age and the ability to attain a language proficiently should stop at a certain age. However, studies have shown controversial outcomes in this respect.

Patkowski (1980, 1990), for instance, investigating bilinguals' pronunciation in their L2, found a discontinuity at a certain age, which does not correspond to the terminus of any of the proposed CPHs. In this study, the participants' ability to pronounce words in a native-like way was marked by a discontinuity at an AoA of 15, which is obviously much later than, for example, Lenneberg (1967) or Long (1990) suggested. However, Harley and Wang (1997) stated that in Patkowski's study, the discontinuity described was not very striking as the decline in pronunciation abilities was actually very similar among the group having acquired their L2 before the age of 15 and the post-15 groups (Bongaerts, 2005). There are numerous other early studies investigating the issue, which support Harley and Wang's statement. Oyama (1976), for instance, found a gradual decline in proficiency with increasing AoA. Similarly, Flege, MacKay and Munro (1995), who observed 242 Italian immigrants to Canada, were only able to report a continuing decline in pronunciation ratings but, again, no sharp discontinuities. Also, Flege, Liu and Yeni-Komshian (1999) reported on findings which correspond to the linear decline described above. This challenges the classic notion of a CPH for pronunciation in an LX. Still, these studies show that there is a continuous decline in pronunciation ratings, the higher the AoA is. Does this mean that at some point in life it becomes impossible to acquire pronunciation on a level similar to those of native speakers? What can certainly be concluded from these investigations is that even if there was a critical period for LX acquisition, Long's (1990) suggested age of twelve marking the terminus is probably too early.

Bongaerts and colleagues (Bongaerts et al., 1997; Bongaerts, Mennen, & van der Slik, 2000; Bongaerts, Planken, & Schils, 1995) approached the

question from a different angle: is it possible for people to reach a level of proficiency in the phonological domain in an L2 similar to that of a *native speaker* (NS) when learning it after a certain point in life? The participants of four studies were highly successful L2 learners having learned their L2 after any suggested critical period in instructed settings. All studies included a control group of native speakers as well as experienced judges (linguists) and inexperienced ones (NS), who had to evaluate recorded speech samples on a scale ranging from ‘definitely native’ to ‘definitely non-native’ (Birdsong, 1999). In these studies, the participating NNS (*non-native speakers*) differed on the level of language exposure, motivation, type of L1 (e.g., Dutch, French, German, Armenian or Turkish) and, consequently, the typological proximity of the L1 and L2 (in three studies English, in one study Dutch). In all studies, some participants were in fact assigned ratings similar to those of the NSs. Interestingly, these findings correspond to Moyer’s suggestions, who concluded from her own study that in sequential LX acquirers “overt phonological instruction appears necessary for some learners to acquire native-level production” (1999, p. 99). This is also in line with Klein’s (1995) suggestion of biological constraints being not as severe as being an actual barrier.

From these studies, Bongaerts concludes that “the success of the exceptional adult learners we identified may have been at least partly due to the combination of three factors: high motivation, continued access to massive L2 input, and intensive training in the perception and production of L2 speech sounds” (1999, p. 155). This suggests factors other than AoA, such as motivation (Moyer, 1999), appraisal, amount of exposure and typological proximity of the L1 and L2 (Bongaerts et al., 2000) might actually be decisive in ultimate attainment too, as was also put forward by neuroscientists (see, e.g., Abutalebi et al., 2001; Mehler & Christophe, 2000; Zhang & Wang, 2007).

To sum up, it seems a foreign accent is easily discernible in most people starting to acquire an LX relatively late in life. Still, there are some exceptionally talented sequential LX acquirers who are even mistaken for native speakers, which is taken as evidence against a CPH (e.g., Bongaerts, 1999). However, proponents of a CPH would not accept this as counter-evidence and would doubt the measures’ validity and reliability due to typologically close L1-L2 pairings, native speakers performing on

lower levels than 100%, and/or including non-native speakers sounding very foreign in their sample so that near-native speakers more easily sound native, which would lead to a distortion of the results (Long, 2005).

Of course, the aforementioned studies can be criticized easily – whether they support or reject the idea of a CPH – as the extent to which age is confounded with other variables, such as amount of input, naturalistic exposure, motivation and frequency of use was most often not disentangled sufficiently. Furthermore, the presented studies are difficult to compare due to different elicitation tasks and different L1s. These aspects are crucial though as studies such as Bongaerts', for instance, demonstrated the important role of the typological proximity/distance of the L1 and LX. Therefore, it is important to be aware of LX attainment always being determined by various factors (Moyer, 2004).

4.2.2 *Morphosyntactic rules*

Besides pronunciation, morphosyntax has been another area of great interest to SLA researchers investigating ultimate attainment. However, the results from these studies are quite contradictory. In 1989, Johnson and Newport carried out an influential investigation regarding this matter: they analyzed 43 Korean and Chinese L2 learners of English with the aim to investigate the relation between L2-proficiency and age. Participants were tested on grammaticality judgment, and the results showed a relationship between the age of arrival in the United States and the proficiency level reached, indicating a clear advantage for early arrival. According to Johnson and Newport, the performance on the task was neither influenced by motivation, nor by identification with the US, nor by self-consciousness. They considered their findings as evidence for a critical period in SLA. Other researchers heavily criticized their study for several reasons. Bialystok and Hakuta (1994), for instance, stated that if the classification of participants had been different, the data would have revealed entirely different results. Moreover, Bialystok (1997) criticized Johnson's and Newport's results, as different educational backgrounds could be regarded as a trigger for different proficiency levels too (Van Bostel, 2005).

Since then, numerous researchers (see, e.g., Bialystok & Miller, 1999; Birdsong & Molis, 2001; DeKeyser, 2000; Flege et al., 1999) have tried to replicate the famous study by Johnson and Newport. The outcomes of these studies were quite contradictory and either showed no discontinuities (Bialystok & Miller, 1999) or an inflection point of, for instance, 27.5 years, contradicting any CPH proposed so far (Birdsong & Molis, 2001). Another study showed a strong link between high proficiency in the L2 and AoA, which was also linked to low proficiency in the L1 though (Jia, 1998). This led to the conclusion that factors other than maturational ones, such as L1 proficiency, might be decisive in attaining an L2 too (see also Van Boxtel, 2005). A highly innovative study on ultimate attainment in grammar was carried out by Van Boxtel, Bongaerts and Copen (2005): they compared the performance of 44 native speakers of Dutch with 43 highly successful late learners of it from various L1 backgrounds (German, French and Turkish) on tasks including dummy subject constructions, which is highly unusual and interesting as they are not covered in prescriptivist literature. In both a sentence imitation and sentence preference task, L2 learners could be identified who performed at the same level as native speakers. Typological proximity was an influential factor though as Turkish learners of Dutch performed poorest. The results led Van Boxtel et al. to question the existence of a CPH for syntax in L2 acquisition, but they still acknowledge the decisive role of age-related differences, such as type of input and biological factors, and state that these might eventually lead to differences in the performance of those with an early start and those with a late start. Nevertheless, it needs to be noted that age-related constraints are “not specific to language and not absolute” (Van Boxtel et al., 2005, p. 377).

In summary, the results of studies on morphosyntax in SLA diverge as do researchers' opinions on the topic as a consequence. As already stated, there are studies which may be viewed as evidence for a critical period as all late learners performed more poorly than native speakers (see Coppeters, 1987; Hyltenstam, 1992; Johnson & Newport, 1989); however, there are also numerous studies in which at least some highly successful L2 learners attained ultimate levels of proficiency in L2-grammar (see Birdsong, 1992, 1997; Hyltenstam & Abrahamsson, 2003; McDonald, 2000; Van Boxtel et al., 2005; White & Genesee, 1996).

4.3 Concluding remarks on the CPH in SLA

According to Bialystok and Hakuta (1994), it cannot be denied that children tend to acquire an L2 with less effort than older learners, but one must be careful in going so far as to view biological constraints as the single decisive factor, as there are obviously exceptions to this rule. Differences in input and amount of exposure might explain early birds' advantageous position in many cases. Still, young acquirers also sometimes tend to be unsuccessful and some late learners are able to overcome age-related obstacles. Thus, AoA might be an important factor in the acquisition process, but not necessarily the most influential variable, and ultimate attainment is clearly multiply determined (Moyer, 2004). Therefore, confounds between the AoA and other influential variables need to be disentangled carefully to make claims for or against a CPH more convincing. Furthermore, it is crucial not to mistake causality for correlation: the critical period hypothesis certainly is a causal explanation but, so far, there has only been evidence for correlation between AoA and ultimate attainment (Bialystok & Hakuta, 1994, cited in Birdsong, 1999), and this correlation has not consistently been shown. The results of various studies even contradicted any assumption of a negative correlation in this respect.

Even though in early tests of the CPH either instructed learners (see, e.g., Bongaerts' studies) or those having acquired an LX in naturalistic settings were investigated more recent approaches to a CPH negate the applicability of any CPH to instructed settings. A recent longitudinal study by Pfenninger and Singleton (2016), who investigated 200 Swiss learners of EFL (*English as a foreign language*) with L1 German and different ages of onset of instruction (group 1: AoA = 8; group 2: AoA = 13) "provided no clear evidence that there is any special advantage in starting the study of an FL very early" (see also Pfenninger & Singleton, 2017, p. 215). Their data showed, in fact, a rate advantage for the late starters. After six months of instruction, the group with a later start caught up to and performed on similar levels as early starters (some even outperforming early starters), and also, when tested at the end of high school they still did so. Moreover, their findings demonstrate the "multi-faceted complexity of the role played by starting age" (Pfenninger & Singleton, 2016, p. 311) and highlight the role of socio-psychological factors in SLA

as well as the interaction of these with age. Indeed, affect may trump age in instructed learning (Singleton & Pfenninger, 2016), which points to the crucial role emotions play with regard to successful LX attainment (for a more detailed discussion see below).

To conclude, what is stated above clearly demonstrates that an early AoA cannot be taken as a guarantee for success in learning another language (see also Grosjean, 1982). Reality is more complex and early research on the age factor frequently neglected the complexity inherent in the process of acquiring another language and the possible interaction between AoA and other variables (Moyer, 2014). Therefore, the following section calls for a long overdue shift of paradigm towards a holistic view on LX users in study designs on various levels and postulates different premises for any investigation into the age factor in SLA.

5 **A CALL FOR A CHANGE OF PARADIGM TOWARDS A HOLISTIC VIEW ON MULTILINGUALISM AND ULTIMATE ATTAINMENT**

What can be derived from the previous sections is that the question of the link between AoA and attainable proficiency is not as easy to answer as linguists in the past had hoped. The difficulty lies in the complexity and dynamics underlying LX attainment. Therefore, this chapter also aims to highlight the necessity for a change of paradigm when investigating the age factor in the context of SLA research and puts forward three premises.

Firstly, previous research most often ignored the fact that “L2 acquirers, by definition, possess [...] knowledge of an L1 [...] when they begin learning the additional one” (Ortega, 2009, p. 31), and this knowledge is certainly not to be treated as isolated from the L2 (or LX). Thus, previous research often took a monolingual perspective (Cook, 2016, p. 1) on L2 users, which means that the languages an LX user knows were treated as separable and comparable to NSs’ performance. Consequently, L2 users were frequently measured against NS, which is equal to comparing apples and oranges (Cook, 2009), as “[i]n the literal sense it is impossible for an L2 user to become a native speaker, since by definition you cannot

be a native speaker of anything other than your first language” (Cook, 2007, p. 240). Thus, the “knowledge of more than one language in the same mind” (Cook, 2012, p. 3768) needs to be approached adequately in scientific investigations as L2 users are language users in their own right and should be treated as such and not as if they used an LX deficiently (i.e., deviating from a native speaker norm). They will never use their language in the same way as a(n idealized monolingual) native speaker of said language (see also Selinker, 1972), as the languages in their mind show a mutual influence. This call for a change of paradigm towards a holistic view on multilinguals is also known as a linguistic perspective called *multi-competence* (Cook, 2009), the first version of which was proposed by Cook in 1991. Linking it to the idea of a CPH, this means the following: strictly speaking, when measuring NNSs against NSs, of course, “non-nativeness will eventually be found” (Birdsong, 2014, p. 47). The results from a study by Abrahamsson and Hyltenstam (2009), who investigated 195 Spanish-Swedish bilinguals, for instance, made them conclude that nativeness is unattainable by adult learners and actually hardly ever attained when learning another language in childhood. If native-likeness is what the CPH requires, then this is, if even, only possible for people growing up with two languages simultaneously, which might eventually reduce the idea of a CPH to absurdity.

The second premise is linked to the first one and refers to the dynamic underlying linguistic systems: knowing a language involves various skills and this knowledge is neither fixed nor static – neither in an individual, nor in the community. The languages in an LX user’s mind clearly behave like liquids, which means “when mixed, they acquire completely new properties” (Herdina & Jessner, 2002, p. 27). Even though the dynamics underlying *linguistic systems* are also prominent in monolinguals, they become more complex (and obvious) in speakers knowing more than one language: all languages a person knows show constant interplay, making multilinguals’ situations unique (Cook, 2006). Thus, the second premise is, consequently, a call for acknowledging *dynamic systems theory*: not only do the languages in someone’s mind show a mutual influence, but learning another language is also a highly dynamic process as such and assessing someone’s proficiency equals measuring the current state only. In fact, achieved proficiency is always to be seen as a basis for future developments and the outcome of previous ones (Peltzer-Karpp, 2012, see

also Hohenberger in this volume). To put it in Hohenberger and Peltzer-Karpf's words: "[l]anguage learning is a nonlinear dynamic process in time. It is poised between determinism and indeterminism, order and chaos" (Hohenberger & Peltzer-Karpf, 2009, p. 504). Research on the effect of age is often criticized for not having captured the complexity and dynamic inherent in LX attainment as well as the multiple influential factors in these processes (Moyer, 2014). Nowadays, statistical tools enable researchers to build statistical models, such as the *multilevel modeling approach* (MLM), which was applied by Pfenninger and Singleton (2016, p. 315) in their longitudinal study. These allow researchers to investigate the interaction of possibly influential variables.

Such an approach would also allow fulfilling the third premise: a stronger focus on individual differences in SLA research. Interestingly, "[t]he traditional age effects/CPH literature has been overwhelmingly concerned with universals, not with individual differences" (Moyer, 2014, p. 447), which are clearly illusive and unrealistic as they are highly idealized. When trying to depict the processes underlying ultimate attainment in a foreign language, such a focus is much needed as the individual plays a decisive role in both language outcome and processing (Moyer, 2014). This focus on individual differences is also linked to the need for taking a *complexity perspective* (Mercer, 2011, p. 57). Even though Mercer suggested it with a focus on the self-concept of language learners, grappling with the complexity of ultimate attainment is much needed too. As recent studies have shown, there is a much stronger need for investigating psychological aspects in foreign language learning including learners' emotions (e.g., Dewaele, MacIntyre, Boudreau, & Dewaele, 2016; Dewaele, Witney, Saito, & Dewaele, 2017; Pfenninger & Singleton, 2017) and potentially those of teachers (Gkonou & Mercer, 2017) as these are much more influential than had been previously assumed. This need for a stronger focus on emotions holds true for SLA and multilingualism research in general (see, e.g., Dewaele, 2010; Resnik, 2018). So far, motivation has been the only variable which has been investigated extensively (see, e.g., Dörnyei & Ushioda, 2009; Gardner & Lambert, 1959, 1972). Motivation might actually have appraisal at its basis (Schumann, 1997) and emotions are crucial regarding the absence or presence of learning (see, e.g., MacIntyre, 2002) and, consequently, decisive in (un)successful LX acquisition (Dewaele, 2010). AoA or one's chronological age might,

for instance, interact with the emotions of LX learners and, hence, these should certainly not be neglected. Being, besides language, one of “the two basic systems involved in communication” (Reilly & Seibert, 2009, p. 535), the need for investigating the interplay of language and emotion in SLA processes becomes obvious. Positive valuations of a language and culture as well as the learner’s perception of self are also decisive in ultimate attainment (Panicacci & Dewaele, 2017). Furthermore, foreign language enjoyment and anxiety are crucial factors in these processes (see, e.g., Dewaele et al., 2016; Dewaele et al., 2017). It might eventually even be suggested that positive emotions of LX users possibly bear the potential of overcoming age-related constraints in SLA.

6 CONCLUSION AND IMPLICATIONS

This chapter shed light on investigations into the age factor in SLA, “one of the most frequently researched and debated topics in Second Language Acquisition” (Muñoz, 2008, p. 578). It showed that early investigations into these matters mostly focused on testing proposed CPHs for SLA, which were entirely based on brain maturational factors. These investigations led to contradictory results not only with regard to the nature of the differences between younger and older learners, but also with regard to whether or not there is an actual end to becoming a highly proficient user. While any CPH for SLA is actually a causal link between AoA and proficiency, most of the studies to date could only reveal a negative correlation (Bialystok & Hakuta, 1994; Birdsong, 1999), which cannot be seen as evidence for any CPH. In addition, early investigations into the relevance of AoA did not distinguish between “ultimate attainment and rate” (Krashen, Long, & Scarcella, 1979, cited in Muñoz, 2006, p. 2), a difference of which is crucial. Furthermore, often no distinction was made regarding the nature of the input, and findings from studies on SLA in naturalistic settings were frequently compared to processes underlying foreign language learning in instructed settings, without acknowledging the differences in quality of input and also amount of exposure (Muñoz, 2006, 2008). Disentangling effects of the context of acquisition is important to prevent unjustified generalizations.

This is also linked to another important aspect: the complexity and intersectionality of variables (possibly mutually) influencing the success of the learning process. To date, findings from various studies – large- and small-scale – showed that various factors might be age-related and shape attainment as well as underlying learning processes (Moyer, 2014). Importantly, there is a strong need for investigating the mutually constitutive relations of influential variables (see, e.g., Pfenninger & Singleton, 2016), including psychological factors. I proposed in this chapter that emotions play a crucial role in the success of attainment and any kind of learning too, and it is, thus, essential to also investigate emotions in these processes (see, e.g., Dewaele, et al., 2016; Dewaele et al., 2017; Mercer, 2011) as these are crucial in the process of becoming a multi-competent successful LX user (Cook, 2016; Dewaele, 2017; Resnik, 2018). This includes another vital aspect, namely linguistic multi-competence, and points to the incomparability of native speakers and LX users. As Muñoz and Singleton (2011, p. 2) state, the “maturational constraints perspective has relied too much on native speaker behaviour as a basis for comparison”. Clearly, it is more about “difference” rather than “deficit” (Moyer, 2014, p. 447).

While fully acknowledging the importance of early studies in the field and not questioning their relevance in any way, research has also led to progress, and this is what future investigations need to build on. As Singleton and Ryan (2004, p. 227) mention, “the idea of a critical period specifically for language development may well have its day”. This does not mean that investigations into the age factor become irrelevant, but researchers will simply need to build on the newly gained insights to do the complexity of the underlying processes full justice.

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Age constraints in phonological learning: On the relevance and efficiency of pronunciation training

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ABSTRACT Accent has shown to be one of the most salient features of speech. Listeners are particularly sensitive to *foreign* or L2 accents, which are phonological variations attributable to L1 influence on the L2. At the same time, L2 accents are very hard to overcome. As L2 research has shown, pronunciation is the language skill which is most difficult to master, especially late in life. The need for efficient pronunciation instruction in schools and tertiary institutions is therefore undeniable. The chapter at hand provides a literature review of whether pronunciation instruction can be efficient, given maturational constraints with growing age. It investigates the existence of neural plasticity in adults in terms of phonetic learning as well as phonological attainment in adult L2 learners and will thus show that pronunciation training can be efficiently used in adult language instruction.

KEYWORDS neural plasticity, phonological acquisition, phonological proficiency, pronunciation training, speech perception and production

1 INTRODUCTION

Simply phonetics. The science of speech. That's my profession; also my hobby. [...] You can spot an Irishman or a Yorkshireman by his brogue. I can place any man within six miles. I can place him within two miles in London. Sometimes within two streets.

— Shaw, *Pygmalion*, 1.118

The note taker's comments in the first act of *Pygmalion* very well express how salient of a feature *accent* is. Investigating accents (i.e., manners of pronunciation differing from the standard variety, for instance based on speakers' local, ethnic, or socio-economic background), native as well as non-native, is one of the key aims in the linguistic field of phonetics. Yet this salience of accent is not restricted to professional phoneticians. In fact, listeners seem to be remarkably aware of accents and constantly make judgments about their interlocutors' heritage based on their speech. Listeners prove to be especially sensitive to *foreign* or L2 accents, or in other words, to phonological variations attributable to L1 influence on the L2 (Derwing & Munro, 2009). Studies have shown that listeners can detect L2 accents in only 30 ms of speech, in speech played backwards, and even in languages unknown to the listeners (e.g., Flege, 1984; Major, 2007).

In spite of our apparent awareness of foreign accents in the speech of others, it seems to be a different story when it comes to adapting our own accents to a new target language. L2 pronunciation has indeed been attributed with a special status in L2 learning; there seems to be a certain consensus among linguists that pronunciation is the language skill that is most difficult to acquire with high proficiency, especially later in life, after adolescence (see, e.g., Long, 1990). Interestingly, several studies on learners' conception with regard to accent revealed a high importance attributed to highly proficient pronunciation in the target language. In a study with 400 EFL (English as a foreign language) students, Timmis (2002) found that 67% of the students attested to seeking native-like pronunciation in English (see Werk, 2012, for similar results). Derwing (2003) conducted a study with 100 ESL learners, who were asked whether they would take a magic pill, if one existed, to wake up speaking En-

glish with a local accent; 95% of respondents answered with the affirmative.

Furthermore, the expanding role of English as an international language clearly highlights the importance of successful interactions between speakers from different linguistic backgrounds. The focus of pronunciation instruction and research has, accordingly, shifted from native-like models towards concepts of *comprehensibility*, which means how easy it is for the listener to understand an utterance, and *intelligibility*, which means how much of an utterance the listener actually understands (Derwing & Munro, 2009.) As Busà suggests, “interlanguage communication rests on the concept of mutual intelligibility, and pronunciation is one of the main factors contributing to it” (2008, p. 113f.). Several studies, in fact, found a positive effect of pronunciation training on the intelligibility of L2 learners’ speech (see, e.g., Derwing et al., 1997, 1998). It has thus been argued that L2 instruction should focus more strongly on learners’ pronunciation proficiency to ensure successful communication in multi-linguistic contexts (see, e.g., Busà, 2008).

Regarding pronunciation as one of several language skills to be acquired for successful communication, the need for sufficient pronunciation training is certainly understood. As Thomson and Derwing (2014, p. 14) note, “pronunciation instruction is no longer a neglected domain of second language teaching and research”. The major aim of the current chapter is to investigate whether it is still possible to achieve a high level of pronunciation proficiency in an L2, considering different maturational constraints learners experience with growing age. The first section will focus on studies from L1 acquisition to explain the emergence and background of L2 accents. The next section will examine the aging brain and discuss neural plasticity in terms of phonetic learning, followed by a section on *ultimate attainment* in L2 phonology in adult learners. The final section will draw a conclusion on whether it is still possible for adult L2 learners to overcome pronunciation difficulties based on the reviewed literature.

2 THE CRADLE OF L2 ACCENT

When learning a new language, the majority of learners are faced with the challenge of acquiring a new sound system and *speech melody* (i.e., prosody). This challenge apparently increases with growing age (i.e., after adolescence), leaving adult L2 learners to struggle with negotiating the typical pronunciation pattern of their native language and the new, unfamiliar accent of the target language. The result is often a more or less noticeable foreign accent in the L2. Linguists have been highly interested in this seemingly insurmountable phenomenon of target, or native-like, accents. To fully tackle the question of where L2 accents actually come from and why it is so difficult for older learners to adopt a native-like pronunciation in an L2, we need to shed light on our early childhood years.

Interesting insights into the issue of *foreign accentedness* can be gained through studies of L1 phonological acquisition. Several early behavioral as well as brain-based studies in this field have shown that newborn infants are able to discriminate between speech sounds irrespective of their native language, an ability that is no longer present in adults. Werker and Tees (1984) revealed a top-down process of phonological development of infants by testing the discrimination performance of a Hindi dental-retroflex contrast by Hindi and English-speaking infants throughout their first year of life. They found that the initial ability to detect this contrast drastically altered in the English-speaking infants starting at ten months of age. Cheour et al. (1998) confirmed the existence of a top-down process in the acquisition of phonology through *mismatch negativity* (MMN, Pulvermüller & Shtyrov, 2006) experiments. They tested Finnish and Estonian infants' brain responses when discriminating the Finnish/Estonian phonemes /e/ and /ö/ and the exclusively Estonian phoneme /õ/. The MMN amplitude generally increases with an increasing acoustic difference between standard (i.e., /e/) and deviant stimuli (i.e., /ö/ and /õ/). At six months of age, the Finnish infants had larger MMN responses for /õ/ than /ö/ compared to /e/, which was the acoustically more different stimulus; at one year, however, their MMN amplitude was smaller for Estonian /õ/ than for Finnish/Estonian /ö/. Estonian one-year-olds exhibited a slightly larger MMN amplitude for the acoustically more different /õ/ than for /ö/. Cheour et al. thus tracked

the development of *language-specific memory traces* in the infant's brain between six and twelve months, which apparently enables the growing infant to discriminate between the phonemes of their mother tongue.

More recent studies have confirmed that children apparently move from a language-universal perception of speech at birth to the language-specific speech perception of their native language over the course of their first year (e.g., Bohn, 2000; Kuhl, 2004; Kuhl et al., 2008). This shift in children's speech perception occurs very early in life. Starting in the first few months, children become increasingly focused on the sound system of their ambient language, a process that is necessary to acquire speech. As Bohn (2000) writes,

[...] the learning task of infants and children is not to become sensitive to more and more differences among sounds, but to selectively enhance or suppress initial sensitivities to yield perceptual patterns that are needed for efficient processing of the L1 (p. 6).

According to Kuhl et al. (1992), who tested the discrimination performance of English and Swedish-speaking infants throughout their first year, this sensitizing process starts to work as early as six months for vowels. Perception of consonants has shown to become affected at approximately ten months of age (Kuhl, 2009).

Although vital for L1 acquisition, this process of *phonetic narrowing* influences children's perception of speech sounds beyond the native sound repertoire. Kuhl (e.g., 2000, 2004, 2009) developed the so-called *native language neural commitment* (NLNC) hypothesis to account for the strong impact of the native language on children's phonetic discrimination. The NLNC hypothesis was supported by behavioral and brain-based tests (Kuhl & Rivera-Gaxiola, 2008) and implies that due to the influence of the ambient language, children's native language abilities increase while their non-native abilities decrease: "By the end of the first year, the infant brain is no longer universally prepared for all languages, but primed to acquire the specific one(s) to which they have been exposed" (Kuhl, 2009, p. 106).

Kuhl's (2009) NLNC hypothesis shares striking similarities with the *Natural Phonology Theory* proposed by Stampe (1969, 1979), in which phonology is based on a set of universal and interacting phonological

processes. In their language acquisition process, infants learn to suppress those phonological processes that do not apply to their native language. Donegan and Stampe (1979) explain how such language-specific repression mechanisms affect, among other processes, L2 pronunciation in adults:

From adolescence, usually, there is little further change, and the residual processes have become the limits of our phonological universe, governing our pronunciation and perception even of foreign, invented, and spoonerized words, imposing a ‘substratum’ accent on languages we subsequently learn, and labeling us as to national, regional, and social origins (p. 127).

This shift in children’s phonological system elaborated by Kuhl (2009) and Donegan and Stampe (1979) thus also explains the difficulty encountered by many adult language learners in properly perceiving and producing the sound pattern of a new language. Children, however, can still reverse this process when exposed to another language. Experiments with American infants of nine months showed that short-time exposure to Mandarin Chinese resulted in phonetic learning in the target language (Kuhl et al., 2003). Adults, by contrast, are less likely to overcome those early-acquired perception constraints.

The early changes in children’s speech perception and the resulting difficulties in pronunciation experienced by adult L2 learners raise the question of whether it is still possible to overcome these constraints and acquire proficient pronunciation ability in an L2 later in life. The following sections will focus on neural plasticity as the neurophysiological prerequisite that is necessary for phonetic learning and will then discuss relevant behavioral and neurolinguistic experiments on ultimate attainment of pronunciation in adult L2 learners.

3 NEURAL PLASTICITY IN ADULTHOOD

[...] the wiser mind mourns less for what age takes away than what it leaves behind.

— Wordsworth, *The Fountain*, 34–36

A highly relevant question in adult L2 acquisition is the extent of plasticity in the aging brain. The notion of *neural plasticity*, which can be defined as “the brain’s capacity to get organized and to reorganize itself as a reaction to internal or external changes”, has eradicated the long held idea of the brain as a physiologically static organ (Peltzer-Karpf, 2003, p. 369). In fact, ongoing research in the field of cognitive neuroscience has provided clear evidence for learning-induced neural plasticity in adults (Brown et al., 1991; Levi-Montalcini, 1998; Pascual-Leone et al., 2005; Rakic, 2002; Zhang & Wang, 2007).

It is well known that neural plasticity does slow down after several growth spurts until early adolescence (Peltzer-Karpf, 2003). However, the brain can compensate for such changes by reorganizing the given repertoire in the form of a “remodeling of connections”, which includes dynamic processes such as rewiring the cortex, using alternative circuits, and reorganizing cortical maps (Peltzer-Karpf 2003, p. 377). As Peltzer-Karpf (2003) states,

[...] though the human brain may have to suffer the loss of certain neurons and to undergo biochemical alterations at an advanced age these changes do not bring about a noticeable loss of cognitive and creative capacities (p. 391).

The existence of neural plasticity throughout adulthood has important implications for the processes involved in L2 acquisition. From the current perspective, it can be argued that “language learning is not an irreversible age-bound event” (Zhang & Wang, 2007, p. 154). It has further been shown that younger and older learners, despite the fact that their neural networks differ, undergo similar paths in the acquisition process and also use comparable mechanisms during the early stages of acquisition.

A more problematic situation within the domain of L2 acquisition is attributed to *phonetic learning* (Peltzer-Karpf, 2003), considering the early transition from a language-general to a language-specific speech perception as discussed above. Zhang and Wang (2007) argue that the perceptual reorganization involved in this transition reflects “a continuous process of neural commitment towards the first language and gradual decrease in neural plasticity to acquire another language” (p. 148).

Behavioral studies have shown that adults are generally less successful in differentiating between non-native speech contrasts than young learners (Strange, 1995). As Flege et al. (1996) have shown, sounds that are acoustically close to L1 phonemes are particularly difficult to acquire for late L2 learners. These findings were supported by neurophysiological studies, which provided evidence of *memory traces* for language-specific phonemes in the adult brain (Cheour et al., 1998; Näätänen et al., 1997; Rivera-Gaxiola et al., 2005). Näätänen et al. (1997) found higher MMN and MMNm activity for native vowel discrimination despite larger acoustic differences in non-native contrasts.

Zhang and Wang (2007) claim that this “loss of perceptual sensitivity for non-native phonemic contrasts” described above is quite difficult to reverse in adulthood since “the brain would have become committed to the analysis of native language structure with reduced neural sensitivity for non-native speech perception” (p. 148). However, the authors strongly highlight the prevalence of linguistic experience over such biological and maturational constraints in the acquisition process, which influences language-related cortical responses (see, e.g., Binder, 1999; Gaillard et al., 2000; Yetkin et al., 1996). Learners’ proficiency levels as well as the typological proximity between L1 and L2 are further related to plasticity in the brain (Abutalebi et al., 2001; Mehler & Christophe, 2000).

Despite early neural commitment to the native language, it can thus be argued that linguistic experience can still enhance the perceptual skills of adult L2 learners. As Zhang and Wang (2007, p. 152) conclude, “early language exposure does not produce the complete loss of sensitivity to nonnative distinctions”. Accordingly, it is still possible to reverse the NLNC process and to develop sensitivity towards non-native speech contrasts even in adulthood. Enriched linguistic experience in the form of specialized phonetic training has shown to be of particular relevance in achieving this reversal.

A great variety of studies have shown that intensive short-term training methods can improve the perception of non-native speech in adult learners, which can be interpreted as a sign of neural plasticity (Akahane-Yamada et al., 1997; Bradlow et al., 1999; Hazan et al., 2006; Iverson et al., 2005; Jamieson & Morosan, 1986; Logan et al., 1991; McCandliss et al., 2002; Pruitt et al., 2006; Strange & Dittmann, 1984; Tremblay et al., 1997; Wang et al., 2003). For example, Zhang et al. (2000) developed a

training software that is based on the features of child-directed speech such as acoustic exaggeration and visible articulation cues. Testing a group of Japanese adults with little previous English exposure, they found a highly significant improvement in the perception of the /l/ – /r/ contrast, as well as enhanced neural sensitivity and efficiency. The authors conclude that, given such enriched linguistic experience, “there is substantial neural plasticity for the acquisition of new phonetic categories in adulthood” (Zhang & Wang, 2007, p. 152). Moreover, Winkler et al. (1999, p. 638) conducted MMN experiments with Hungarian learners of Finnish on the Finnish phonemes /æ/ vs. /e/, revealing a “dynamic nature of cortical memory representations for phonemes in adults”. Their study provided evidence that training in an L2 elicits the formation of new phoneme representations in the adult brain, which further indicates the existence of neural plasticity at an advanced age.

Phonetic training can thus lead to clear improvements in speech perception of an L2. Perceptual learning has shown to have an effect on the participants’ production skills in the target language as well. Several studies have documented a transfer of improvements in perception to the production domain (e.g., Callan et al., 2003; Zhang et al., 2001). Zhang et al. (2001) thus conclude that neural plasticity can be induced in adult L2 learners through specialized phonetic training (Zhang et al., 2009).

4 L2 PHONOLOGICAL PROFICIENCY IN ADULTS

The fact that children can easily acquire the sound system of a new language implies the existence of a *sensitive period* for language learning (Kuhl, 2010, see also Resnik in this volume). Non-native phonetic contrasts can be easily integrated by children, yet not by adult language learners. Various studies have been conducted on the offset of this ability, although with differing conclusions. So far, no exact age can be consistently determined that could be said to mark the end of a sensitive period for L2 phonology. Instead, the majority of studies reported the absence of a sharp discontinuity in age, which consequently implies a linear, gradual decline in pronunciation ratings (see, e.g., Flege et al., 1995a, 1999).

There is still a certain consensus among empirical studies regarding a negative correlation between the age of language acquisition and the attained proficiency level in pronunciation. Therefore, younger language learners seem to have a clear advantage regarding ultimate phonological proficiency, both in perception and production (see, e.g., Abrahamsson & Hyltenstam, 2009; Burda et al., 2003).

However, this does not rule out the possibility of achieving phonological proficiency late in life. The aging brain is still active and can also adapt to environmental experiences such as language input. Evidence of learning-induced plasticity thus shows that the neurophysiological prerequisites for efficient language acquisition, and phonetic learning in particular, are still in place throughout adulthood (see, e.g., Peltzer-Karpf, 2003, 2012; Zhang et al., 2009; Zhang & Wang, 2007).

These findings were supported by a number of behavioral experiments which showed that adults are still able to overcome barriers to pronunciation. Bongaerts et al. (Bongaerts, 1999, 2003; Bongaerts et al., 1995, 1997, 2000) conducted a series of experiments focusing on phonological attainment in exceptional cases of late L2 learners. The participants consisted of carefully selected highly proficient late learners of English or French with a Dutch language background, who studied the target language at university. In each study, several of the learners were rated as native speakers in the target language by native evaluators. These results are in line with other studies on phonological attainment of non-exceptional late L2 learners (see, e.g., Derwing et al., 2014; Flege & Eefting, 1987; Flege et al., 1995b; Moyer, 1999), which proved that adult language learners may still be able to acquire authentic L2 pronunciation under special conditions such as intense pronunciation training.

In light of these results, age cannot be the only determining factor for L2 phonological proficiency. In his studies with highly proficient late L2 learners, Bongaerts (1999, 2003) identified at least four additional factors likely to influence ultimate attainment. First, the motivation and importance attributed by learners to phonological proficiency has shown to play an essential role in their success. Second, a further important role was attributed to continued and substantial authentic input in the target language. Third, intensive training in the perception and production of speech sounds in the L2 was assumed to have contributed to the participants' high phonological proficiency. And finally, an increased awareness

of the phonetic contrasts between the native and the target language was attested to have had positive effects on participants' pronunciation as well.

From the perspective of such phonetically-oriented studies, focusing primarily on external factors such as age of onset, motivation and intensive training and L2 input, it is possible to create ideal conditions for phonological learning and thus foster ultimate phonological achievement in the target language. Still, the question remains of why some individuals integrate the sound system of a language more easily and faster than others. Recent studies in the field of cognitive neuroscience have shifted the focus to physiological factors inherent to the learner, such as special genetic equipment to account for differences in learners' ability and velocity in acquiring L2 phonology, as will be outlined in the following. The underlying assumption is that some language learners are innately more talented than others and that language aptitude is genetically inherent in the learners' brain.

In an early study on the neurological substrates of linguistic talent, Geschwind and Galaburda (1985) found a connection between *pathological language talent* and enhanced growth of particular brain areas. Jilka et al. (2007) investigated neuronal correlates of talent in a large-scale study, in which they conducted fMRI (functional magnetic resonance imaging) scans with subjects classified according to different degrees of talent while performing phonetic perception and production tasks. Their results suggest higher brain activation in untalented speakers, indicating that "high proficiency correlates with reduced effort in speech production, and enhanced cortical efficiency" (Jilka et al., 2007, p. 256). Further, MRI scans investigated with the VBM (voxel-based morphometry) method revealed a connection between individual differences in the perception of foreign speech sounds and the anatomy of the left auditory cortex white matter (Golestani et al., 2002), as well as between the accuracy of foreign speech sound production and white matter anatomy in brain regions involved in articulation and phonological working memory (Golestani et al., 2007). In spite of such compelling evidence, further neurolinguistic studies are necessary to determine neurological substrates of language talent as well as the effect thereof on the adult learners' brain.

Even though the existence of individual *language aptitude* would imply that some aspects of language learning could be immune to the external factors outlined before, Bongaerts' (1999, 2003; Bongaerts et al., 1995, 1997, 2000) findings are still highly relevant in assessing ultimate attainment in late L2 learners. In fact, he focuses on the interaction of several different factors, even including innate talent since his participants are selected cases of highly proficient L2 users. To conclude, the behavioral studies with highly proficient late language learners clearly show that it is still possible to attain native-like proficiency in an L2 in adulthood. In line with those findings, Bohn (2000, p. 11) remarks on the "malleability of language-specific patterns of perception", suggesting that the influence of the selectivity process during early infancy is powerful, but not all-pervasive.

5 CONCLUSION

Can old brains learn new language tricks? Judging from the studies reviewed in the present chapter, the answer to this question seems to be yes. Neurolinguistic evidence suggests that our brain is still malleable. Also, studies on phonological attainment show clear evidence that it is still possible to attain a native-like accent as an adult. It can thus be concluded that phonetic training is still relevant in adulthood and can be efficient even at an older age.

The human brain still exhibits plasticity during adulthood, which is needed for efficient processing of a new language. Numerous brain-based studies have shown that language experience, and specialized phonetic training in particular, can indeed induce neural plasticity. In spite of early neural commitments to the native language system, phonetic learning is therefore still possible in adults. The notion of critical or sensitive periods for language acquisition should consequently be re-evaluated in linguistics. As Zhang and Wang (2007, p. 154) aptly suggest, "language learning is not a strictly timed developmental process with rigid cut-off period" (see also Hakuta et al., 2003; Wang et al., 2003b).

Similar findings were gained by behavioral studies, which have shown that late learners are still able to attain a high or even native-like level of

phonological proficiency in a new language. Ultimate attainment in L2 phonology must therefore be multiply determined, with several further influencing factors in addition to age. Motivation, sufficient language input, phonetic awareness, as well as phonetic training were all identified as key factors for a high proficiency in L2 phonology.

It can thus be concluded that intense pronunciation training can help adult learners overcome age-related disadvantages in achieving authentic L2 pronunciation (see also Lee et al., 2015; Thomson & Derwing, 2015, for a literature review). Pronunciation has recently been granted more focus in the language classroom, yet the crucial question remains of which training method works most efficiently. One major incentive of future research in this area would thus be to investigate different methods and models of pronunciation instruction, as well as to examine the efficiency of specific technologies which could be effectively used to complement regular classroom instruction.

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Exploring the neurofunctional underpinnings of dyslexia: A review focusing on dyslexic children

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ABSTRACT Dyslexia is a hereditary impairment characterized by effortful and slow reading acquisition that is often accompanied by severe difficulties in writing and spelling. Inconsistencies regarding the definition and assessment of dyslexia have led to considerable variation in prevalence rates and gender-ratios. However, it is agreed upon that dyslexia affects between 3 and 17% of school-aged children who mostly display deficits in pre-literacy skills already at pre-school age. Since neuroimaging provides a unique opportunity to shed light on potential anomalies in neural functioning underlying this impairment, reviewing the most recent results of fMRI studies of affected children can help us better understand this impairment. The present chapter provides a review of 24 functional magnetic resonance imaging (fMRI) studies (conducted between 2000 and 2016) investigating reading-related processing in children diagnosed with dyslexia (age: 8–15 years). The results suggest a clear underactivation in almost all areas designated as core reading areas (left-hemispheric occipito-temporal, temporo-parietal and frontal circuits) during orthographic, phonological and auditory tasks. Different and reduced patterns of activation were also found in the inferior frontal cortex, with a peak in the inferior frontal gyrus. Moreover, numerous studies reported a large network of compensatory activation in right-hemispheric and bilateral

reading-related areas in dyslexic children, which was particularly active in more demanding tasks (e.g., rhyming of words and non-words). These findings support the hypothesis that children with dyslexia often also display deficits in auditory comprehension of speech input and generally struggle with the processing of phonological properties of words and non-words as well as simpler units like letters and symbols.

KEYWORDS auditory processing, developmental dyslexia, dyslexic children, fMRI, phonological processing, reading circuits

1 INTRODUCTION

Becoming literate is a crucial milestone in every child's life. It opens doors to education, employment, career, social contacts and possibly even adult well-being (Snowling & Hume, 2012). However, not every child manages to master this task. Numerous children face severe difficulties in literacy acquisition and consequently fail to develop age-appropriate reading skills for no obvious reason. Many of these children suffer from a disorder termed *developmental dyslexia* (henceforth *dyslexia*).

Even though dyslexia has been explored in much depth in the past decades, the neural underpinnings of this impairment remain largely unknown to date. Moreover, a considerable number of studies, but very few of the meta-analyses and reviews about dyslexia so far, have explicitly addressed reading processing in children with a diagnosis of dyslexia. Therefore, the following chapter reviews the most recent results on deficient reading processing in children with dyslexia, aged 8–15 years. First, a basic understanding of the symptoms, causes and the prevalence of this impairment will be given. Second, we will have a closer look at reading processing more generally in order to understand possible differences in brain activation in dyslexic individuals in contrast to non-impaired readers. Before analyzing the selected studies, the findings of other meta-analyses that primarily investigated adults and teenagers suffering from dyslexia will briefly be discussed. Finally, the findings of 24 functional magnetic resonance imaging (fMRI) studies conducted between

2000 and 2016 investigating children with dyslexia will be summarized and interpreted accordingly.

1.1 **Developmental dyslexia**

Dyslexia is a specific reading disorder marked by substantial deficits in reading achievement below the expected level given a child's chronological age (World Health Organization, 2015). It also usually affects spelling and writing in spite of normal intelligence and educational opportunity (Bishop & Snowling, 2004; Snowling & Göbel, 2010). Dyslexia is said to affect about 5–10% of the population (Landerl, Fussenegger, Moll, & Willburger, 2009; Siegel, 2006), but numbers ranging from 2.28%–3.9% (Miles, Haslum, & Wheeler, 1998; Sun et al., 2013) to 7.49% (Jepkoech, Mathai, & Kumar, 2015) and even 17–20% (as mentioned in Ozernov-Palchik & Gaab, 2016) have been reported. Prevalence rates vary mostly due to inconsistencies in assessing and defining dyslexia and differences due to the language and writing system being acquired. In addition, gender-ratio remains a highly debated issue. Studies with dyslexic children have reported gender ratios between 2:1 and 15:1, with girls usually being less frequently diagnosed and less severely affected (Hawke, Wadsworth, Olson, & Defries, 2007; Miles et al., 1998; Shaywitz, Shaywitz, Fletcher, & Escobar, 1990; Sun et al., 2013).

Even if prevalence rates vary and the gender-ratio is debatable, there is clear indication for the heredity of dyslexia because family history is considered the strongest risk factor. Research has shown that 68% of identical twins and 40–60% of children with one parent suffering from dyslexia are affected (Fisher & Francks, 2006; Francks, MacPhie, & Monaco, 2002). However, it seems that the interplay of various genes is responsible for the development of this impairment and the search for a specific causative agent is therefore extremely challenging (for a summary see Mascheretti et al., 2017). Recently, for instance, phonological deficits in dyslexics were linked to genetic anomalies of the temporal lobe (Giraud & Ramus, 2013), but more research is needed to confirm this finding. Regarding behavioral deficits, pre-literacy skills (skills at the intersection of phonology and written language) remain the most robust predictor among kindergarten children, including *letter-sound knowledge*, *phonological awareness* (awareness of the sound structure of syllable

bles, words and sentences) and *rapid automatized naming* (rapid naming of words) (Landerl et al., 2009; Landerl & Wimmer, 2008; Olzernov-Palchik & Gaab, 2016).

Theories concerning the origin of dyslexia are diverse and still hotly debated (Goswami, 2015) and despite the contributions of neuroimaging methods to this debate, no simple common ground can be found so far (Ziegler, 2006). While earlier studies considered a visual processing deficit, it is now mainly believed that dyslexics have incomplete or deficient representation, storage and retrieval of phonological input, which leads to faulty *grapheme-phoneme correspondences* (Ramus et al., 2003). However, this so-called *phonological awareness theory* cannot account for the variety of sensory deficits (e.g., visual, auditory, motor skills) frequently observed in dyslexics (Eden & Zeffiro, 1998; Goswami, 2015). A comprehensive review by Hämäläinen, Salminen and Leppänen (2013), for instance, has even revealed that up to half of all children diagnosed with dyslexia display major auditory deficits. Moreover, since not all children display the same visual, auditory or phonological deficits, there has been discussion as to whether dyslexia could be present in a variety of subtypes or should generally be considered a multi-deficit disorder (Fostick & Revah, 2018).

1.2 Reading and the brain

Learning to read fluently is a long and complex process that requires a highly organized brain system specialized for the integration of the four subcomponents related to reading: pre-lexical, phonological, orthographic and lexico-semantic processing¹ (Liebig et al., 2017; Sandak, Mencl, Frost, & Pugh, 2004). Furthermore, metacognitive resources, instructional factors and individual differences, such as motivation, practice and experience, also heavily influence literacy acquisition (Snowling & Göbel, 2010).

¹ The four subcomponents of reading designate the basic processes taking place when an individual is reading. While pre-lexical refers to the processing of units smaller than words, lexico-semantic processing refers to the stage at which whole words are processed and their semantic information is retrieved automatically (Sandak et al., 2004).

According to the classical neurological model of reading (Pugh et al., 2001), the highly intertwined reading network comprises three core areas: (1) a left dorsal temporo-parietal network [including superior temporal areas and the inferior parietal lobule (IPL)], (2) a left ventral occipito-temporal network [involving extrastriate cortex, fusiform gyrus (FG), inferior temporal areas and the visual word form area (VWFA)] and (3) a left inferior circuit [inferior frontal gyrus (IFG) and precentral gyri (PrCG)]. The first area is believed to be involved in phonology-based reading (grapheme-phoneme conversion, phonological assembly), whereas the second plays an essential role in visual-orthographic word recognition. The third circuit in the frontal lobe is linked to speech-gestural articulatory recoding of written words (Liebig et al., 2017; Martin et al., 2015; Pugh et al., 2001).

Liebig et al. (2017) state that it has often been assumed that each basic subcomponent of reading can be linked to one specific neural network. Identifying letters, for instance, is primarily linked to the occipital cortex (more specifically to the VWFA), while whole words would be more likely to be computed in the ventral stream only [inferior temporal gyrus (ITG), middle temporal gyrus (MTG) and IFG]. When dyslexic children have difficulties with literacy acquisition, they would possibly rely more on the dorsal stream [superior temporal gyrus (STG) and parietal cortex], since grapheme-to-phoneme conversion and phonological analysis are performed therein. Adding difficulty to this process, both routes (ventral and dorsal) rely on the IFG and the insula, which are thought to be of great importance for the integration of information and adding semantic knowledge to what has been read (Binder, Desai, Graves, & Conant, 2009) as well as for processing and making decisions. In other words, even though one or the other processing stage might be more linked to one network or circuit, they cannot function properly without one another. Furthermore, it has only partly been revealed what happens when specific parts are deficient and have to be compensated for and how this affects later processing stages.

Although studies have provided evidence that these core circuits are already spatially restricted and lateralized in children, e.g., during single-word reading (Brem et al., 2010; Church, Coalson, Lugar, Petersen, & Schlaggar, 2008), age-related changes have only been marginally addressed so far. A decreased reliance on phonological mechanisms com-

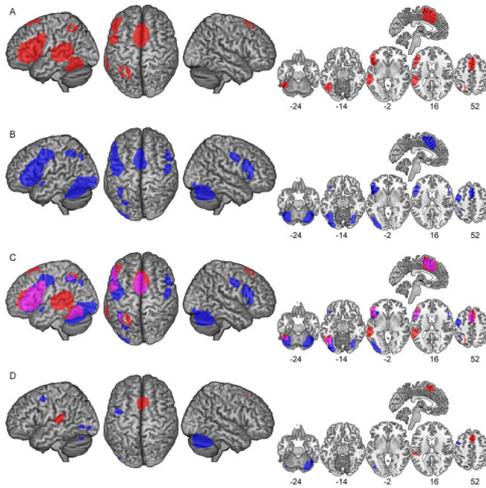


Figure 1. A comparison of brain activation in two age groups in 40 fMRI studies during reading-related tasks. (A) Brain activation in children (7–12 years) in red. (B) Brain activation in adults in blue. (C) Overlapping activation between both age groups shown in pink. (D) Direct comparison between adults and children (Martin et al., 2015, p. 1970).

bined with an increased reliance on visual mechanisms could be one age-related change from child- to adulthood (Church et al., 2008; Pugh et al., 2001). A meta-analysis by Martin, Schurz, Kronbichler and Richlan (2015) has also found differences between reading processing in adults and children, which may highlight developmental processes and possible adjustments due to reading experience and practice. Martin and colleagues extended Houdé, Rossi, Lubin and Joliot's (2010) meta-analysis on reading processing in healthy adults and children, analyzing 20 fMRI studies with adults and 20 with children (7–12 years). Despite a very common pattern of brain activation in both groups in left ventral occipito-temporal, inferior frontal and parietal areas, within-group convergence was found in many reading-related areas in both groups. Differences between children and adults were evident in both the extent and location of the reading-related activation clusters in the core reading circuits (e.g., the inferior frontal cortex including the motor cortex, the superior temporal lobe, small areas in the superior parietal lobe and

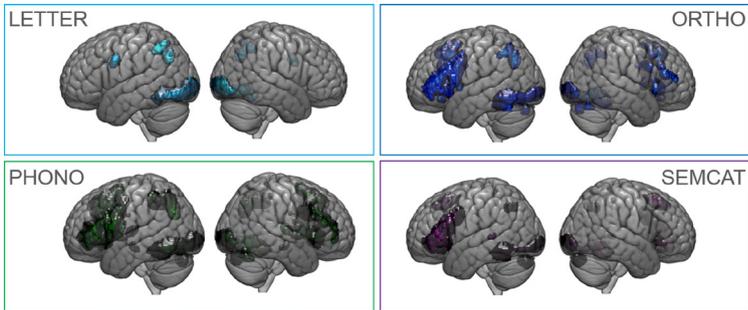


Figure 2. Differences in brain activation in children when performing different tasks: letter identification, orthographic decision, phonological decision and semantic categorization (Liebig et al., 2017, p. 49).

the temporo-occipital area; see Figure 1). Moreover, the shift of the more temporal focus towards the dorsal areas (the occipital lobe) in the left hemisphere from child- to adulthood is clearly visible.

In a single study, Liebig et al. (2017) intended to shed light on differences in reading processing in children applying four different tasks related to the four subcomponents of reading. They applied *letter identification* (processing stage: pre-lexical; task: detect letters in words/non-words), *orthographic decision* (processing stage: orthographic; judge whether a presented letter string is a correctly spelled word or a pseudohomophone²), *phonological decision* (processing stage: phonological; judge whether a visually presented word sounds like a real word or not) and *semantic categorization* (processing stage: lexico-semantic; decide if a word is a living or non-living object). The results confirm differential activation according to task type (see Figure 2). Regardless of the specific task, however, engagement primarily involved the core reading circuits with the exception of the cerebellum, which is known to play an extraordinary role in language processing and dyslexia.

² *Pseudohomophone* refers to a word that sounds like a real word but is spelled differently (e.g., ‘Haus vs. Hauß’ in German – only the first is a German word but both are pronounced exactly the same way; Liebig et al., 2017).

To summarize, reading relies on the interconnection and general functioning of a number of areas designated as core reading circuits. These areas are engaged in a similar fashion in both children and adults, but there are slight age-related differences concerning extent and location of activations (Figure 1). Additionally, the specific task and processing stage in a study may lead to very distinct activation profiles (Figure 2). When investigating functioning of these reading circuits in dyslexics, it is thus inevitable to pay close attention to the precise age of the individuals and the employed tasks.

1.3 Reading processing in dyslexics

Behavioral differences between impaired and non-impaired readers have been thoroughly explored up to now (e.g., Landerl et al., 2013), but little is known about the underlying neural deficits or anomalies that characterize this reading impairment. Since there are three main reading circuits that need to work in concert for successful reading (Pugh et al., 2001), it seems plausible to argue that at least one of the three, or the interaction between them, must somehow be deficient in dyslexics. So far, quite a large number of single studies with small sample sizes but few meta-analyses have focused on uncovering differences in brain activation between children suffering from dyslexia as compared to healthy controls.

As a first step, let us briefly examine the few meta-analyses that have attempted to explore the suspected anomalies in brain activation in dyslexic children and adults. With regard to terminology, it is noteworthy to state that authors usually report under-/overactivation when talking about significantly less or more activation of dyslexics in contrast to non-impaired peers (i.e., the two terms do not designate increasing or decreasing activation as the name might imply).

Maisog, Einbinder, Flowers, Turkeltaub and Eden (2008) performed a meta-analysis on dyslexia focusing on teenagers and adults. They reported overactivation in dyslexics in right thalamus and insula, and underactivation in left ventral extrastriate cortex, ITG, FG, precuneus and right FG. They concluded that left-hemispheric areas are more active in non-impaired readers, while greater right-hemispheric activity (seen as compensatory activation) is indicative of dyslexia.

Richlan, Kronbichler and Wimmer (2009) analyzed 17 fMRI studies in which dyslexic children, adolescents and adults performed reading-related tasks. They reported significant underactivation in dyslexic individuals (regardless of age) in left-hemispheric IPL, STG, MTG, ITG and FG. Moreover, they reported more activation in inferior frontal regions (mostly IFG) in controls while motor areas were activated more strongly in dyslexics. The studies included in Richlan et al. were further included in a larger meta-analysis by Paulesu, Danelli and Berlinger (2014; 53 fMRI studies altogether), who reported very similar findings. They emphasized that single-word reading is marked by dysfunction of left occipito-temporal areas and/or left temporo-parietal areas, the latter assumed to display an early dysfunction of phonological processing. Through their meta-analysis, Paulesu et al. (2014) confirmed the importance of left occipito-temporal cortex in normal populations alongside a lack of such engagement in dyslexic individuals.

Major drawbacks of the last two meta-analyses, however, are that they compared the results of studies with children even if they were not diagnosed as dyslexic but referred to as *poor readers*, and these meta-analyses only differentiated between two age groups, namely adults (18 or older) and children (18 or younger). This is not an ideal approach as the groups are inhomogeneous and Martin et al. (2015) have shown that between adults and children reading activation differences exist. Therefore, only half of the studies with children in Paulesu et al. (2014) were considered suitable for the present review. Additionally, one of the major issues that arises when working with dyslexic children is that training and practice may significantly affect (and supposedly improve) reading performance and brain activation. Therefore, including teenagers of 17 years and comparing their results to children aged 8–12, for instance, should certainly be avoided.

In contrast, a small meta-analysis (18 studies) by Richlan, Kronbichler and Wimmer (2011) examined studies with children between 9 and 11 years of age and compared them to young adults (nine studies for each age group). They found that dyslexic children had less activation compared to peers in left IPL and supramarginal gyrus (SMG). Additionally, they reported a small cluster in the right IPL and in the left ventral occipito-temporal cortex (VWFA). Slight overactivation in dyslexic children was only found in the frontal lobe (IFG) and PrCG. To summarize

the findings by Richlan et al. (2011), substantial differences exist when comparing adults and children with dyslexia in a more controlled manner. This is a clear indication that mixing different groups of adults, teenagers and children may obliterate important developmental age-related differences.

2 METHODOLOGY

The major aim of this review is to provide the reader with a wide-ranging overview of studies involving dyslexic children of the past two decades. Such a review is needed to finally pinpoint the neural underpinnings of dyslexia, while eliminating the major drawbacks encountered in earlier analyses. In contrast to the aforementioned meta-analyses, only a rather limited age range (8–15 years) and only reading-related and auditory tasks were included. Overall, this review summarizes 24 fMRI studies investigating different processing mechanisms related to reading in dyslexic children. fMRI studies were first collected through Google Scholar and PubMed using the key words “dyslexia AND fMRI”, “reading processing AND dyslexia” and “children AND fMRI AND dyslexia”.³ Studies were included if they met the following criteria:

1. Participants are children (8–15 years) with an official diagnosis of dyslexia and without any comorbidities (e.g., dyscalculia, attention deficit disorder).
2. Participants are monolingual speakers of alphabetic languages.
3. The study applies one or more reading-related tasks (i.e., reading, rhyming or auditory tasks) during an fMRI session.
4. At least one control group, either age-matched or reading-matched, is present.
5. Whole-brain analysis is performed (i.e., no mere region of interest analyses).

³ A list of abbreviations of brain regions commonly used in the following sections is provided at the end of the chapter.

6. If the study uses intervention or remediation, only the results before treatment are taken into account.

In total, 24 studies conducted between 2000 and 2016 fulfilled these criteria and were thus included in the review. A time span between 2000 and 2016 was chosen because neuroimaging has been widely used since 2000, in particular with children, and dyslexia has received increasing interest in the cognitive neurosciences at the end of the 20th century.

It should be mentioned again that this chapter provides a review and not a meta-analysis. Sample size and statistical significance are usually not taken into account in a review, and thus the results have to be treated with some caution.

2.1 **Tasks**

The aforementioned meta-analyses differentiated mainly between reading-related and non-reading-related tasks. For the sake of simplicity, all non-reading related tasks were excluded and all relevant tasks were categorized into two umbrella categories, namely (1) auditory processing and (2) reading processing (including all phonological, orthographic and semantic tasks). A further differentiation of tasks only seems meaningful in the latter category, where three specific task categories, namely *rhyming* (focus on phonological aspect), *reading* and *other tasks* are distinguished (see Table 1 for a general overview of all tasks used in the studies). It is important to note that many tasks are merely applied to guarantee that subjects pay attention to the stimuli, and the main task is just reading. For instance, lexical decision tasks require subjects to read a word (e.g., cat) or non-word (e.g., cit) and to decide whether it is a real word in the native language or not. In this case, what researchers are really interested in, is the activation for reading the word or non-word and not the decision subjects make, even if this might lead to activation for decision-making processes.

Table 1. Summary of all tasks employed in the studies of this review together with a brief instruction of what participants were asked to do

Task	What did participants have to do?
Auditory discrimination	Listen to and discriminate between given acoustic stimuli/sounds (e.g., /ba/ vs. /da/ or /b/ vs. /p/)
False font reading	Read false fonts
Letter rhyming	Decide whether given letters rhyme (e.g., b and t)
Lexical decision	Decide whether a given presented word/non-word is a real word or not (e.g., cat vs. cit)
Morpheme mapping	Make associations between elements (affixes) that carry grammatical information and the meaning attached to them (e.g., build and builder)
Non-word reading	Read non-words/pseudo-words ⁴
Non-word rhyming	Decide whether non-words rhyme (e.g., hime and brime)
Passive listening	Listen passively to acoustic stimuli, such as speech sounds, words or non-speech sounds
Phoneme/orthographic mapping	Make associations between sounds and letters or letter combinations
Semantic judgment	Decide whether two presented items are semantically (meaning-wise) related (e.g., table and desk; anger and floor)
Sentence reading	Read full sentences
Silent/overt word generation	Generate words (either silent or overt) after having seen a given image/word
Symbol reading	Read a symbol
Word reading	Read single words
Word rhyming	Decide whether presented words rhyme (e.g., mine and fine)

⁴ The terms non-word and pseudo-word refer to words that do not actually exist in a language but follow the phonotactic rules of the language (for instance, 'brime' is not an English word although one could probably imagine it being one because it follows the phonotactic rules of English). The two words are used interchangeably in studies.

2.2 Studies and participants

All children had alphabetic languages (German, Swiss German, English, Dutch, French or Norwegian) as their native languages. Initially, the age range was set to 8–12 years, but since Hoeft et al. (2007) and Shaywitz et al. (2002) included an impressive number of participants and applied highly relevant reading-related tasks, these two studies were included as well, which led to a redefinition of the age group to 8–15 years. For a complete list of all studies and the used tasks, as well as information on the number and age of participants, see Table 2.

Table 2. Complete list of all studies selected for the review including number of participants, number of dyslexics, mean age of participants and tasks applied (differentiating between auditory and reading tasks)

Study	Year	Participants		Task(s) (A/R)
		Number (D)	Mean age	
Aylward et al.	2003	21 (10)	11.6	Phoneme mapping, morpheme mapping (R)
Backes et al.	2002	16 (8)	11.5	Non-word rhyming, semantic judgment (R)
Baillieux et al.	2009	22 (15)	11.4	Silent word generation (R)
Blau et al.	2010	34 (18)	9.4	Passive listening (A)
Boros et al.	2016	33 (15)	11.5	Non-word reading, false font reading (R)
Cao et al.	2006	28 (14)	11.6	Word rhyming (R)
Corina et al.	2001	16 (8)	10.8	Word rhyming, non-word rhyming, lexical decision (R)
Gaab et al.	2007	45 (22)	10.5	Passive listening (A)
Georgiewa et al.	2002	17 (9)	12.6	Word reading, non-word reading (R)
Heim et al.	2010a	40 (20)	9.6	Auditory discrimination (A), phonological decision (R)
Heim et al.	2010b	37 (18)	9.4	Overt word reading (R)
Hoeft et al.	2006	30 (10)	10.4	Word rhyming (R)
Hoeft et al.	2007	53 (23)	14.4	Word rhyming (R)
Kovelman et al.	2012	39 (12)	9.0	Word rhyming (R)
Maurer et al.	2011	27 (11)	11.4*	Word reading, symbol reading (R)

Study	Year	Participants		Task(s) (A/R)
		Number (D)	Mean age	
Monzalvo et al.	2012	46 (23)	9.9	Word reading (R), passive listening (A)
Morken et al.	2014	29 (11)	11.8	Word reading, sentence reading (R)
Olulade et al.	2015	28 (16)	10.0	False font reading (R)
Richards et al.	2006	39 (18)	10.9	Phoneme mapping, morpheme mapping, orthographic mapping (R)
Schulz et al.	2008	52 (16)	11.6	Sentence reading (R)
Schulz et al.	2009	45 (15)	11.6	Sentence reading (R)
Shaywitz et al.	2002	144 (70)	13.3	Letter rhyming, non-word rhyming, semantic judgment (R)
Temple et al.	2000	39 (24)	10.7	Letter rhyming, letter matching (R)
Van der Mark et al.	2009	42 (18)	11.3	Phonological decision (R)

Note. D dyslexics; *rough estimates as not indicated in the study (e.g., due to exclusion of participants); Tasks: (A) auditory processing, (R) reading processing.

Given the lack of a larger review of studies investigating brain activation differences in dyslexic children only, I have decided to make an attempt to fill this gap. There is no doubt that behavioral differences are of great significance for understanding dyslexia but (1) there is already an impressive body of research on this topic and (2) behavioral differences cannot help us uncover the underlying impairment in terms of anomalies in the human brain (be it structurally or functionally). It is often argued that the brains of dyslexics function differently, and many fMRI studies have tried to investigate these differences. Still, small-scale studies do not allow a proper evaluation of the nature of this impairment and only reviews and meta-analyses can provide us with a clearer picture.

Of the 24 studies I considered suitable after the first screening, I investigated every single study looking at the participants (diagnosis, age, first language) and the tasks applied in the study (see Table 1), and made sure they analyzed the results of whole brain analyses. The behavioral findings are only of marginal interest for me in this review, and therefore they will only be addressed in a brief, separate section. The major focus lies on the neural findings in the form of brain activation during certain linguistic and non-linguistic tasks.

3 RESULTS

3.1 Behavioral findings

In all reading-related measures and auditory tasks (see Table 1 and 2 for a complete overview of tasks), the control group significantly outperformed the dyslexic group. Very few studies failed to detect differences between the two groups. Concerning the control tasks (line orientation, visual tasks or letter detection), no differences were reported between dyslexics and their age-matched peers, except for auditory tasks involving tone judgment or passive listening.

3.1.1 Accuracy and reaction time

Almost all studies reported that during reading-related tasks (e.g., reading pseudo-words, words, pseudohomophones or sentences), controls outperformed dyslexics with respect to accuracy (Blau et al., 2010; Hoeft et al., 2007; Shaywitz et al., 2002; Schulz et al., 2008; Van der Mark et al., 2009). Monzalvo, Fluss, Billard, Dehaene and Dehaene-Lambertz (2012) reported that more generally, reading time was faster and error rate was considerably lower in controls as compared to dyslexics. Interestingly, they could also link a low socio-economic status to a tendency to produce more reading errors.

Dyslexics were particularly less accurate and slower during the non-word rhyming and the semantic categorization tasks (Backes et al., 2002). In Boros et al. (2016), reaction times did not differ, but dyslexic children were also less accurate in letter and digit reading. However, no interaction was found between group (impaired vs. non-impaired) and stimuli (letters vs. digits) presented. Mainly, a lack of engagement in a variety of areas and an activation of the *default-mode network*⁵ instead might be responsible for the difficulties encountered (Boros et al., 2016).

The more difficult the task, the larger the discrepancy between the performances of the groups. Increasing difficulty in conflicting trials led

⁵ The default-mode network is a resting state network that shows a decrease in activation as soon as a task is performed by an individual. It comprises the precuneus, posterior cingulate cortex, anterior cingulate cortex and temporo-parietal junction areas (Heine et al., 2012).

to less accuracy and delayed responses in impaired readers, although dyslexics were slower and less accurate more generally in all tasks as reported by Cao, Bitan, Chou, Burman and Booth (2006). This increasing difficulty for dyslexics was confirmed by greater activation in conflicting vs. non-conflicting trials in bilateral IFG and left-hemispheric regions in temporal areas, FG and the parietal lobe. In other words, the increasing complexity and difficulty of the task led to overactivation in a large network of areas, especially in IFG, the region responsible for making decisions, executing and joining orthographic and phonological information.

Although most studies found delayed responses and worse accuracy in dyslexics, a number of studies did not detect differences in response times or failed to detect any group-related differences at all. In Morken, Helland, Hugdahl and Specht (2014), accuracy and response time did not differ between the two groups during alphabetic and sentence processing, but differed significantly between the groups in the orthographic processing task (reading of long and irregular words). This is interesting because brain engagement showed large discrepancies in all three processing stages, that is, during all tasks, which could not be confirmed behaviorally.

Similarly, applying false font reading and letter detection, Olulade, Flowers, Napoliello and Eden (2015) failed to detect an effect due to condition (accuracy during tasks), but they observed a group effect regarding response times with dyslexics responding more slowly than the control children. They reported that both groups actually scored very high in the real word and false font reading tasks, which might indicate ceiling effects. On the other hand, the behavioral findings do not support the differences in engagement detected with the help of fMRI because differences between controls and dyslexics were confirmed in both tasks. Furthermore, Van der Mark et al. (2009) reported that false-font and word reading did not reveal any differences between the performances of the two groups.

In sum, while reaction times between the two groups did not often differ significantly (e.g., Boros et al., 2016; Corina et al., 2001), accuracy was far worse in dyslexic children with very few exceptions (Morken et al., 2014; Olulade et al., 2015). The more complex the task, the larger the differences in behavioral performance.

3.1.2 *Auditory processing*

The *auditory deficit hypothesis* is supported by Gaab, Gabrieli, Deutsch, Tallal and Temple (2007), reporting that even in a pitch discrimination task of a non-linguistic nature, dyslexics respond less accurately compared to age-matched peers. Measures of language and reading ability led to significant differences between the two groups. Even after remediation and improvement in dyslexics as compared to constant results in the non-impaired group, dyslexics significantly underperformed controls. In another study by Temple, Poldrack, Protopapas, Nagarajan and Salz (2000), controls were more accurate for rapid and slow non-speech analogues than dyslexics and, not surprisingly, accuracy was greater for the slow stimuli more generally. However, no interaction between group and stimulus type and no difference in response time was reported. Specifically, phonological awareness and phonological decoding revealed significant deficits in the reading-impaired children (Blau et al., 2010). Also in Corina et al. (2001), dyslexics were less accurate in lexical decision and tone judgment tasks (mainly requiring auditory processing). Still, brain activation differences reflected discrepancies during both tasks, and more specifically, tone judgment difficulties were related to a lack of engagement of the parietal cortex.

3.1.3 *Performance of control groups*

Interestingly, the studies that included two control groups (Hoeft et al., 2006; Hoeft et al., 2007), namely one age-matched group and one reading-level-matched (younger children) group, showed that there were no differences in response time and accuracy between the latter and the dyslexics. In fact, only the age-matched peers outperformed the reading-impaired children and the reading-matched group. Hoeft et al. (2006) highlighted reading deficits regarding receptive vocabulary and IQ in the dyslexics. However, their study also revealed that nonsense word decoding and comprehension showed differences between dyslexics and their age-matched peers but not with their reading-matched peers. In other words, reaction time and accuracy were only significant between impaired readers and their age-matched peers. This confirms that dyslexics fail to develop age-appropriate reading skills, but there is

nothing that distinguishes dyslexic children from those of the same reading-level. Dyslexics suffer from a severe developmental delay and their deficits might indicate a lack of reading exposure and experience, but this is usually not the case.

3.1.4 *Visual tasks*

During all kinds of control tasks, such as visual tasks (line orientation and string comparison), no differences between dyslexics and non-impaired readers were found. It has been a matter of debate whether dyslexia is mainly a visual deficit, but this could not be supported by the behavioral results of this review. With regard to differences in brain activation, line orientation led to higher activation in parietal cortex in control and in left lateral extrastriate cortex in dyslexics, but the behavioral performance was not affected.

In sum, behavioral deficits and discrepancies were confirmed in almost all studies with respect to slower response and higher accuracy for the control groups compared with the dyslexics. Most strikingly, even if studies found large differences on the neural level (i.e., significantly more or less activation in a number of areas or compensatory activation), some studies only found minor or no differences in behavioral performance between the groups. Furthermore, only age-matched peers significantly outperformed dyslexics, while those studies introducing reading-matched groups reported no differences.

3.2 **fMRI findings**

3.2.1 *Group-related differences in auditory processing*

Gaab et al. (2007), Monzalvo et al. (2012), Blau et al. (2010) and Heim et al. (2010a) focused on auditory processing and found (1) less activation differentiation for slow and fast stimuli, (2) weaker auditory incongruency effects in auditory cortex (AC), (3) reduced right and left frontal activation during phonological awareness and (4) small regions of compensatory activation in the dyslexic population (in particular in the right hemisphere).

Gaab et al. (2007) investigated passive listening to acoustic stimuli with either slow or fast transitions. The control group showed higher

activation for rapid vs. slow stimuli in the left prefrontal cortex primarily in superior and medial frontal gyrus (SFG, MFG) and right-hemispheric areas (including peri-sylvian regions). In dyslexics, the left MTG was the only region showing activation for the fast vs. slow distinction, which indicates a lack of specialization for this particular task.

In the study of Blau et al. (2010), children had to listen to speech sounds while reading Dutch letters (pairs were either matched or deviant). They found that children with dyslexia had significantly weaker activity for processing speech sounds in anterior STG and for processing letters in FG bilaterally. Moreover, they observed that fluent readers showed a congruency effect close to the primary AC (Heschl's sulcus), which was absent in all dyslexics.

In the study by Heim et al. (2010a), a variety of tasks was applied. For testing phonological awareness, participants heard words and pseudo-words and had to indicate the initial sound of each word (single choice). The auditory discrimination task included words and non-lexicalized syllables, and the participants were required to indicate if the speech sound pairs were identical or not (e.g., /ba/ – /pa/). According to their findings, dyslexics showed higher activation in the left inferior frontal lobe (inferior frontal sulcus and MFG) during auditory sound discrimination tasks. Additionally, dyslexics had more activation in frontal areas during this task, whereas phonological awareness was linked to reduced activation in the left frontal cortex (only at uncorrected level, however) and reduced activation in the right fronto-medial wall (superior medial gyrus).

Finally yet importantly, Monzalvo et al. (2012) investigated both visual and auditory processes in dyslexic children. In their visual experiment, houses, faces, words and a checkerboard were presented. In their auditory task, on the other hand, 40 sentences in the subjects' native language (French) and in a foreign language were presented. They discovered that the control group had higher activation in supplementary motor area (SMA) bilaterally and the right temporal region when listening to the short French sentences. Only marginal clusters were found in the left hemisphere, for instance, in planum temporale (PT) and insula, and slight activation asymmetries were found in the temporal cortex (e.g., normal readers were more right lateralized in auditory areas extending to SMG).

3.2.2 *Reading processing in dyslexic children*

3.2.2.1 Rhyming tasks

The variety of rhyming tasks used by the selected studies led to under- and overactivation in several regions. Non-word rhyming, on the one hand, led to significant overactivation in all reading-relevant brain regions, with little or no activation in areas that were not engaged in the control group. Word and letter rhyming, on the other hand, were marked by more frequent compensatory activation (right-hemispheric and bilaterally) together with a lack of engagement of the core reading circuits as reported in the non-word rhyming tasks.

Backes et al. (2002) and Shaywitz et al. (2002) used non-word rhyming tasks. Dyslexics exhibited less activation in left inferior prefrontal regions and left cingulate gyrus, and in contrast to controls, did not activate the superior temporal cortex (bilaterally) at all. Instead, dyslexics activated the left extrastriate cortex (Backes et al., 2002). In Shaywitz et al. (2002), controls exhibited more activation in core left hemisphere regions, namely IFG, posterior STG, MTG and right-hemispheric IFG, STG, MTG and medial orbital gyrus. No compensatory activation was found in dyslexics.

Corina et al. (2001) applied both non-word and word rhyming and suggest that dyslexics differ in auditory language processes (rhyming) and attention processes. They reported asymmetry during rhyming in ITG (left > right in controls, vice versa in dyslexics) and PT (left more in controls), and underactivation of dyslexics in PrCG, MFG. Altogether, the lexical task they applied additionally engaged more regions in both groups, resulting in many regions of difference, such as less bilateral insula, left ITG and IFG.

The following four studies relied on word-rhyming tasks only. Cao et al. (2006) included non-conflicting (easy) and conflicting (difficult) trials, which posed heavy demands on phonological processing. Only the more challenging trials led to different activation patterns, namely more activation in controls in bilateral IFG and left-hemispheric ITG, FG, IPL and MTG (i.e., areas in all core circuits involved in reading). Without considering difficulty levels, Hoeft et al. (2006) found that age-matched controls engaged the left parieto-temporal cortex, right parieto-temporal regions, two frontal regions and right occipito-temporal cortex more

than dyslexics. They state that the core differences between groups can be found in three regions, namely the frontal lobe, the parietal lobe and the temporal lobe. In a follow-up study, Hoeft et al. (2007) reported more activation in control children in left IPL, bilateral FG and lingual gyri. The dyslexics, on the other hand, engaged the left IFG, left MFG, left caudate and right thalamus more often. Kovelman et al. (2012) had rather opposing findings to those observed in previous studies. Dyslexics showed greater activation in the right temporo-parietal region including STG, MTG and angular gyri (AG). In contrast, controls activated more strongly the left dorso-lateral prefrontal cortex for rhyming in contrast to the baseline task.

Several studies applied word or non-word rhyming tasks known to elicit phonological processing areas. Temple et al. (2000) employed the simplest task, namely letter rhyming. Whereas the control group activated the left temporo-parietal cortex, dyslexics did not engage this region at all. Dyslexics, however, had higher activation in many regions, for example, in the bilateral SFG, right IFG, right MTG, bilateral PrCG and postcentral gyri and right-hemispheric occipital areas [middle occipital gyrus (MOG) and inferior occipital gyrus (IOG)], as well as in bilateral basal ganglia and right vermis.

3.2.2.2 Reading tasks

The majority of studies included in this review laid their focus on silent or overt reading of linguistic material, such as reading words, letters, symbols, digits, non-words and sentences. In the following subsections, studies involving words and sentences will be discussed separately due to the large number of studies employing these tasks. The other types of stimuli, namely letters, symbols, false fonts and non-words, will be presented in a separate section.

LETTERS, SYMBOLS, FALSE FONTS AND NON-WORDS. Using a letter-reading task, Boros et al. (2016) found that controls exhibited more activation in right STG and bilateral MOG. Dyslexics, on the other hand, had more default-mode-network activation bilaterally in parietal, temporal and frontal lobes. Similarly, controls activated left FG (peak in left occipital-temporal cortex) anterior to VWFA and right MFG more

strongly during false font reading (Olulade et al., 2015). Also in Boros et al. (2016), false font reading led to higher activation in temporal and occipital areas (MOG) bilaterally. Reading symbols, on the other hand, led to higher activation in the left ventral visual stream, temporal areas bilaterally and frontal areas in controls. In accordance with the letter reading task, the default mode network showed higher activation in the dyslexics. During non-word reading, mainly temporal (ITG, MTG) and occipital gyri (IOG, MOG) bilaterally showed higher activation in controls (Boros et al., 2016).

WORDS. Most studies applied silent reading of words. Georgiewa et al. (2002) reported that the three core areas of activation in dyslexics were (1) left IFG, insula and STG, (2) left thalamus and (3) left nucleus caudatus. Additionally, contrasting words vs. pseudohomophones led to stronger engagement of left IPL, STG and insula, whereas pseudo-words vs. words led to no significant distinction between the groups (Van der Mark et al., 2009). Contrary results were found by Heim et al. (2010a), who reported differences in word vs. pseudo-word reading mainly in the right fronto-medial wall and left IFG.

Maurer et al. (2011) observed increased activation for controls in inferior occipito-temporal regions extending to VWFA when subjects had to read normal words. Also in Van der Mark et al. (2009), processing words vs. false fonts led to more activation in inferior and occipital regions in the left hemisphere, plus bilateral cingulate and right-hemispheric cuneus activations. Only one study reported hyperactivation in left IFG, insula and lingual gyrus in dyslexics (Georgiewa et al., 2002); the other studies found no word-specific overactivation in impaired readers (Van der Mark et al., 2009).

Morken et al. (2014) added some complexity to the design by using regular and irregular words and found differences in several regions (involving bilateral frontal areas, SMA, cerebellum, thalamus etc.) but mostly in the form of hyperactivations of dyslexic children due to increasing difficulty. Generally, they argued that six regions were related to increasing processing demands, namely right SFG, left pre-SMA, left nucleus caudatus and right SFG and MFG. They therefore stated that these areas may show considerable differences in activation between dyslexics and controls.

In the study by Baillieux et al. (2009), subjects had to generate words from cues. The authors reported more diffuse and widespread left-hemispheric activations in temporo-occipital, temporo-parietal and occipital areas in dyslexics. Additionally, they found that activation in the cerebellum differed extensively between the two groups. In Heim et al.'s study (2010b), overt word reading activated frontal, parietal AG and temporal regions in both hemispheres, as well as the right hippocampus and the left cerebellum. Dyslexics activated very similar regions, but different tasks were associated with different strengths of activation in dyslexics and controls.

To sum up, reading of single words and smaller units led to striking differences in all core reading circuits, in particular in frontal areas, but few studies reported compensatory activation. Compensatory activation was only reported in two studies (Georgiewa et al., 2002; Morken et al., 2014), one of which applied irregular words and thus added difficulty to the task. It can be argued that simple word reading does not lead to any overactivation due to the simplicity of the task, but if complexity is added, for example by using irregular or infrequent words, additional areas are engaged.

SENTENCES. Differences in sentence reading were not only found between dyslexics and age-matched controls (controls > dyslexics: left IPL, frontal, temporal and fusiform areas) but also between dyslexics and reading-matched controls (controls > dyslexics: bilateral IPL, frontal, temporal and cingulate; Schulz et al., 2009). In an earlier study, Schulz et al. (2008) found similar results, where controls engaged left-hemispheric regions (frontal, IPL) more strongly. In another study by Morken et al. (2014), both groups showed a widespread network of activation, but the control group also activated right MTG and thalamus. The sentence condition generally led to increased activation in dyslexics (the control group showed a decrease, instead) in right SFG and left pre-SMA. Overall, Morken et al. reported hyperactivation due to increasing processing demands in dyslexic children, particularly in sentence processing.

Only three out of the 34 studies applied sentence reading but all reported slight underactivation in frontal, parietal and temporal areas, with minor compensatory areas (right MTG and thalamus). What is more, one study further reported increased activation in dyslexics interpreted to be

due to the increasing demand in sentence reading compared with single word reading.

3.2.2.3 Other tasks

This section deals with phonological, orthographic and morpheme mapping tasks and semantic aspects of word and sentence reading, which were specifically addressed in a number of studies. In Aylward et al. (2003), controls showed more activation in left frontal regions (IFG, MFG), bilateral (left > right) superior parietal regions and slight differences in bilateral AG, SFG, FG and temporal regions (ITG, MTG) during phoneme mapping. Morpheme mapping led to more activation in controls in right FG, right superior parietal regions, bilateral occipito-parietal junction and left MFG, which was not statistically significant, however. Using the same tasks and criteria for groups, Richards et al. (2006) found different activation patterns during all tasks. During morpheme and orthographic mapping, dyslexics only activated about half of the regions that controls activated, but they instead also activated several compensatory regions. Only in phoneme mapping did the two groups engage a similar number of regions, but with different activation profiles (e.g., additional activation of left STG or bilateral activation in controls of thalamus and PrCG, whereas dyslexics only activated one hemisphere).

During semantic categorization in Schulz et al. (2008), dyslexic children showed reduced incongruency effects in the parietal lobe and precuneus. Shaywitz et al. (2002), who found more activation in left parietal, temporal and occipital and right temporal and occipital areas in controls, reported a larger difference for semantic judgment. Wide-spread compensatory activation in dyslexics was reported by Backes et al. (2002), in particular in the right inferior frontal areas as well as in bilateral prefrontal and extrastriate cortex.

It is not possible to summarize these findings in a uniform manner, but to put it in a nutshell, semantic categorization tasks and specifically mapping tasks led to striking differences in neuronal activation, even though they are not the primary focus of most studies investigating dyslexia. The mapping tasks especially are very complex and investigate core principles when it comes to reading acquisition. Discrepancies in

these tasks on the behavioral and neural level highlight the enormous difficulties dyslexic children encounter during literacy acquisition.

4 **DISCUSSION**

In summary, all studies of this review reported different activation patterns in dyslexic children compared with controls in a variety of areas during auditory or reading-related tasks. The most striking differences were a lack of engagement of all core reading areas, namely inferior frontal cortex (including IFG and MFG), the parieto-occipital network (including inferior parietal areas and FG) and temporo-parietal areas (including STG, MTG and PT) together with a network of compensatory activation in bilateral and right-hemispheric areas. The latter, however, was only found in more demanding tasks (e.g., rhyming, mapping and semantic tasks and in some reading tasks). The results of this review should be regarded with some caution, as statistical effect sizes were not taken into consideration, which limits the comparability of the studies included. Nonetheless, the overall findings suggest a tendency towards a large network of engaged regions that seem to be deficient in dyslexic children.

The findings favor the belief that dyslexics engage fewer and/or different brain areas in contrast to non-impaired readers in all tasks related to reading and at different processing stages. In addition, a large number of studies reported bilateral and particularly right-hemispheric compensatory activation in reading-related areas (inferior frontal lobe, inferior parietal areas, FG, temporo-parietal regions). In other words, the compensatory activation was predominant in the right hemisphere, but not limited to it. The areas showing the most striking underactivation in dyslexics during reading processing are primarily those of the left-hemisphere, the so-called core reading circuits as presented in the Introduction. It is interesting to see that rather simple tasks like false font reading, symbol or word reading do not lead to additional engagement of brain areas. This might be due to the simplicity of the task and the fact that the dyslexic children are already familiar with most words which therefore does not pose major challenges to them anymore. Rhyming tasks, on

the other hand, require explicit phonological information and are more complex, in particular when rhyming non-words. Furthermore, sentence processing or processing of irregular words led to additional activation, which is most likely to be due to increasing complexity as well.

In the auditory tasks, differences in activation and asymmetry were reported most often in the classical auditory areas, that is STG, MTG and PT. Since phonological processing deficits are often assumed to be predominant in dyslexics, basic auditory processing has received minor attention in past years. Still, as already mentioned, a comprehensive review has revealed that auditory deficits affect about 30–50% of dyslexic individuals (Hämäläinen et al., 2013), and it therefore seems necessary to investigate different aspects of elementary auditory processing in dyslexics as well. There seems to be poor differential activation for slow vs. fast auditory stimuli in dyslexic children. Segmenting and decoding speech requires engagement of the temporal and prefrontal cortex, and there is evidence for a lack of corresponding IFG integration in dyslexics (Tallal & Gaab, 2006). They are very likely to be impaired in the “ability to track brief, rapidly successive, dynamic acoustic changes within the complex acoustic waveform of speech” (Tallal & Gaab, 2006, p. 382). As a consequence, the processing of single speech sounds and letters is also impaired in dyslexic children. The lack of response to incongruous speech-letter pairs may reflect an insufficient integration of these speech sounds (Heim et al., 2010a). The findings of this review support the hypothesis that many children with dyslexia also experience major difficulties when categorizing, discriminating and integrating single speech sounds. Even if not all children display auditory deficits, these deficits may heavily influence subsequent literacy acquisition. Furthermore, a very impressive longitudinal study (Serrallach et al., 2016) has clearly linked differences in auditory cortex (functionally and structurally) to dyslexia, but it remains to be seen whether developmental changes and improvements might influence these anomalies. To summarize the findings on auditory processing, I argue that auditory processing does not deserve to be overlooked as basic auditory processing may have a considerable impact on literacy acquisition, and the present review clearly speaks for a striking role of deficient auditory processing in dyslexic children. Even if auditory processing deficits are not as striking as phonological

and orthographic integration deficits, they have to be taken into account when further exploring the underpinnings of developmental dyslexia.

Phonological processes are at the core of all reading-related tasks explored in the numerous studies of this review. The capacity to immediately understand the phonological value of a sound or letter (e.g., rhyming letters) in words requires efficient processing in the left and right parieto-temporal cortex, frontal areas and the occipito-temporal cortex. Letter, non-word and word rhyming have been found to mostly engage the three core circuits with a focus in the temporo-parietal region. In dyslexics, letter rhyming revealed deficits mainly in temporo-parietal areas combined with a large compensatory network in right and bilateral areas in occipital and frontal lobes and motor areas. Apart from these findings, reduced functional connectivity was confirmed in Hoeft et al. (2006) in the left occipito-temporal cortex and middle occipital cortex, left MTG, STG and insula, that is affecting all areas relevant for mapping auditory and visual input. Non-word rhyming, in contrast, led to compensatory activation in dyslexic children in the left extrastriate cortex. Significantly less activation was found in the prefrontal cortex (IFG) and temporal areas and additionally, dyslexics failed to engage bilateral temporal areas and IPL. Also word rhyming requires the three core circuits for reading, namely parieto-temporal, frontal and occipito-temporal cortex. Especially IFG bilaterally and right-hemispheric temporal cortices (MTG and ITG) led to differential activation in dyslexics (Kovelman et al., 2012). Furthermore, the more phonologically demanding the word pairs, the more differences found between dyslexics and controls (Cao et al., 2006).

To summarize, rhyming tasks led to striking underactivation as well as overactivation (i.e., compensatory activation; bilaterally and on the right) possibly due to the more challenging nature of the task. Both the occipito-temporal and the temporo-parietal cortex seem to be heavily involved and thus severely impaired in dyslexics, which would explain their significantly worse performance on all rhyming tasks and their slower response times. Hand in hand with the significant underactivation in the variety of areas, the rhyming tasks led to compensatory activation in right and bilateral areas and the left extrastriate cortex. In fact, rhyming is a complex task that requires an immediate phonological analysis of a given orthographic cue, not the word itself. During normal

single word or sentence reading, children are not required to process single units and their smallest elements. During rhyming tasks, however, concrete phonological knowledge is required, which was also highlighted in the large behavioral differences in accuracy and reaction times between the impaired and non-impaired readers. It seems, thus, that the more demanding a reading-related process, the more impaired readers try to compensate their deficits by engaging a large variety of brain areas. This might be due to the insufficient integration of speech sounds and their correspondence to letters in the impaired group.

In overt word reading, however, deficits could only be attributed to the extent but not the location of activation. Slight differences were further found between word reading vs. reading of pseudo-homophones and pseudo-words and between regular and irregular words, which could be linked to the increasing processing demands, which may be more difficult to cope with for dyslexic children. Both letter and non-word reading typically showed deficient processing in occipital (visual) and temporal (STG; auditory) areas in dyslexics (Backes et al., 2002). For letter and symbol reading, less deactivation was found in dyslexics in areas associated with the default mode network. In addition, false-font reading, related to the other three categories, led to activation differences in visual (VWFA) and occipito-temporal areas (Backes et al., 2002; Olulade et al., 2015).

Interestingly, there were also major differences between sentence reading and single word reading with the first leading to compensatory activation. For both tasks, sentence and word reading engaged core reading circuits and large differences in extent and intensity of activation were found in the left frontal regions, the IPL, temporal areas (mostly MTG) and occipital areas. It may be speculated that the higher complexity of sentences as compared to words – which represents a higher cognitive load – leads to a higher activation in frontal areas relevant for working memory functions but has very little effect on the reading circuits. In the studies, however, overactivation in additional areas was further spread and not limited to the frontal areas but rather to the core reading circuits. Still, this finding has to be treated with much caution as sentence reading was only applied in three studies and only one directly compared word and sentence reading. It has to be considered, however, that differences in age might lead to very different results in sentence

reading. More reading exposure and practice consequently lead to much greater ease while reading. Therefore, reading sentences or words might be much easier than reading non-words or pseudohomophones, for instance. It is also interesting that studies apply simpler tasks like word reading or reading of letters rather than more challenging ones like non-word or sentence reading. Reading words might be a process that can become automatized even in dyslexic children, who undoubtedly struggle with this process. Therefore, reading single words might even be very simple for them, especially if very easy, regular words are used.

With regard to the brain areas most often found to be over- or under-activated during the reading tasks, only one single study found an under-activation of the cerebellum, which has been a topic of its own with respect to dyslexia in the past years. Therefore, I would argue at this point that the cerebellum is not essential for literacy acquisition to the extent that the brain has to rearrange according to the difficulties encountered. It might also have been a coincidence that none of the other studies found over- or underactivation in the cerebellum. Another explanation would be that the cerebellum plays a bigger role in adults and teenagers, which is why no cerebellar activation was found in the studies analyzed in this review.

I would like to briefly mention the behavioral findings and how far they can relate to the neural findings. It is interesting that no behavioral differences could be found between reading-matched control children and the dyslexics, whereas the age-matched clearly outperformed both groups with ease. Interestingly, brain activation showed a very different picture. During sentence reading, for instance, there were striking differences between reading-matched controls and dyslexics and not only between age-matched and dyslexics, as would have been expected. It might be the case that the differences between the reading-matched groups and the dyslexics are so subtle that behavioral measures fail to detect them at all, while minor differences on the neural level are visible and found to be significant in the studies. This was confirmed throughout the review and even though reaction times did not add much to the picture (if one needs longer to relate a sound and a letter or to read a word it seems logical that it takes one longer to respond), accuracy did. There were very few tasks that did not reveal differences between dyslexic readers and the non-impaired group and among them was false font reading, which

is not strongly related to reading and the result is therefore somewhat expected.

To the best of my knowledge, Richlan et al. (2011) are the only ones so far who have looked at studies investigating reading-related processing through fMRI in dyslexic children with a strictly-defined age group. The main aim of Richlan et al. was to explore whether the predominant phonological deficit of temporo-parietal regions in children progresses towards a visual-orthographic left occipito-temporal dysfunction in adults. The results of their meta-analysis, however, were quite complex and could not fully confirm their primary hypothesis. They reported that the visual-orthographic deficit assumed to be predominant in dyslexic adults might have been underestimated in dyslexic children in the past. In particular, a lack of studies involving pseudo-words and pseudohomophones could have caused this underestimation (also in the current review, only a limited number of studies applied pseudo-word reading or rhyming). Moreover, they reported marginal overactivation in dyslexics, which is not in accordance with what the studies analyzed in this review have found.

In the present review, I extended Richlan et al.'s sample (9 fMRI studies with children) and limited and extended Paulesu et al.'s sample. The findings of this extended review support the results reported by Maisog et al. (2008), who found a small but significant network of compensatory activation in the right hemisphere and a lack of engagement in the core reading areas, namely FG, precuneus and ITG. Furthermore, Richlan et al.'s (2009) study reported very similar results as the ones I found. The only difference is that they also highlighted overactivation of motor areas in dyslexic individuals, which cannot be supported by this review.

I have to agree with Richlan et al. (2009) that more pseudo-word/non-word reading tasks need to be applied to help uncover the deficient mechanisms behind dyslexia. Even if single word or letter reading are slower and less accurate tasks for dyslexics, the brain activation patterns behind this process will probably reveal a focus on grapheme-phoneme conversion due to insufficient integration of the word or not reveal differences at all if the child has adapted adequately. When reading pseudo-words, on the other hand, the child has no knowledge to rely on and it allows us to a certain extent to investigate how encoding and grapheme-to-phoneme conversion take place at the same time. I therefore en-

courage those researchers dedicating their career to exploring dyslexia to become more creative and to increase difficulty levels while conducting fMRI.

All in all, the behavioral and fMRI findings are far from uniform and many specific regions reported in one study are not found in another although they apply the same task. Still, all reading-related tasks led to considerable underactivation in dyslexic children, while at the same time, dyslexics engaged a large network of compensatory areas instead, in particular during phonological tasks (e.g., rhyming). Thus, the review supports the findings from the other meta-analyses that dyslexic children between 8–15 years old fail to engage the typical reading-related areas during reading processing (also found in adults, see Maisog et al., 2008). Furthermore, and possibly in some contrast to adults, they use strikingly large right-hemispheric and bilateral compensatory networks to make up for the lack of engagement of the core reading circuits, which were only marginally reported in Richlan et al. (2009, 2011).

In general, I aimed at creating strict and homogenous criteria for the inclusion of relevant studies, and I tried to include as many studies as possible. Since only experimental paradigms with phonological, orthographic and auditory tasks were included, no inferences can be drawn with regard to visual processing. This does not imply that visual deficits are marginal and not worthy of discussion. Furthermore, I am well aware that reviews do not take into account statistical effect sizes. However, the review does show a clear picture and even if the findings have to be treated with some caution, they support previous meta-analyses and highlight the lack of engagement of core reading areas in dyslexics paired with networks of compensatory activation due to increasing task difficulty.

5 CONCLUSION

Given the results of the present review, I have to partly agree with Ramus, Altarelli, Jednoróg, Zhao and di Covella (2018), who criticize that small-scale studies and reviews tend to show a rather homogeneous picture, which cannot be confirmed in large-scale meta-analyses and stud-

ies. Mostly, large-scale analyses reveal few robust results and highlight inconsistencies instead. Likewise, the results of the review show a small number of robust patterns found in dyslexic children. Still, it remains debatable whether these small-scale studies with few participants not only report false positives but also blur the overall picture. However, one finding that will survive any criticism is the fact that activation in reading circuits differs between children with a diagnosis of dyslexia and non-impaired readers – even if the extent and location of differences vary with task, severity of the disorder and concrete age of the participants. Additionally, right-hemispheric and bilateral compensatory activation has been confirmed in such a large variety of studies that one could argue that this finding is also quite robust and reliable. It seems that dyslexic children show processing deficits in all core reading circuits and the more challenging the task, the more likely it is that they need engagement of additional regions to compensate for those deficits.

ACKNOWLEDGEMENTS

I am recipient of a Doc-team fellowship of the Austrian Academy of Sciences and would therefore like to thank the Austrian Academy of Sciences for supporting my scientific career. I would like to thank my supervisor PD Dr. Annemarie Seither-Preisler for her support and for proofreading this review. I would also like to thank our student assistant Magdalena Ramsey for helping me in the final stages of the submission.

ABBREVIATIONS

AG	Angular gyrus	MTG	Middle temporal gyrus
FG	Fusiform gyrus	PrCG	Precentral gyrus
IFG	Inferior frontal gyrus	PT	Planum temporale
IOG	Inferior occipital gyrus	SFG	Superior frontal gyrus
IPL	Inferior parietal lobule	SMA	Supplementary motor area

ITG	Inferior temporal gyrus	SMG	Supramarginal gyrus
MFG	Middle frontal gyrus	STG	Superior temporal gyrus
MOG	Middle occipital gyrus	VWFA	Visual word form area

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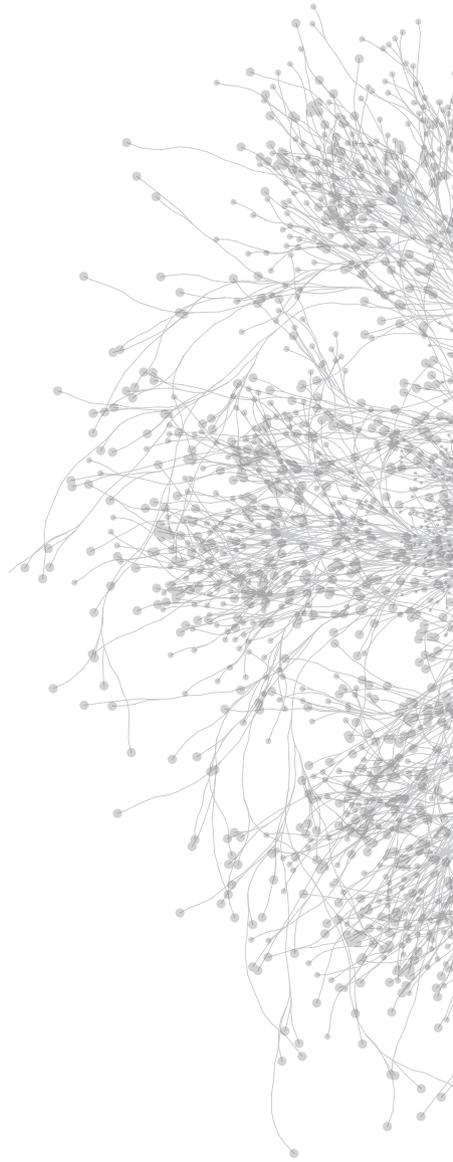
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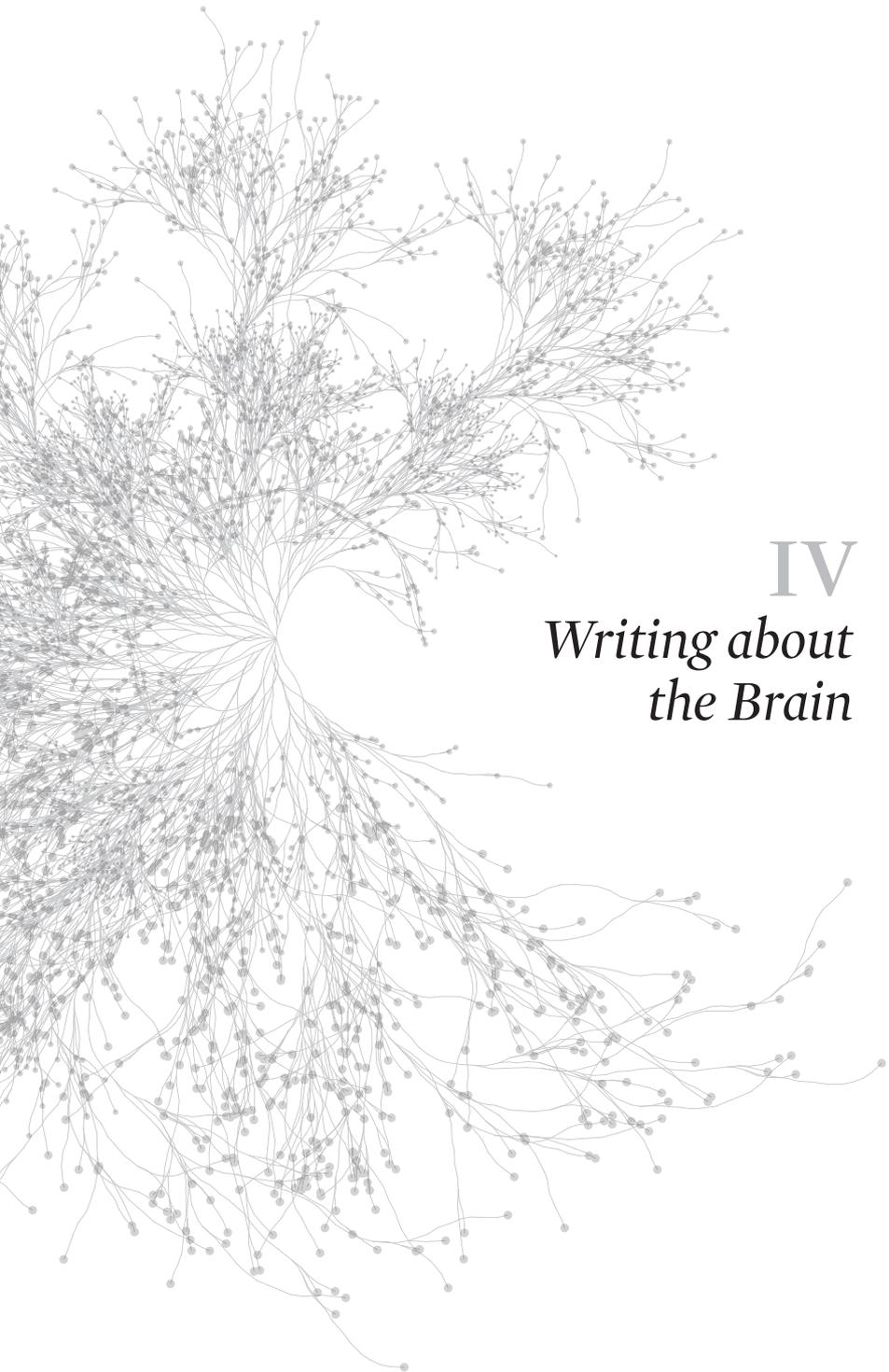
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IV

Writing about the Brain

HEAFOD ('head') and BRÆGEN ('brain') in Old English medical texts

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ABSTRACT Based on the comprehensive *Dictionary of Old English (DOE)* and the reading of the relevant Old English (OE) texts, this chapter illustrates the occurrence of two central medical terms, *heafod* 'head' and *brægen* 'brain', in OE medical texts. After a survey of OE medical texts and their editions in the first part, the second part presents the data arranged according to the main sub-meanings of the two items as presented in the *DOE*. Most of the quotations are taken from the *DOE*, with some additions by the author. The translation of the quotations enables the non-specialist reader to follow the argumentation of the author.

KEYWORDS brægen, heafod, historical linguistics, OE medical texts

FOREWORD

I have known Annemarie Peltzer-Karpf for more than 40 years, in the course of which we always had sympathy and respect for each other although our scientific interests were fairly different. This did, however, not mean that we had no interest for our mutual areas of research; therefore, I immediately agreed when asked to contribute to this book for Annemarie. Because of the great difference between our fields of

interest, the only common denominator seemed to be the *hardware* of language (i.e., the head and the brain), and I thought the occurrences of the words *heafod* and *brægen* in Old English medical texts might be of interest to Annemarie and the readers of this book. Since my special field of research is the botanical – and not medical – vocabulary in OE texts (cf. Bierbaumer, 1975, 1976, 1979, and e.g., Biggam, 2003), I have refrained from adding any comments on the remedies connected to the two terms¹. For readers interested in Anglo-Saxon medicine I have included, as a kind of introductory reading, Grattan and Singer (1952), Cameron (1988) and Cameron (1993) in my references.

1 THE OLD ENGLISH MEDICAL TEXTS

What mainly encouraged me to write this chapter is the fact that the Old English medical texts, in particular the Old English *Læcebot* (*Lb*), today known as *Bald's Leechbook* (Cockayne, 1864–66, vol. II), depend on classical as well as Germanic sources and thus give a fairly reliable picture of the medical knowledge at the end of the first millennium. Cameron (1983b, p. 153) sums up:

Bald's *Leechbook* [...] is (together with the accompanying third book of recipes) the oldest English medical work to survive in anything like complete form, and it is also the oldest to survive in a European language other than Greek or Latin. It is not merely a collection of recipes, but a treatise which attempts to handle all aspects of diseases.

¹ Since I am currently supervising a doctoral dissertation with the aim of producing an annotated translation of the most important OE medical text *Læcebot I and II* (for various reasons) into German, I am optimistic that this will provide the necessary basis for interesting links with modern psycholinguistic approaches. On a more general level, this dissertation will also provide a link with the German-speaking scientific community. That this is necessary can be seen from the fact that the most recent comprehensive work on the early history of medical literature in German mentions the Old English *Leechbooks* in only one sentence (Riecke, 2004, vol. I, p. 16).

For the Germanic sources the most definite proof seems to be the occurrence of the evidently Germanic names of the owner and compiler of *Lb I* and *II* (Bald and Cild, see below) and the names of the two apparently Anglo-Saxon *læcas* (OE *læce* 'doctor'²) Oxa and Dun: *Lb I xlvi: Læcedomas wiþ þeoradlum... Oxa lærde þisne læcedom... ('Recipes against inflammations... Oxa taught this recipe...')*; *Lb II lxxv: Wiþ lungenadle læcedom dun tæhte. saluie... ('against lung-disease a recipe that Dun taught: sage...')*. For an in-depth discussion of the Latin sources I refer to D'Aronco (2005), and concerning the role of the names mentioned above to Banham's article "Dun, Oxa and Pliny the Great Physician. Attribution and Authority in Old English Medical Texts" (2011).

1.1 **Læceboc (Lb) (eds. Cockayne, 1864–66, vol. II; Leonhardi, 1905; Deegan, 1988; reprints of Cockayne's edition: Singer, 1961; CUP, 2012)**

The *Lb* only survives in *MS Royal 12 D xvii*. As mentioned above, the *Læceboc* (Cockayne distinguishes between *Lb I*, *Lb II* and *Lb III*) is the most important OE medical text, not only because of its length and quality but also because of the fact that at the end of the first two parts we find a Latin colophon that mentions the names of the owner and of the compiler, which are definitely Anglo-Saxon and most probably *læcas*: *Bald habet hun[c] librum/Cild quem conscribere iussit...* (see translation below). What strikes me, however, is the fact that the colophon, which one would expect in some prominent form and place, is almost hidden (not divided from the OE text) because it is placed at the beginning of a

² OE *læce* = 'doctor', cf. BT (Bosworth-Toller Anglo-Saxon Dictionary), s.v. *læce I*; the word *læce* also denotes the 'leech' in its modern sense: BT, s.v. *læce II*: a leech (species of worm). *Læce sanguisuga vel hirudo* Ælfc. 23. The word *læce* 'worm' is originally a distinct word from *læce* 'doctor' but later assimilated to it (cf. Onions, 1966: s.v. *leech 1* and *leech 2*). There is no indication in the OE medical texts that leeches were used for blood-letting, this was carried out by using cupping glasses or horns: cf. e.g., *Lb II, LIX: Wiþ þære healf deadan adle [...] hwilum þu teoh mid glæse oþþe mid horne blod of þam saran stowan adeadodum ('For the half dead disease [...] at whiles draw blood with a cupping glass or a horn')*. Hankins (1992, p. 1) confuses the OE word *læca* as in *ag-læca* 'demon, monster' (Hall, 1960, s.v.) with *læce* ('doctor').

new folio (fol. 109a) which contains the beginning of *Læceboc III*. This and the fact that the MS looks quite unused might indicate that it was not owned by a practitioner (Bald) but goes back to an older exemplar.

1.1.1.1 *Læceboc I and II (Bald's Leechbook)*

Lb I consists of 88 chapters, which are briefly described in a table of contents. The first chapter contains recipes against diseases of the head and the chapters 2–30 follow the order introduced by the late-Greek physician Alexander Trallianus *a capite ad calcem* ('from head to heel'), that is, against headache, ailments of the eyes, ears, teeth, throat, chest etc.

Lb II, also with a table of contents, consists of 67 chapters that mainly deal with diseases of inner organs. At the end of *Lb II* we find the Latin colophon mentioned above; the full text of the colophon does not only give the names of the owner and compiler, but it also shows that Bald apparently had a collection of books at his disposal:

Bald is the owner of this book, which he ordered Cild to write; earnestly here I beg everyone in the name of Christ that no deceitful person should take this book from me, neither by force nor by stealth nor by any false statement. Why? Because no richest treasure is so dear to me as my books which the grace of Christ attends (transl. Wright, 1955, p. 13).

1.1.1.2 *Læceboc III (ed. Cockayne, 1864–66, II)*

Lb III, also with table of contents, consists of 76 chapters, which were added by the scribe immediately after the colophon concluding *Lb II*. It differs from *Lb I* and *II* in that it has no systematic structure and contains many magical elements.

1.2 **Lacnunga ('medicaments') (ed. Cockayne, 1864–66, III)**

The text only survives in *MS British Museum Harley 585*. It is a collection of herbal recipes and magical formulas going back to various Roman, Greek and heathen Germanic sources.

1.3 **Herbarium Apuleii (HA) (ed. Cockayne, 1864–66, I; De Vriend, 1984; van Arsdall, 2002)**

The *HA* survives in three Old English and one Early Middle English manuscripts, the most important one being *British Museum, Cotton Vitellius C iii*. The OE *HA* was translated around the year 1000 from a Latin text of the 5th century. It contains names and use of medical plants and instruction for their use.

1.4 **Medicina de Quadrupedibus (MQ) (ed. Cockayne, 1864–66, III; De Vriend, 1984)**

The *MQ*, which survives in the same manuscript as the *HA*, is a translation of three Latin texts, that is, *Liber de taxone* ('book about the badger'), *Liber medicinae ex animalibus* and one treatise about the healing properties of the mulberry tree (cf. De Vriend, 1984, lxii).

1.5 **Peri Didaxeon (ed. Cockayne, 1864–66, III; Löweneck, 1896)**

The text survives in a manuscript of the second half of the 12th century, but due to its partly Old English character it was included by Cockayne as a late Old English text. The standard of knowledge displayed in this text is far below that of the texts written before the Norman Conquest.

1.6 **Old English glossaries and glosses**

The numerous Old English glossaries, interlinear glosses and individual glosses contain many Latin-Old English terms, the majority of which (ca. 6500) are botanical (cf. Bierbaumer, 1979); medical terms (denoting parts of the body and diseases) are much rarer and can best be seen in *Aelfrics Grammatik und Glossar* (Zupitza, 1880).

2 OCCURRENCES OF ‘HEAFOD’ AND ‘BRÆGEN’ IN OLD ENGLISH MEDICAL TEXTS

The occurrences are quoted (with permission of the editors) from the monumental new *Dictionary of Old English* (DOE, Cameron et al., 2016). Translations are either entirely mine or adapted (i.e., modernized to make comprehension easier) versions of Cockayne’s translations. The adaptations were either made by myself or, where existent, taken over from modern translations (e.g., Hankins, 1992). Where the text specimens exceed the quotations in the DOE in length, they are, for practical reasons, always taken from Cockayne.

Altogether (including the non-medical texts) there are 1800 occurrences in OE of the word *heafod* and more than hundred entries of compounds with *heafod* as first or second element. There was another word for ‘head’ in Old English, i.e., *hafola* (cf. DOE, s.v.), which I have not included here because it occurs only in poetic texts (17 occurrences, 13 of them in *Beowulf*). *Brægen* has only 35 occurrences because it mainly occurs in medical texts (DOE, s.v.).

2.1 heafod

According to Pokorny’s *Indogermanisches etymologisches Wörterbuch* (1959, p. 529f), *heafod* belongs to the Indo-European root *kap-ut* ‘head’; original meaning ‘cup-like’; related words are Latin *caput* ‘head’, Old Norse *hofuþ* and *haufuþ*, Gothic *haubiþ*, Old High German *houbit*, Modern German *Haupt*. According to Kluge (1967, s.v.), *Haupt* was the dominant word in German until the Modern High German period, when the word *Kopf*, related to English *cup*, ousted *Haupt* as the primary word. The development of OE *heafod* > Modern English *head* is shown in Pinskyer (1974: §§ 49,63A2): OE *heafod* > 11/12th c, *hevd(es)* > 14th c *heed* > 16th c > [he:d] spelling <HEAD> shortened [hed], spelling HEAD remained.

2.1.1 *Head of a human being*

Lch I (Herb) 1.2.: ‘gif mannes *heafod* tobrocen sy genim þa ylcan wyрте betonican, sceafta hy þonne & gnid swyþe smale to duste... þige hit þonne

on hatum beore, þonne halap þæt *heafod* swyþe hraþe æfter þam drince
(Lat. ad capitis fracturam).'

TR(ANSLATION): 'if a man's head be broken, take the same plant betony,
scrape it then and rub it very small to dust... swallow it in hot beer, then
the head heals very quickly, after the drink.'

2.1.2 *Head of an animal*

Med 1.1. (B) 10.2.: 'to slæpe, wulfes *heafod* lege under þone pyle (Lat. de
lupo ad somnum caput lupi suppositorium sub pulvino, dormiet aeger)'

TR.: 'to sleep, lay a wolfe's head under the pillow'

Lch II (2) 65.1.1.: 'gif hors ofscoten sie... writ... þam horse on þam *heafde*
foran Cristes mæl & on leoþa gehwilcum þe þu ætfeolan mæge '

TR.: 'if a horse is elf-struck [= struck by a sudden disease]... write upon
the horse's forehead Christ's mark, and on each limb which you may feel
at'

AntGl 2 182: 'brunda heortes *heafod*'

TR.: 'brunda, head of a hart' (prob. from ISID. Etym. 15.1.49 Brundisium
autem dictum [est] Graece quod brund caput cervi dicatur)

2.1.3 *Referring to a part of the head*

AEGram 63.12 (not medical): 'haec frons þis forewearde *heafod*'

TR.: 'this forehead'

Lch II (1) 1.17.13: 'rude getrifuladu mid sealte & mid hunige, smire þæt
heafod forward mid þy'

TR.: 'bruised rue with salt and honey; smear the forehead with it'

AEGram 74.6.8. (not medical): 'hoc occiput se æftra dæl þæs *heafdes*'

TR.: 'the rear part of the head'

Lch II (2) 64.1.6: 'Eal swa same se petra oleum he is god anfeald to drin-
canne wiþ innan tiedernesse 7 utan to smerwanne on wintres dæge for
þon þe he hæfþ swiþe micle hæte... 7 he is god gif hwam *seo spræc oþfylþ*

nime þonne 7 wyrce cristes mæl under his tungan 7 his an lytel swelge. Gif mon eac of his gewitte weorþe þonne nime he his dæl & wyrce Cristes mæl on ælcra lime, butan cruc on þam *heafde* foran, se sceal on balzame beon & oþer on þam *heafde* ufan.’

TR.: ‘Similarly also petroleum is good to drink unmixed for inward tenderness, and to smear outwardly on a winter’s day, since it has very much heat... and it is good if for *anyone his speech fails*, then let him take it, and make the mark of Christ under his tongue and swallow a little of it. Also if a man become out of his wits, then let him take part of it, make Christ’s mark on every limb, except the cross on the forehead, that shall be of balsam, and the other also on top of his head.’³

2.1.4 Referring to headache

The *DOE* gives more than ten passages.

Lch I (Herb) 3.4: ‘wiþ *heafdes* sare genim fifeafan þa wyrnt... gegnid swyþe smale & bind on þæt *heafod*, þonne biþ se ece lytliende’

TR.: ‘for head’s sore, take five leaf the wort [plant]... rub it very small, and bind it on the head; then the ache will be diminishing’

Lch II (1) 1.16.1: ‘wiþ langum sare þæs *heafdes* oþþe þara earena oþþe þara toþa... geseoþ cerfillan on wætere, sele drincan (cf. Phys. Plin. 1.1.: diu permanente capitis dolore)’

TR.: ‘for chronic disorder of the head or of the ears or of the teeth... see the chervil in water, give it to drink’

Lch II (3) 1.1.1: ‘wiþ þon þe mon on *heafod* ace genim niopowearde wrætte, do on readne wræd, binde þæt *heafod* mid’

³ The text passage quoted here is longer than the one in the *DOE* because of its relevance for the topic of this essay (‘loss of speech’) and, of course, because it is part of the chapter on the recipes which are said to have been sent to King Alfred by the patriarch of Jerusalem: *þis eal het þus secgan Ælfrede Cyninge domne Helias, patriarcha on Gerusalem* (‘All this Dominus Helias, patriarch at Jerusalem, ordered to say to King Alfred’).

TR.: 'in case a man has ache in the head; take the lower part of crosswort, put on a red band, bind the head with it'

2.1.5 *Referring to migraine (headache affecting one half of the head, cf. Lat. hemigranius)*

Lch II (1) 1.10.1: 'wiþ healfes *heafdes* ece, laures coppan getrifula on eced mid ele, smyre mid þy þæt wenge (cf. MARCEL. Medic. 2.19: aduersum eterograni molestias)'

TR.: 'for a half head's ache, bruise in vinegar with oil the clusters of the laurus, smear the cheek with that'

Lch II (3, Head = contents) 1: 'wiþ heafodece & wiþ ealdum heafodece & wiþ *healfes heafdes* ece'

TR.: 'for head ache, and for old head ache, and for ache of half the head'

2.1.6 *Referring to the head as the seat of thought (non-medical texts)*

CP 18.131.24: 'þæt *heafod* sceal wisian þæm fotum, þæt hie stæppen on rihtne weg... ut recta pedes ualeant itinera carpere, haec... caput debet... prouidere)'

TR.: 'the head shall direct the feet that they step on the right way'

AECHom I, 40 527.81: 'on halgum gewrite biþ gelomlice *heafod* geset for þæs mannes mode: for þan þe þæt heafod gewissaþ þam oþrum leomum swa þæt mod gediht þa gēpohtas... in scriptura... sacra saepe caput pro mente ponitur, quia sicut capite reguntur membra, ita cogitationes mente disponuntur'

TR.: 'in the Holy Scripture the head is frequently used for the mind of man: because the head directs the limbs in the same way as the thoughts are directed by the mind'

2.2 **brægen**

According to Pokorny (1959, s.v.) *brægen* belongs to the Indo-European root *mregh-m(n)o-* 'brain- pan, brain', Greek *brexmos*, *brexma* 'forehead', OE *brægen* n. 'brain', Old Frisian *brein*, Middle Low German *bragen*, *bre-*

gen, Modern High German *Brägen*. According to Kluge (1967, s.v.) *Brägen* is Low German.

2.2.1 *As a substance: The brains*

Lch II 1, Cockayne II, p. 176 (not in *DOE!*): ‘Se maga biþ neah þære heortan 7 þære gelodr[e] 7 geadortenge þam *bræge[ne]*, of þam cumaþ þa adla swiþpost of þæs magan intingan 7 o[f] yflum seawum wætan atterberendum.’

TR.: ‘The stomach [C.: ‘maw’] is near the heart and the spine, and in communication with the brain, from which the diseases come most violently, from the circumstances of the maw, and from evil juices, humours venombearing.’

Lch III 2, DE GENERATIONE HOMINIS (MS. Cotton Tiberius, A.iii. fol. 38 b): ‘Her onginþ secgan ymbe mannes gecynde. Hu he on his modor innoþe to men gewyrþeþ. ærest þæs mannes *brægen* biþ geworden on his moder innoþe, þonne biþ þæt *brægen* utan mid reaman bewefen on þære syxtan wucan. On oþrum monþe þa ædran beoþ geworden...’

TR.: ‘Here begins the description of man’s nature, how in his mother’s womb he grows to be man. First the man’s brain is formed in his mother’s womb, then the brain is furnished on the outside with membrane in the sixth week. In the second month the veins are formed...’

Lch II (1 Head) 1.3.: ‘& hu mon scyle gebrocenes heafdes tiligean & gif þæt *brægen* ut sie’

TR.: ‘and how one must tend a broken head, and how if the brain is out’

Lch II 1 61ff: ‘Genim wiþ tobrocenum heafde betonican... 7 gif þæt *brægen* utsige, genim æges þæt geoluwe 7 meng ly[t]hwon wiþ hunig 7 afyl þa wunde 7 mid acumban besweþe 7 forlæt swa þonne, 7 eft ymb þry dagas gespæt þa wunde and 7 gif se hala [f]erþe wille habban readne ring ymb þa wunde, wite þu þonne þæt þu hie ne meaht gehælan. Wiþ þon ilcan: genim wudurofan 7 wudumerce 7 hofan, 7 wel on buteran, 7 seoh þurh hæwenne claþ, do on þæt heafod, þonne gangaþ þa ban ut.’

TR.: ‘For a broken head take betony... and if the brain be exposed, take the yolk of an egg and mix it a little with honey and fill the wound and

swathe up with tow, and so let it alone; and again after about three days syringe the wound, and if the hale sound part will have a red ring about the wound, know thou that thou mayest not heal it. For the same, take woodruff and woodmarch and hove, and boil in butter and strain through a coloured cloth, apply it to the head, then the bones come out.⁴

2.2.2 *An ingredient in medical recipes*

Med 1.1.5.1: 'wiþ oferslæpe, haran brægen on wine geseald to drence (Lat. ad submeiulos cerebrum leporis ex vino)'

TR.: 'for oversleeping, a hare's brain in wine given for a drink'

Med 1.1.9.2: 'wiþ hærþena sare & teorses, bares brægen meng wiþ hunig & wriþ on'

TR.: 'for sore of the testicles [Cockayne: 'coillons'] and of the penis [C.: 'yard'] mingle a boar's brain with honey, and bind it on'

2.2.3 *With reference to functions of the brain (resting place for the soul, centre of sensation, communication and thought)*

Sol I 41.3 [non-medical text]: 'ic þe secge on þrim stowum heo byþ, on þam brægene, oþþe on þære heortan, oþþe on þam blode (Ref. to places where the soul resides during sleep)'

TR.: 'I tell you it is in three places, in the brain, or in the heart, or in the blood'

Lch II (2) 27.2.1: 'sio wamb sio þe biþ cealdre oþþe wætre gecyndo oþþe misbyrdo, him cymþ brægenes adl & ungewitfæstnes him biþ.'

TR.: 'The womb which is of a cold or moist nature or malformation [C.: 'caprice']; on the man comes disease of the brain and loss of his senses.'

⁴ Deegan (1988, p. 226) in her commentary on this passage says that "Nowhere in the Old English medical texts is there any mention of trepanning for head wounds, although we know from archaeological remains that this was practised in England. I actually do not think that in the text passage quoted any kind of trepanning the wound was involved. The physician apparently only relied on the 'bone extracting' powers of the herbs used."

CP 18.139.16 [non-medical text]: þæt feax þonne on hira heafde getacnaþ þa uterran geþohtas, þæt grewþ & scinþ ofer þam *brægene*'

TR.: 'the hair then on their head signifies the outer thoughts; that grows and shines over the brain'

2.2.4 *Faran forwendum brægenum* 'to go (about) with turned brains, to experience giddiness/vertigo'

PeriD 13.9.11: 'ad tornionem capitis þis ys þe læcecræft be þan manne, þe hym <þingþ>, þæt hyt turnge abotan hys heafod and farþ furwendum *brachenum*: nim man rudan and ceruellan and enneleac and cnuca þa wurtan togadere (cf. PS.PETR.SAL. Pract. 10, 8.7 ad vertiginem capitis vel quod versatum cerebrum habet)'

TR.: 'For giddiness of the head. This is the leechcraft for the man to whom it seems that his head is turning about and who goes about [C.: 'fareth'] with turned brains. Let one take rue and chervil and onion, and pound the worts together.'

In his first footnote to his edition and translation of *Peri Didaxeon*, Cockayne (vol. III, p. 82) says that because so "many variations from the true inflexions and true construction occur in this piece, that it would be unreasonable to take special note of them." From my own studies of the botanical lexicon of *Peri Didaxeon* (Bierbaumer, 1976, s.v. *cicena mete*), I can provide three examples demonstrating the author's apparent lack of knowledge/and or lack of resources: the translation *cicena mete*, 'chicken-weed' (*Stellaria Media* L.), is induced wrongly by the similarity of the respective Latin words: *gallicano* (geographical term) *absinthio*: confusion with *gallus* 'cock', *pulegium* (OE *dweorgedwostle* 'pennyroyal') and *herbe polline* ('pollen') confusion with Lat. *pullus* 'hen'.

3 CONCLUSION

As can be seen from the text just quoted (*Peri Didaxeon*: Late Old English/Early Middle English, 2nd half 12th century), the quality of the language of the text is much inferior to that of all the other texts cited before. This is

quite clearly a consequence of the Norman Conquest through which the West Saxon *standard* developed since Alfred the Great's (2nd half 9th century) era had come to an end and was replaced by Anglo-Norman culture and institutions. By *standard* I mean not only the West Saxon language (which was in fact the first English standard language), but the West Saxon culture in general and medical knowledge in particular. Cameron (1983a, 1983b) stresses the fact that we have no reason to assume that the Anglo-Saxon *læce* was in any way less competent than his Greek and Roman predecessors. We should, however, bear in mind that the standard of medicine in Western Europe of the second half of the first millennium A.D. was not as high as the one in Ancient Egypt and in Ancient Greece and Rome (Hippokrates, Galenus). Moreover, we should also mention that Arabian medicine became known in Europe only from the 12th century onwards. Furthermore, I would like to point out that an inclusion of the medical literature in German can also contribute to our understanding of Old English medical texts, however, such an endeavor was beyond the scope of this article.

ABBREVIATIONS AS USED IN THE DOE

AECHom	Aelfric's Catholic Homilies
AEGram	Aelfrics Grammar and Glossary
CP	Gregory the Great: Cura pastoralis
Lch I (Herb)	Herbarium-Apuleii (Pseudo-Apuleius: Herbarium)
Lch II (1) (2)	Bald's Leechbook: Læceboc I and Læceboc II
Med.1.1.	Medicina de Quadrupedibus
PeriD	Peri Didaxeon
Sol I	Solomon and Saturn

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The brain is like a muscle – the brain is like a control center: Conceptualizing the brain in expert and popularized scientific discourses

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ABSTRACT This chapter examines conceptualizations of the brain as constructed in the discourses of popular science and the neurosciences, focusing on the dichotomy between *mentalism* and *physicalism*. This dichotomy rests on further conceptual oppositions, namely *holism* vs. *fragmentation* (brain or brain components), *personalization* vs. *de-personalization* (related to or abstracted from persons), and *agentization* vs. *passivization* (active or passive and not central in processes). The chapter takes a corpus-based discourse analytical approach, using corpora of popular scientific books on the brain and academic neuroscientific articles. As a triangulating effort, we add a questionnaire-based investigation into students' understanding of differences in linguistic representations of the brain. We examine various linguistic structures assumed to contribute to the conceptualizations mentioned. Quantitative results for these constructions are in line with our assumption that mentalism is more strongly associated with the expert-to-lay discourse of popular science and physicalism more with the expert-to-expert discourse of the neurosciences. Responses to the questionnaire indicate that mentalist and physicalist concepts play a role in students' understanding of the brain, but not in a clear and consistent way, possibly as a result of representations of the

brain students are exposed to which go beyond the discourses examined in our research.

KEYWORDS corpus analysis, discourse analysis, mentalism, physicalism

1 INTRODUCTION

To understand how the brain as a physical organ translates patterns of electrochemical activation into experience, thought and emotion, and thus physicality into mind, meaning and information is the ultimate goal of the interdisciplinary field of the cognitive neurosciences. It is widely acknowledged that Annemarie Peltzer-Karpf has contributed her substantial share to this endeavor, especially if the focus is on language and its ontogenetic development (for a selection of her works, see Hohenberger in this volume). As a discourse analyst (GM) and a sociolinguist focusing on lesser used languages (UW), we have no immediate contribution to make to the scientific study of the aforementioned connection between brain, mind and language, lacking the required expertise in anything cognitive or *neuro*. What we can do, however, is take the discourse analytical meta-position and investigate how the cognitive neurosciences conceptualize the brain in the ways in which the discipline uses language and creates meanings in discourse. This could mean looking at similes such as the two in the title of this contribution, but it could – and will, in our case – go well beyond such figurative representations.

Our perspective on cognitive neuroscientific language is informed by two dichotomies. Firstly, we will not only be concerned with academic texts and thus with how the brain is conceptualized within the exclusive expert community, but also with texts written by experts for a lay audience and thus with notions of the brain that might be more influential for the ways we as a society think about our most human of organs. If differences can indeed be found, then we expect them to be localizable on a scale from *mentalism* (focus on the mind) to *physicalism* (focus on the organic brain) – and this is the second of the aforementioned dichotomies. Our study will thus focus on aspects of meaning related to this

scale and the linguistic elements and structures that can be argued to help construct such meanings.

We will use corpus-based discourse analysis as our methodological approach, using a corpus of neuroscientific articles and a corpus of popular scientific books on the brain. In an attempt to triangulate the results of the text-based analysis, we will add a small-scale questionnaire-based investigation of how students perceive the different linguistic strategies and meanings found.

A caveat: our contribution will not focus on metaphors and metonymies of the brain, since the texts examined do not use them as widely as we would have expected (but see our comment on *brain* compounds in section 3). We nevertheless decided to retain the original title, as figurative language still captures better than other dimensions the variation in conceptualizing even something as physical as the brain.

2 PHYSICALISM AND MENTALISM

Physicalism means conceptualizing the brain primarily as a physical biological organ and modeling and explaining cognition mainly as physiological processes involving the various systems – nerves, blood, hormones, etc. – and structures of the physical brain. Mentalism, on the other hand, means conceptualizing the brain primarily as an information-processing system and modeling and explaining cognition mainly as mental processes involving an abstract architecture, all this always in relation to the *mindful* people in their personal and social environments.

The main objective of a popular neuroscientific discourse¹ is to create interest and establish comprehension in the non-expert target audience by using relatability – focusing on what the brain means to them as thinking, feeling, and perceiving and thus *mindful* individuals – and simplicity – focusing on an easily imaginable mental rather than a complex organic architecture. Experts talking to experts can presuppose knowledge and

¹ We take a constructionist position here, assuming that discourses are particular forms of using linguistic forms and linguistic meanings associated with particular forms of conceptualizing the world.

do not need to take the aspects mentioned into account, which means brains can be abstracted from people and dissected into their organic, chemical and physical components. The different conceptual perspectives on the brain are thus contextually motivated, for instance by theoretical and practical goals, assumed shared background knowledge, etc.

Our main research question is whether and if so, to what extent a popularized discourse of the brain can be located more towards the mentalist pole of the scale mentioned above, and an expert discourse of the brain more towards the physicalist pole (that this is indeed the case is the guiding assumption – or our superordinate hypothesis, as it were – in our study), and where (i.e., with respect to which sub-aspects) and by which linguistic means such a difference becomes manifest.²

We assume that the distinction between mentalism and physicalism rests, among others, on the following three subordinate conceptualizations, which are at the basis of our sub-hypotheses and sub-research questions.

Holism vs. fragmentation: We associate mentalism with holism, this is, conceptualizing the world in terms of whole entities, particularly in terms of whole persons, whole bodies and – even though this is to a certain extent a contradiction in terms – whole organs. By contrast, we associate physicalism with fragmentation, this is, conceptualizing the world in terms of parts, with a particular emphasis on lower-order and *trans-substantial* (i.e., components are of a different nature than the whole) components.

Personalization vs. de-personalization: We associate mentalism with personalization, this is, conceptualizing the brain in relation to individual human people and their lives. By contrast, we associate physicalism with de-personalization, this is, conceptualizing the brain as abstracted and independent from its *owner*.

² This is our personal perspective on the issue. Others assume that the physical brain – especially represented by the visual image of this organ – has become the most prominent factor in popular science in many different fields. They mention examples such as personal identity, social behaviour or cultural phenomena that popular science now tends to locate in the physical brain (see Racine, Bar-Ilan & Illes, 2005; Thornton, 2011).

Agentization vs. passivization: We associate mentalism with agentization, this is, conceptualizing the brain as engaged in active and partly even intentional behavior. By contrast, we associate physicalism with passivization, this is, conceptualizing the brain as passively undergoing processes or as partly only playing an even more circumstantial role in processes, for instance being the place rather than an immediate participant.

Our task for the linguistic analysis is to look at linguistic elements and structures that create meanings contributing to these conceptualizations. This chapter does not stand in the tradition of studies on science popularization that look at how expert knowledge is represented in discourses targeted at a lay audience and at the transformation processes this involves, such as the foregrounding of science as a spectacle and scientists as geniuses and of the use value of scientific findings and the backgrounding of doubts or qualifications of results (for an early representative of the approach see Fahnestock, 1986). The focus will thus not be on this direct relationship between the two discourses under scrutiny.

3 APPROACH AND DATA

We use corpus-based discourse analysis as our approach, tracing patterns of meaning in recurrent configurations of linguistic elements and structures in collections of electronically-stored texts (= corpora), trying to relate the former to their social, cultural, political or other contexts (as outlined in Marko, 2015, drawing upon ideas presented in Baker, 2006; Fairclough, 1992; Mautner, 2009; Partington, Duguid, & Taylor, 2013). Concordance software allows us to find linguistic patterns in corpora, as it can search texts for particular elements or structures and display them in – and allows analysis of – their immediate verbal contexts (we used Wordsmith Tool 7.0 created by Mike Scott as our concordancing program). We compiled two corpora representing the two discourses described above: on the one hand professional texts on the brain written by experts for other experts in the cognitive neurosciences, and on the other hand popularized scientific texts on the same topic written by experts for a wider, non-expert readership.

Our professional corpus consists of academic articles from two important peer-reviewed academic journals, namely *Neuroscience*, with a stronger neuroscientific focus, and *Trends in Cognitive Sciences*, with a stronger general psychological focus. Considering that there are a wide range of high-profile journals in the field, any choice of two specific journals is always somewhat arbitrary. In this case, our choice was also practically motivated as we were looking for journals held by our university library in electronic format and which we could easily access and transform into text files. We included 100 articles in our corpus, 50 from each of the two publications, aiming for 500,000 words, a reasonable target for a research project like ours. We randomly selected one article from each of the 50 most recent issues of both journals (taking the first article from the first issue used, the second from the second, etc.; in case there were not enough articles in an issue, we started with the first one again).

Our popular corpus consists of popular science books on cognitive science and brain research. We would have preferred articles to avoid a generic imbalance, but popular scientific articles on the brain are published less regularly and less consistently in particular media so it is more difficult to find a sufficient number. To find relevant books, we used *brain* as a search word in the “popular science” category on amazon.co.uk and chose the first ten books listed that seemed to represent the target field from a fairly general perspective with a relatively recent publication date. Ten seemed a plausible number, containing some variation without resulting in a much larger corpus than the professional one. We bought the electronic versions of these books and transformed the texts from these into plain text files using OCR software (converting pictures – or scans – of texts into electronically readable text), excluding anything not part of the main running text (e.g., tables of contents, references, captions).

The two corpora were tagged for parts of speech/word classes and semantic categories with the help of the automatic tagger CLAWS, a service available via the platform WMatrix3 created and maintained by Paul Rayson (see Rayson, 2009). Table 1 includes all the relevant statistical information on the two corpora.

Table 1: *Descriptive statistics of the two corpora*

	Popular	Professional
Texts	10 books	100 articles
Overall size ³	916,012 words	549,945 words
Range	45,337-126,705 words	2,356-12,883 words
Average length	91,601 words	5,499 words

The following four sections will focus on one of the three conceptual strategies described above and test assumptions about these against the data from the corpora just described.

4 RESULTS AND DISCUSSION

4.1 Holism vs. fragmentation

Everything you are is a feature of *your brain*, and as such much of what *your brain* does is dedicated to making you look and feel as good as possible [...].

Neogenin-expressing neurons in the *rhombencephalon* and *mesencephalon* projected to the *spinal cord*.

The first example above, with its references to the brain as a whole and to activities that the latter engages in, contributes to creating meanings that support a holistic conceptualization of the brain. The striking aspect of the second example is that it does not use the noun *brain* at all, but instead in one relatively short sentence features four complex and technical terms for brain parts and thus constructs a fragmented conception of the brain. In this section, we will look at linguistic elements such as those highlighted in italics in the examples above to see whether popularized neuroscience presents a more holistic view and professional neuroscience a more fragmented view of the brain, as hypothesized.

³ Not including the passages just mentioned.

The most obvious strategy of creating holistic meanings in connection with the brain is to use the very noun itself. We therefore looked for occurrences of the word *brain* in our two corpora. While the simple noun can certainly be argued to have the strongest effect with respect to holism, we decided to include all occurrences, whether in orthographically separate (e.g., *rat brain*), hyphenated (e.g., *Albert-Einstein-brain*), or orthographically combined (e.g., *forebrain*) compounds, whether in compounds with *brain* as the head (e.g., *bird brain*) or as the modifier (e.g., *brain disorder*), and whether as complex compounds (e.g., *blood brain barrier penetration*) or as derivations (e.g., *no-brainer*, *brainy*).

Table 2 below contains the absolute and relative frequencies (occurrences per 10,000 words, here and elsewhere) of *brain* occurring in any of the constructions mentioned in the previous paragraph. As the data covers a very heterogeneous set of constructions, we will not count the number of different expressions here, ignoring the aspect of lexical diversity.

Our approach to quantification relies heavily on descriptive statistics. However, we also compared all frequencies with the help of Log-likelihood [using an Excel spread sheet provided by Jiajin Xu (n.d.)]. All results to be presented in this article are statistically significant at $p < .001$.

Table 2: *Frequencies of the word brain occurring in any construction in the two corpora*

	Popular		Professional	
	Absolute	per 10,000 words	Absolute	per 10,000 words
Tokens	9,164	100.04	1,818	33.06

The word *brain*, on its own and in all the combinations described above, occurs almost exactly three times more often in the popular science books than in the neuroscience articles. As assumed, the brain as a whole entity – and thus holism – therefore plays a more significant role in the expert-to-public discourse than in the expert-to-expert discourse.

The examples of combinations involving the noun *brain* highlight the fact that there are many complex words integrating the brain as a whole organ. We would argue that such words, particularly compounds, also contribute to a holistic conception of the brain. This might seem par-

adoxical at first – after all, the brain is by definition incorporated into a larger or more complex concept in compounds, for instance in *brain training*, the brain only plays the role of the object of an activity. But as this more complex concept still features an explicit reference to the whole brain, rather than to its parts, attributes, or functions, the compounds denoting these concepts may eventually still enhance the holistic dimension of the texts in which they are included. We therefore decided to look at the frequencies and the lexical diversity of such compounds.

Table 3 includes the numbers of different nominal compounds with *brain* and their frequencies in our two corpora. Type numbers (how many different words, as opposed to token numbers, which represent how often words occur in a corpus), here and elsewhere in the article, are based on *lemmatization*, which means that different grammatical forms are all subsumed under one entry. Since there is no linear relation between type numbers and overall corpus size, relative frequencies are not provided.

We add a second relative number to tokens, representing the ratio between how often the word *brain* occurs in any construction in a corpus (the figures presented above) and how often it occurs in the above-described compounds (called *brain-ratio* in the following). It seems relevant since the frequency of a construction involving the word *brain* necessarily depends on the latter's overall frequency, too, not just on the size of the corpus. The value x can be read as 'one in x occurrences of *brain* is a compound [or any other construction]'. The full set of compounds found are contained in Supplementary Table A (see References).

Table 3: *Frequencies and lexical diversity of compounds with brain in the two corpora*

	Popular			Professional		
	Absolute	per 10,000 words	<i>brain-ratio</i>	Absolute	per 10,000 words	<i>brain-ratio</i>
Types	474			222		
Tokens	2,968	32.40	3.1	1,257	22.86	1.4

The figures in Table 3 present a heterogeneous picture. The popular science corpus contains a lexically much richer set of expressions, with more than twice as many different compounds. And, relatively speaking, *brain* compounds also occur approximately 50% more often in the pop-

ular neuroscience corpus. All these figures are in line with our expectations. However, if we factor in the number of occurrences of *brain* overall in the two corpora, which is what the *brain*-ratio does, we see a reversal of relations: ratios of 1.4 for the professional corpus and 3.1 for the popular corpus mean that if the neuroscientific articles use the word *brain*, even though they do so less frequently, it is more than twice as likely to be part of a compound. So the data on compounds does not provide support for the assumption that a holistic conception of the brain is a more central feature of a popular scientific discourse on the brain than of a professional one. It cannot easily be interpreted as counterevidence either. We rather assume that we underestimated other factors playing a role here, for instance, the fact that there is a tendency towards condensation in scientific discourses – presenting more information in smaller units – which normally leads to a more extensive use of compounds than in discourses targeting a more general audience.

A brief aside: when looking at the set of compounds we have found in our corpora, there are some that clearly have a metaphorical basis; we may even identify conceptual metaphors such as the brain is a building/architectural construct (realized in components such as *architecture*, *cell*, *wall*, or *bridge*) or the brain is a plant (realized in components such as *stem*, *branch*, or *growth*). In light of such findings,⁴ we have to admit at this point that we might have given up too early on actually focusing on figurative language.

Let us look more closely at elements that enhance the opposing conceptualization, namely fragmentation. Lexemes denoting different parts of the brain are of prime importance here. We focus on two types of brain components, both of which qualify as *transsubstantial* (i.e., with an essential difference between these elements and the brain as a whole). These two categories are *neurotransmitters* (the substances chemically transferring electrical activation between nerve cells) and *neurocytology* (all aspects concerned with types and components of nerve cells).

⁴ We thank the anonymous reviewer who has drawn our attention to these expressions.

An exhaustive search in a corpus for terms⁵ for neurotransmitters and neurocytology is impossible as the target structures do not share any formal features. However, there are sources, whether websites or books, that contain a wide range of relevant terms for the respective field. If search lists containing these words can be compiled from such sources, then approximative searches, covering the vast majority of – though not all – expressions, can be performed. We used such approximative searches for tracking the above-mentioned terms. Table 4 presents all the relevant figures concerning terms for neurotransmitters (for the full list of terms see Supplementary Table B).

Table 4: *Lexical diversity and frequencies of terms for neurotransmitters in the two corpora*

	Popular		Professional	
	Absolute	per 10,000 words	Absolute	per 10,000 words
Types	32		53	
Tokens	1,091	11.91	1,444	26.26

Unsurprisingly, and in line with our expectations, we see a clear quantitative advantage here for the neuroscientific articles over the popular scientific books with respect to both lexical diversity and frequency. Being more likely to refer to these small-scale and transsubstantial components, the professional discourse on the brain can therefore rightly be claimed to present a more fragmented conception of the brain than its popular counterpart. As far as neurocytological terms are concerned, figures for their lexical diversity and frequencies can be found in Table 5 (for a full list see Supplementary Table C).

⁵ We are using terms here in the sense of words that are “neutral and unambiguous, [...] condense information into compact units and their meanings are usually opaque being tightly integrated into a system of specialized knowledge that is created, administrated and disseminated in and by institutions (e.g., by medicine and professional healthcare)” (Marko, 2017, p. 150).

Table 5: Frequencies and lexical diversity of neurocytological expressions (referring to entities) in the two corpora

	Popular		Professional	
	Absolute	per 10,000 words	Absolute	per 10,000 words
Types	218		520	
Tokens	3,760	41.05	3,760	68.37

Our interpretation of the data on lexical diversity and frequencies of expressions for brain components on the level of the nerve cell reiterates the points made above in connection with neurotransmitter terms. There is a slight difference here, though, since the quantitative advantage for the professional neuroscience corpus primarily becomes manifest in the lexical diversity of neurocytology in the corpus, pointing to the detailed distinctions that are made there. The terms also occur more than 50% more often, relatively speaking, in the professional corpus than in the popular corpus, but the gap here is smaller than with neurotransmitters, mostly due to some high-frequency general terms that belong to this semantic class (e.g., *nerve* and *cell*). But all data suggests that the fragmentation of the brain plays a much more salient conceptual role in the expert discourse on neuroscience than in the popular discourse on the same topic.

If we consider all linguistic structures examined in this section, our overall conclusion is that our expectations have been fulfilled, with the exception of compounds with *brain*, where the results are somewhat heterogeneous, and that the expert-to-expert neuroscientific discourse creates a more fragmented conception of the brain and the expert-to-lay discourse a more holistic one. The former may therefore be said to be more physicalist and the latter more mentalist, if we accept the conceptual associations between fragmentation and physicalism, on the one hand, and holism and mentalism, on the other.

4.2 Personalization vs. de-personalization

In a series of brilliant experiments *he* showed that the shape of [the maps of *our brains*] changes depending upon what *we* do over the course of our lives.

Incorporating the statistical methods mentioned above is vital to harness the power of Network Science to reveal the dynamical principles by which *the brain* is structured and by which brain functions emerge, develop, and decay.

The first example above, with its references to persons in the immediate co-text of the word *brain* (or a compound containing it, to be more precise) and especially with its use of the possessive pronoun *our*, which stresses the link between person and organ, contributes to a personalized conception of the brain. By contrast, the second example avoids mentioning persons by using subject-less non-finite verb forms (*incorporating, to harness, to reveal*) and the agent-less passive voice (*is structured*) and by combining *brain* with the definite article *the* rather than with a possessive pronoun. The meanings created are much more abstract and distanced, contributing to a de-personalizing perspective on the brain. In this section, we will look at linguistic elements such as those highlighted in the examples to see whether popularized neuroscience presents a more personalized and professional neuroscience a more de-personalized view of the brain, as hypothesized.

Explicitly relating the brain to its *owner* by using a possessive pronoun (*our brains*) or a genitive (*the patient's brain, everyone's brain*) is the first linguistic structure we will examine in this section. As the majority of these *owners* are human beings, this construction creates a direct link between the organ and a person and can therefore be argued to create personalization. Table 6 below contains all the relevant figures describing the frequencies of this construction in the two corpora.

Table 6: Frequencies of 'brain' occurring with a (personal) possessive (possessive pronoun or genitive noun) in the two corpora

	Popular			Professional		
	Absolute	% ₀₀₀	brain-ratio	Absolute	% ₀₀₀	brain-ratio
Possessive + <i>brain</i>	1,563	17.06	5.9	21	0.38	86.6
Possessive + <i>brain</i> (human)	1,489	16.26	6.2	11	0.20	165.3
Possessive + <i>brain</i> (animal)	74	0.81	123.8	10	0.18	181.8

Note. %₀₀₀ = per 10,000 words.

As can be seen from Table 6, the two corpora differ substantially with respect to the use of possessives in connection with the brain. In the neuroscientific articles, the construction [possessive + *brain*] is generally very rare with only one occurrence per 25,000 words (approximately) and with only one instance per 87 occurrences of the word *brain*. The gap to the popular books is wide: in the latter the combination is used more than 40 times more often overall, and with one occurrence per six explicit references to *brain*, we can truly claim that relating the organ to its *owner* is a very common pattern in these texts. Considering that almost half of all possessive constructions with *brain* in the expert articles are concerned with animals, but only about 5% are in the popular books, the relevance of these numbers for the construction of personalization in the latter is further enhanced. We may therefore conclude that, in agreement with our prediction, the popular scientific discourse on the brain has a more prominent element of personalization than its expert counterpart.

The first of the introductory examples in this section suggests that talking about human beings at the same time as talking about the brain may also have a personalizing effect on our conceptions of the brain. We will therefore examine how common this phenomenon is in the two discourses under scrutiny. Linguistically speaking, we interpret this as the word *brain* occurring in close vicinity to expressions referring to human beings. Practically speaking, we thus looked for a reference to a person occurring in the same sentence within a span of five words to the noun *brain*. This does not specify the relationship between the person and the organ, there is just the assumption that mere co-occurrence creates a link between the two dimensions. In Table 7, we present the absolute and

relative frequencies of *brain* and references to human beings co-occurring in the two corpora.

Table 7: Frequencies of 'brain' occurring together with a noun referring to a person (within a space of five words within the same sentence) in the two corpora

	Popular			Professional		
	Absolute	‰	<i>brain</i> -ratio	Absolute	‰	<i>brain</i> -ratio
<i>brain</i> + personal reference	1,563	17.06	5.9	97	1.76	18.7

Note. ‰ = per 10,000 words.

With a relative frequency that is ten times as high and a *brain*-ratio that is only a third (keeping in mind that the *brain*-ratio is inversely correlated with frequency), there is also a considerable quantitative advantage for the popular science books over the neuroscientific articles. As the former are thus much more likely to talk about the brain in connection with human beings than the latter, our assumption that personalization is an important conceptual strategy in the expert-to-lay discourse on neuroscience, but less so in the expert-to-expert discourse, seems very plausible.

What could relativize the figures presented above is the fact that scientific discourses are generally more impersonal and abstract so that it is less a lack of a personalized conception of the brain, but rather a general absence of a personalized perspective on the world. While this seems indisputable, we would nevertheless maintain that it is still legitimate to look more specifically at the conceptualization of the brain in a scientific discourse and describe it independently, even though this conceptualizing blends in with the general perspective conveyed.

In conclusion, the linguistic elements and structures examined in this section provide support for our assumption that popular neuroscience presents a conception of the brain that is more tightly associated with and related to human beings, while professional neuroscience prefers a perspective on this organ that abstracts from persons. If we accept the idea put forward in section 2 that opposition between personalization and de-personalization is subsumable under that between mentalism and physicalism, all this lends further weight to the hypothesis that pop-

ular notions of the brain are more mentalist and professional ones more physicalist.

4.3 Agentization vs. passivization

In the case of anger, something happens, your brain *experiences* it, *decides* that it's *really not happy* about it, and produces an emotion (anger) in order to *respond* and effectively *deal with* it in a satisfactory manner.

Although effects at the cellular level may be heterogeneous, all anesthetic agents are similar in decreasing neuronal firing, either through the enhancement of inhibitory currents or the reduction of excitatory currents *within the brain*.

In the first example above, the noun *brain* serves as the subject of several verbs, namely *experience*, *be happy*, *decide*, *produce*, *respond* and *deal with*. The subject of the latter four takes an active role; in the former two, it has the role of an entity – normally a human being – mentally experiencing something. These linguistic details contribute to the construction of the brain as an agent and as human being-like. By contrast, the second example generally represents processes in a very abstract way – mostly by using nominalizations such as *firing*, *enhancement* or *reduction* – and who or what is involved in or affected by these processes remains unclear. What is obvious, though, is that the brain is not more immediately, let alone actively, participating in these processes, but just provides the location for the latter as the noun *brain* just occurs inside a prepositional phrase headed by the locative preposition *within*. This section will be concerned with linguistic elements such as those highlighted in the examples as we are trying to investigate whether popularized neuroscience incorporates a more agentizing and professional neuroscience a more passivized conception of the brain, as hypothesized.

Both linguistic strategies featured in this section are concerned with the noun *brain* and the semantic roles it is assigned in clauses, and the amount of *agency* that inheres in these roles (for semantic roles, see Halliday, 1994). If we define agency as the extent to which someone or something is able to actively and independently initiate and carry out a

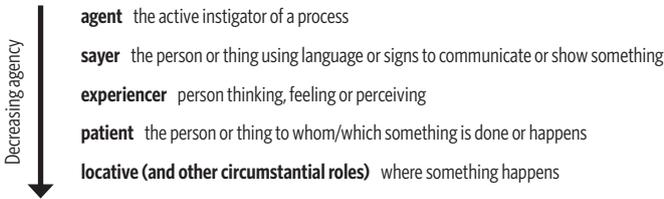


Figure 1. Scale of agency.

process, then the semantic roles mentioned above form a scale of agency, which could look as illustrated in Figure 1.

We need to distinguish between two different types of *experiencer* because especially processes of thinking and perceiving might be intentional, such as, thinking (about something), deciding, observing, listening, or unintentional, for instance, believing, remembering, seeing, hearing. Therefore, there are *active experiencers* and *passive experiencers*, the former of course coming before the latter on the above scale.

We were interested in how often the brain appears in the more active roles, this is, as agents, sayers and active experiencers, and how often in the passive circumstantial role of the locative.

Readers find information on frequencies and lexical diversity (of the verbs) in Tables 8 and 9. The latter presents how often *brain* occurs in the individual roles of agent, active experiencer and sayer. As a comparison, Table 8 also includes the relevant numbers for the passive experiencer category (for the list of all the verbs involved, see Supplementary Table D).

Table 8: *Lexical diversity and frequencies of 'brain' occurring in an active semantic role in the two corpora*

	Popular				Professional			
	Types	Tokens	% ₀₀₀	brain-r	Types	Tokens	% ₀₀₀	brain-r
brain in active semantic role	209	545	5.95	16.8	24	33	0.60	55.1

Note. %₀₀₀ = per 10,000 words; *brain-r* = *brain-ratio*.

Table 9: Lexical diversity and frequencies of 'brain' occurring in the three different active semantic roles (plus the role of the passive experiencer) in the two corpora

	Popular						Professional					
	Ty	%	To	%	% ₀₀₀	brain-r	Ty	%	To	%	% ₀₀₀	brain-r
Agent	153	73.2	384	70.5	4.19	23.9	16	66.7	22	66.7	0.40	82.6
Active exp.	37	17.7	129	23.7	1.41	71.0	6	25.0	8	24.2	0.15	227.3
Sayer	19	9.1	32	5.9	0.35	286.4	2	8.3	3	9.1	0.05	606.0
Totals	209		545				24		33			
Passive exp.	118		348		3.80	26.3	0		0			

Note. Ty = Types; To = Tokens; %₀₀₀ = per 10,000 words; brain-r = brain-ratio; exp. = experiencer.

As predicted, the noun *brain* occurs significantly more often in an active semantic role in the popular books on neuroscience than in the expert articles (ten times more often in relation to the overall corpus size, and three times more often if just related to the frequencies of the word *brain*). So overall, the data lends some credence to our assumption that in a popular discourse on the brain, agentizing plays an important role in the conceptualization of this organ.

There are no significant differences between the overall numbers and the numbers for the three different active semantic roles (agent, active experiencer, sayer). However, a closer look at the verbs actually used with *brain* in an active role, particularly those in the popular brain research corpus, points to another aspect indirectly related to mentalism. This aspect is perhaps most obvious in the active experiencer category. So what is our notion of a brain that attends to something, chooses, compares, concludes, controls, decides, ignores, infers, interprets, makes assumption, predicts, reassesses, searches for, and teaches itself? Particularly if we add the verbs in the passive experiencer category, where we also see a brain that assumes, believes, guesses, gets things mixed up, knows, prefers, remembers, thinks, and wants? It seems that the brain engages in the same mental operations – whether active or passive – that we, as whole human beings, also use. This means that on a certain level, there is an equation of the brain with the whole person, especially with the thinking, feeling and perceiving person. To put it differently, the

brain is almost a metonymic reference to a mindful human being rather than just being a part of it. This can clearly be seen as an additional factor supporting the overall hypothesis of the prominence of mentalism in a popular discourse on the brain. Keep in mind that this dimension is practically absent from the professional brain research corpus because the active experiencer category is so small in comparison, and no instances of *brain* occurring in the passive experience role have been found.

A circumstantial role, which describes the setting of an event rather than being immediately involved in it, means having no direct impact or influence on the initiation and performance of a process. Passivization is created by the brain often and consistently occurring in such roles, with special emphasis on the locative role, this is, any role concerning the *Where*, *Where from*, *Where to*, and *How far* of a process.

If *brain* takes a circumstantial role, it must occur inside a prepositional phrase. Our task in this part of our study is thus to look for such prepositional phrases. We searched for prepositions (with the help of the grammatical tags) if followed by *brain* within a span of three words. Three words would be enough to cover the majority of cases where words intervene between the preposition and *brain* without at the same time producing too many false positives.

Table 10 contains all the relevant figures concerning the occurrence of *brain* inside prepositional phrases in general, and locative prepositional phrases more specifically (for the list of prepositions, see Supplementary Table E). The percentage represents the proportion of locative prepositional phrases in the overall number of prepositional phrases with *brain*.

Table 10: *Frequencies of brain occurring inside preposition phrases with or without a locative meaning in the two corpora*

	Popular				Professional			
	Absolute	‰	%	<i>brain-r</i>	Absolute	‰	%	<i>brain-r</i>
<i>brain</i> in locative PP	1,019	11.12	42.3	9.0	242	4.40	58.7	7.5
<i>brain</i> in PP	2,410	26.31		3.8	412	7.49		4.4

Note. ‰ = per 10,000 words; *brain-r* = *brain-ratio*; PP = prepositional phrase.

The general figures in Table 10 are not really conclusive. While relatively speaking, such constructions with *brain* in a prepositional phrase are more common in the popular books on neuroscience, contrary to expectations, the *brain*-ratios are fairly similar. The fact that locative prepositions form a larger proportion of all prepositions used in the expert articles and that the *brain*-ratio for these prepositions is slightly lower (pointing to a higher likelihood of references to *brain* being part of corresponding prepositional phrases) does not really provide support for our expectation that an expert discourse on neuroscience contributes more to a passivization of the brain than a popular discourse on the same topic.

In conclusion, the data examined in this study lends weight to the one side of our assumption, suggesting that an expert-to-lay discourse on the brain contains a much stronger element of agentization than its expert-to-expert counterpart. However, the data fails to enhance the plausibility of the other side of the assumption as we could not find positive evidence that the professional discourse does in fact present the brain as very passive. We might infer this by implication – after all, if the brain is not active, it must be passive – but not based on the data reviewed. There is a wide range of verbs in the popular discourse which take *brain* as their subject and assign the experiencer role to it. This suggests that there is a blend of the brain with the thinking, feeling and perceiving whole human being, which supports the conclusion that there is not just a difference between the two discourses under analysis with respect to agentizing, but that the popular discourse on neuroscience generally conveys a more prominent mentalist conception of the brain than its professional counterpart.

5 TRIANGULATION: THE QUESTIONNAIRE

This section will briefly discuss the results of a questionnaire that we created to see whether the claims raised in connection with our textual analyses are also relevant if we take a closer look at recipients and their conceptions of the brain. As this part of the study is low-key and small-scale, this form of triangulation must be regarded as an expression of intent rather than the full implementation of a methodological principle.

The idea behind the questionnaire is to find out whether the distinction between mentalism and physicalism and the three sub-conceptualizations examined above are also salient components of people's interpretations of texts concerned with the brain. In addition, we are also interested in whether there is metalinguistic awareness of which linguistic aspects may be instrumental in affecting meanings and interpretations (see "Questionnaire" in References).

We chose the short passages introducing the three sections dedicated to the subcategorizations as our examples for the questionnaire because they highlight the conceptual oppositions we are interested in, even though this by itself may create a less than authentic scenario for an interpretation. For all three pairs, we asked questions about differences concerning impressions and interpretations and also linguistic elements that contribute to the former. We explicitly mentioned the aspects we thought were most relevant for each pair.

There are three further questions at the beginning of the questionnaire. These are supposed to fulfill two tasks. Firstly, they have a *priming* function, foregrounding – and thus making respondents aware of – differences in our thinking and our representations of the brain. This is achieved by using questions that involve ranking different conceptualizations of the brain, whether as a biological organ, a site of electrochemical activity, a whole person, a source of identity construction, etc. A further aspect contributing to this function is that the three questions focus on different forms of representation, the first one including (literal) definitions, the second one metaphorical representations (e.g., the brain is a computer or a city), and the third one pictures. Secondly, the three questions will also allow some insights into respondents' notions of the brain prior to and therefore independently from the main, language-based questions described above.

As we primarily wanted to *explore* the possibility of triangulation, we did not aim for systematicity, exhaustiveness, and/or representativeness. We therefore only had 5 respondents, all 18-year-old female students at a college for nursery education (BAFEP 'Bildungsanstalt für Elementarpädagogik') in Linz⁶ who, as native speakers of German, had learned English as a foreign language for at least eight years. Students of that age

⁶ One of the authors (UW) is a teacher at this school.

group appeared to be an interesting cohort because we assumed they would not have more extensive experience with either neurological or popular psychological texts so that they would approach the textual examples with relatively few preconceptions. We added German translations as English was not the respondents' native language, which might have constituted a major obstacle. While having native speakers of English would definitely be preferable, we opted for *second best* in this case for pragmatic reasons, a legitimate decision considering the status of our investigation.

Responses to the first three questions – we here relied on an informal and simple form of content analysis – reveal that there is no clear prominent conception of the brain. This becomes obvious, for instance, in the fact that two people rank *The brain is a site with complex patterns of electrochemical activity happening all the time* as the best definition and two *The brain is central to who I am*, two sentences which appear conceptually unrelated and far apart.

What we may have underestimated is that certain options in the three first questions are more conventionally and directly associated with the brain even though this might not necessarily mean a stronger impact on overall conceptions. So respondents might choose the computer metaphor rather than descriptions relating the brain to a person simply because the former is an often-used and thus frequently-encountered figure of speech even though the second metaphor (brain as a whole person) may be a stronger factor in our view of the brain. This may also apply to pictures of the brain (as isolated from the person) or of neuronal networks, which could also be argued to be the culturally more salient representations of this organ than a group of people talking to each other, even though under different circumstances respondents may still give preference to the notion of the *social brain* over a fragmented biomedical one.

As far as the two passages related to the opposition between fragmentation and holism are concerned, respondents say that the first example presents the brain as a physical object – “what you ‘see’ inside the brain”⁷ – and foregrounds its parts, sections and structures. The second example is less interpreted in terms of a holistic view of the brain, but rather as

⁷ All examples are *sic*.

highlighting its role for humans and their experience – “how the brain is affecting the humans” – and would therefore put more emphasis on personalization. The main linguistic element mentioned as relevant for creating meanings in the examples given is technical – variously called *technical*, *academic*, *medical*, or *complicated* – language and, more specifically, technical terms.

The comments on the second set of examples are very similar. Again, one passage is perceived as personal and concrete, the other as more abstract. Technical language is also seen as important in creating this difference. The respondents all mention that using the possessive pronoun *our* rather than just the definite article *the* in connection with *brain* also contributes to creating personalization in the first example. Two answers also refer to the metaphor of the map as a personalizing factor: “The first passage is more personal than the other one, because the writer describes the brain as a map which is more imaginable for me.”

Respondents have greater problems with the last pair of examples, as four of five focus more on differences in comprehensibility – the first one being easier and the second one more difficult to understand, again mostly as a result of technical language – but only superficially touch upon the issue of agency. The fifth respondent, however, gives a relatively clear statement on the difference, saying “Passage number one attributes a lot of power to the human brain. It’s in position to make its own decisions, or probably for the whole person, it’s able to weigh and to deal with the environment’s influences. Statement two makes the brain look like a robot that reacts instinctive and arbitrary without having huge impact.”

In conclusion, the results of the questionnaire indicate that the dichotomy of mentalism and physicalism and its sub-categories play a role in people’s conceptions of the brain, particularly in the interpretations of concrete textual examples. However, we do not see any clear and consistent trends in how this might affect general notions.

We are aware that this part of our study plays an inferior role to the corpus analysis simply because the number of respondents and the fact that they were not native speakers do not allow any further-reaching conclusions. We are also aware that the selection of examples and the explicit mentioning of certain conceptualizations in our questions had an effect on responses. What we might have underestimated is the multiple and diverse influences that particularly students focusing on pedagogy

are exposed to in their studies with respect to views of the brain and also the impact that culturally salient conceptions and representations have. Of course, only a larger, more representative sample of respondents allows insight that could really support or challenge the findings of our textual analyses.

6 CONCLUSION

In order to pay tribute to Annemarie Peltzer-Karpf, who as a teacher has sparked our interest in linguistics and as a colleague inspired us to pursue this interest further, we changed the conjunction of her special field into a preposition, turning *language AND the brain* into *language ABOUT the brain*, a theme that we feel more comfortable with.

Language about the brain in our case meant a discourse analysis focusing on conceptualizations of the brain as constructed in popular scientific books and academic articles on the cognitive neurosciences. Our initial hypothesis was that the former would represent the brain mainly as a mental information-processing device standing in close relation to its *owner* (sometimes even being equated with them), a conceptualization we called *mentalism*, and the latter would represent it mainly as a physical and biological entity, a conceptualization we called *physicalism*. We further assumed that the opposition between mentalism and physicalism could be mapped onto further dichotomies, namely holism vs. fragmentation (conceptualizing the brain as a whole or in terms of its parts), personalization vs. de-personalization (conceptualizing the brain as related to and associated with persons or as personally de-contextualized and abstract), and agentization vs. passivization (conceptualizing the brain as active and initiative or as passive and not centrally involved in processes). These dichotomies also formed the backbones of our sub-hypotheses, which we tested against quantitative and qualitative data from our corpora.

In connection with holism, we examined the use of the word *brain* itself, generally and when integrated into nominal compounds, in connection with fragmentation and the use of terms for neurotransmitters and nerve cells. Our analysis of personalization focused on the frequen-

cies of the noun *brain* occurring with a possessive pronoun or a genitive or in any combination with a reference to a person. Finally, studying agentization meant looking at the use of *brain* in active semantic roles in clauses, while studying passivization meant looking at the use of *brain* inside prepositional phrases, particularly those with locative meanings.

Overall, most results our analyses yielded provide support for our hypotheses. Only the data on compounds and on prepositional phrases were not conclusive, without, however, substantially undermining our assumptions either. Our investigation into conceptualizations of the brain in two different discourses thus suggests that our superordinate hypothesis that notions of the brain as presented in popular scientific books on neurosciences and academic articles differ with respect to the dichotomy mentalism vs. physicalism seems plausible.

A questionnaire-based study of how students interpret relevant texts – designed to add a triangulating dimension to our research – indicates that mentalist and physicalist concepts do play a role in their understanding. However, given the small scale of the study and the inconsistencies of the results, no far-reaching conclusions can be drawn. What becomes evident from the answers given in the questionnaire is that conceptions of the brain are always subject to all kinds of other influences so that eventually how people think of and evaluate the central human organ may be a heterogeneous mixture of different aspects.

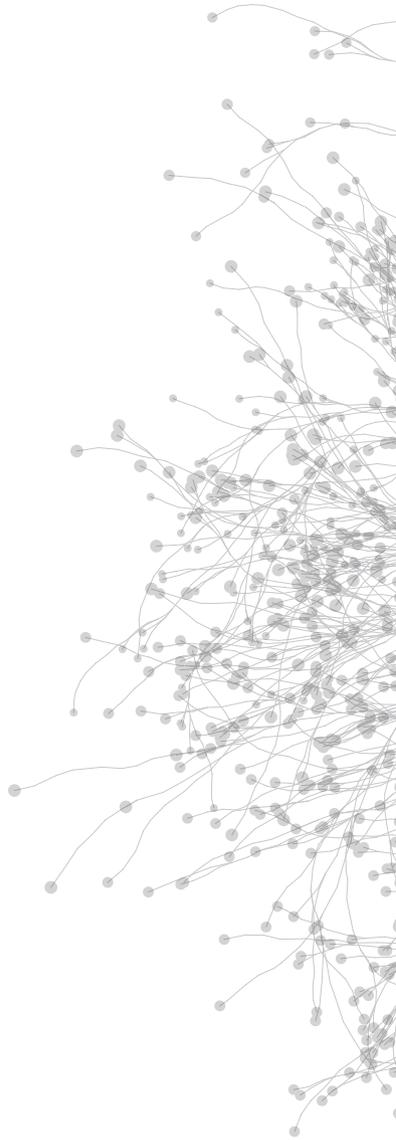
And right at the end, when we were about to step down from the main stage, someone came up to us and asked “But why would we want to know? I mean, about the brain and stuff.” We remained silent for a moment. And then we said “Discourse analysis is a bit like a mirror, creating a reflection on and for those we examine. Now a science of the brain that overemphasizes the biological, chemical and physical dimensions of the organ (to what extent this is really what we have found is another matter) may wonder to what extent it also is a humanity, a discipline exploring what it means to be human. And a science of the brain – even if popularized – that overemphasizes the mental dimension of the organ may wonder whether it is too much of a humanity, not sufficiently distinguishing between the mind and its biological foundation.” The woman looked at us for a few seconds, raising her eyebrows. Then she said, “Well, if you say so” and disappeared.

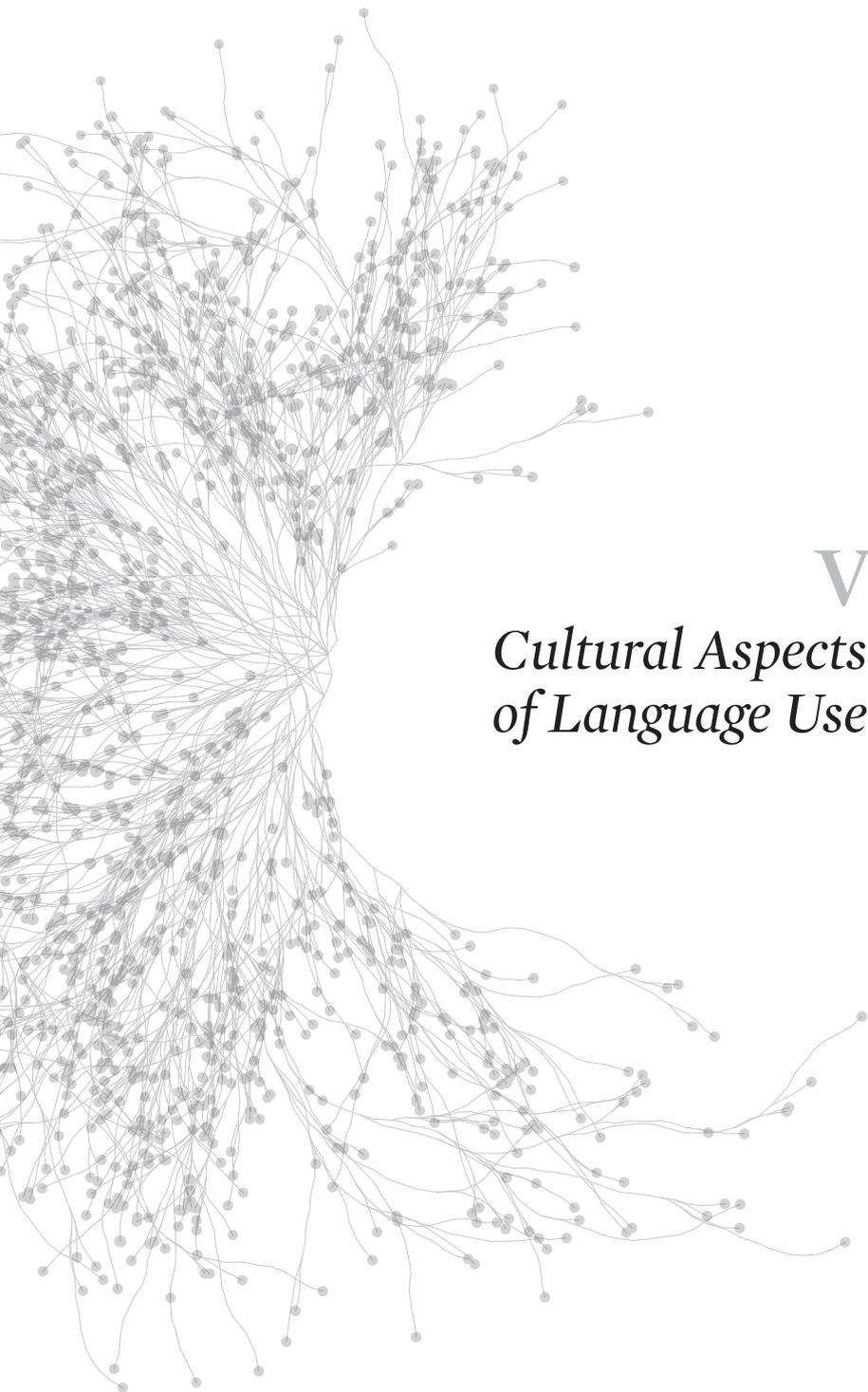
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V

*Cultural Aspects
of Language Use*

The humble linguist: Interdisciplinary perspectives on teaching intercultural citizenship

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ABSTRACT Current worldwide events necessitate educational approaches which prepare students to engage in purposeful and successful intercultural dialogue. In this chapter, we discuss how theories of *Intercultural Communicative Competence* (ICC), *Intercultural Citizenship* (ICit), and *Intellectual Humility* (IH) can inform each other and provide a basis for further developments in foreign language education and beyond. To examine how education for intercultural citizenship and intellectual humility can be mutually enriching, we pose three research questions: 1) How can we operationalize Intellectual Humility (IH) by drawing from Intercultural Competence (IComp), ICC, and ICit theories? 2) How can IH enrich ICit education? 3) What is the role of world/foreign language education in fostering IH education? Our analysis demonstrates that there is considerable overlap between the theories of IH and ICit (which includes IComp and ICC). We then show how combining aspects of both theories can support the implementation of ICit pedagogy by strengthening overlapping concepts or adding components from IH into the different dimensions of ICC, and explain how ICit can operationalize theories of IH. We conclude that theory in ICC/ICit provides a foundation for a

pedagogy which is competence-based and which makes IH accessible and feasible for teachers in schools and other educational institutions by creating a combined model of ICit/IH for pedagogical purposes. Finally, we briefly discuss additional opportunities of applying theories of IH to better understand the benefits of language education.

KEYWORDS foreign/world language education, intellectual humility, intercultural citizenship education, public discourse

1 INTRODUCTION

We live in times of *hypermobility* (e.g., Cohen & Gössling, 2015) and *super-diversity* (Vertovec, 2007). Some types of the mobility are voluntary while others are caused by war and economic crises, which have in recent years made increased numbers of people refugees and asylum-seekers or pushed them into migration (BBC, 2016). At the same time, more and more societies are engaged in divisive dialogue instead of uniting to address problems together (e.g., Johnson, Gunn, Lynch, & Sheff, 2017). Acknowledging that we live in challenging times with a number of global problems, 193 world leaders committed to 17 *Global Goals for Sustainable Development* (UN General Assembly, 2015) as “a plan of action for people, planet and prosperity” (p. 1).

In our view, citizens too need to become engaged, and future generations need to develop strategies to overcome these challenges. The impact of these worldwide changes and challenges on education is, and has already become, inevitable. One consequence is that global citizenship has become a prominent goal in education (e.g., UNESCO, 2015; P21, 2014). In Europe, where mobility of all kinds has become a major political concern, this way of thinking is also mirrored in a focus on democratic citizenship and intercultural dialogue (Council of Europe, 2008). The *Council of Europe*, which comprises 47 countries, including the 28 countries of the EU, and whose purpose is to promote democracy, human rights and the rule of law, has responded to the current situation by developing a *Reference Framework of Competences for Democratic Culture* (RFCDC). The Framework includes a model of twenty competences re-

quired for democratic culture and intercultural dialogue, each of which has a number of descriptors formulated in terms of learning outcomes. The *Framework* is inspired by the *Common European Framework of Reference for Languages* (CEFR; Council of Europe, 2001), which has been used by foreign language educators in Europe and beyond to improve curricula, teaching, and assessment (Byram & Parmenter, 2012). Foreign language education has to an extent anticipated this Council of Europe RFCDC initiative, and should take a leading role in the teaching of the knowledge, skills, and attitudes students need to pursue important global and local challenges (Yulita, 2017).

Concurrently in the USA, researchers in philosophy, psychology and education are in the process of investigating and using the concept of *Intellectual Humility* (IH) in the analysis of societal changes and as a basis for educational response. As Johnson et al. (2017) say:

We are becoming increasingly aware of the ways in which our discourse is hampered by prejudice, dogmatism, and cognitive biases. One exciting hypothesis is that cultivating intellectual humility or even just being aware of the concept of intellectual humility might help agents to overcome these difficulties. If this is the case then intellectual humility may help us with a variety of educational goals, and also improve public and political discourse (para. 1).

This same awareness of prejudice, dogmatism and cognitive biases is part of our interest in the theories of *intercultural (communicative) competence* (ICC/IComp) and *intercultural citizenship* (ICit) in conjunction with the theory of IH as a promising foundation to build the needed educational opportunities. Our work on ICC and ICit began in foreign/world language education, and has been extended to other subjects in combination with language education (see Cardetti, Wagner, & Byram, 2015; Wagner, Cardetti, & Byram, 2016; Cardetti, Wagner, & Byram, in press). In this chapter we discuss how theories of ICC, ICit and IH can enrich each other and provide a basis for further developments in foreign language education and beyond. Furthermore, as we shall see, there are some crucial corollaries of cognitive advantages from language learning supported by research on bilingualism and cognition (for an overview see Marian & Shook, 2012).

In order to address our overarching question, about how we can enrich education for intercultural citizenship and intellectual humility, we pose three research questions:

1. How can we operationalize IH by drawing from IComp, ICC, and ICit theories?
2. How can IH enrich ICit education?
3. What is the role of world/foreign language education in fostering IH education?

2 **INTERCULTURAL COMMUNICATIVE COMPETENCE AND INTERCULTURAL CITIZENSHIP**

The model of ICC/IComp (Byram, 1997) was originally created primarily for foreign language education. ICC combines the linguistic skills of communicative competence with *Intercultural Competence* (IComp). The linguistic dimensions, familiar to language teachers, are defined as follows:

1. *Linguistic competence*: the ability to apply knowledge of the rules of a standard version of the language to produce and interpret spoken and written language;
2. *Sociolinguistic competence*: the ability to give to the language produced by the interlocutor¹ – whether native speaker or not – meanings which are taken for granted by the interlocutor or which are negotiated and made explicit with the interlocutor;
3. *Discourse competence*: the ability to use, discover and negotiate strategies for the production and interpretation of monologue or dialogue texts which follow the conventions of the culture of an interlocutor or are negotiated as intercultural texts for particular purposes (Byram, 1997, p. 48).
4. To these were added the elements of IComp as presented in Figure 1.

¹ A person who is part of a dialogue or a conversation.

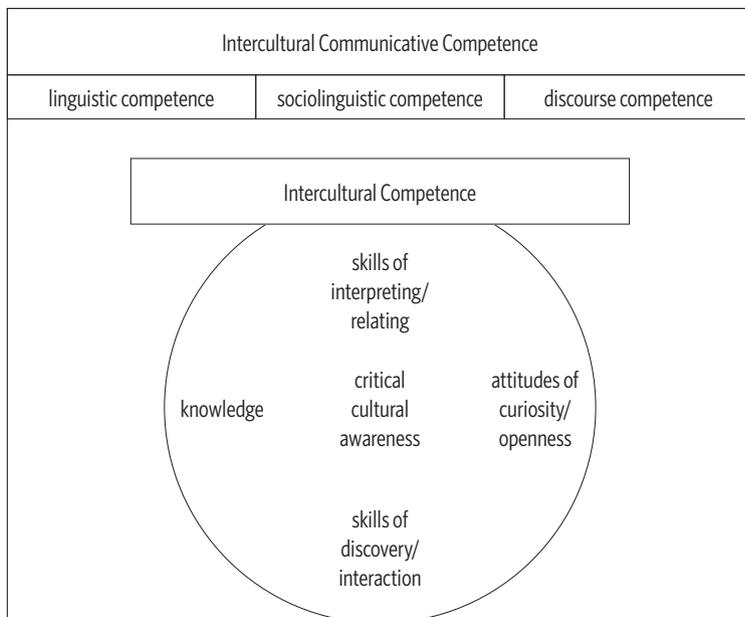


Figure 1. Intercultural Communicative Competence, consisting of linguistic competences and Intercultural Competence (adapted from Byram, 1997).

As can be seen in Figure 1, the dimensions of IComp consist of skills and attitudes in addition to knowledge. Understandably, knowledge might be the dimension that is most often emphasized as it can be taught and assessed fairly easily. However, knowledge about other social groups with whom one might interact in a different language and the bases of those interactions, “knowledge of social groups and their products and practices in one’s own and in one’s interlocutor’s country or region, and of the general processes of societal and individual interaction” (Byram, 1997, p. 51) are not sufficient for students to become interculturally competent. If students do not reflect on what they consider to be facts, knowledge may even lead to the development or reinforcement of stereotypes. Therefore, the comparative element of *skills of interpreting and relating*, the “ability to interpret a document or event from another culture, to explain it and

relate it to documents or events from one's own" (p. 52) is crucial in fostering students' awareness of linguistic and cultural differences, thereby developing their critical language awareness as well as their critical cultural awareness (Byram, 2012). Scaffolding activities in which students apply their *skills of discovery and interaction*, "the ability to acquire new knowledge of a culture and cultural practices and the ability to operate knowledge, attitudes and skills under the constraints of real-time communication and interaction" (p. 52) is another important aspect of education for intercultural competence. In the foreign language classroom, students use their skills to *discover* in the target language in real time. This requires them to negotiate meaning, which also sustains language acquisition (Foster & Ohta, 2005; Long, 1983). In order for students to compare and contrast and to contemplate a topic from a variety of perspectives they need to be open and curious and ready "to suspend disbelief about other cultures and belief about one's own" (Byram, 1997, p. 50). This *attitude* dimension is also a crucial aspect of IH as we shall see in our later discussion under *Operationalizing IH through ICit*. Finally, if students acquire the knowledge and the skills and attitudes, this should lead to the "ability to evaluate, critically and on the basis of explicit criteria, perspectives, practices and products in one's own and other cultures and countries" (Byram, 1997, p. 53). This *critical cultural awareness* is at the center of intercultural competence and can be seen as a goal in all activities in education. Although developed for language teaching, it is important to note the transferability of this model of IComp which can also be taught in other subject areas (see Cardetti et al. 2015; Wagner et al. 2016; Cardetti et al. in press).

When IComp is pursued in language education, it is combined with the linguistic competences mentioned above and becomes ICC. The purpose of teaching ICC, in foreign/world languages is to enable students to become *intercultural speakers or mediators* (Byram, 2009; Wilkinson, 2012), and, when this is combined with ideas from citizenship education, the purpose becomes to enable students to engage in social action and be active as an intercultural speaker or mediator. In order to do so they must first learn to interpret and understand the cultural contexts of their interlocutors – whether native speakers or people using the language as a lingua franca – second, learn to interact with them accordingly, and third learn to act as mediators between two groups with mutually incom-

prehensible languages (and cultures). This is in part dependent on their understanding of the relationships between the two (or more) languages involved, their linguistic competences, and their critical language awareness (Fairclough, 1993, 2013).

Intercultural citizenship in foreign language education (Byram, 2008) is a development of the theory of the intercultural speaker and mediator and involves the preparation of students to act in a multicultural and international community which comprises more than one set of cultural values, beliefs, and behaviors. ICit consists of the components of ICC and adds the acquisition and implementation of skills of *active citizenship* or *political and civic engagement* (Barrett & Zani, 2015). This goes beyond ICC in that it requires students to apply what they learn in the classroom to intercultural interactions outside the classroom with people of another culture in another language. In essence, intercultural citizenship education involves:

- Causing/facilitating intercultural citizenship experience, which includes activities of working with others to achieve an agreed end;
- Analysis and reflection on the experience and on the possibility of further social and/or political activity;
- Thereby creating learning, that is cognitive, attitudinal, behavioral change in the individual;
- And a change in self-perception, in relationships with people of different social groups.

Intercultural citizenship is, furthermore, related to initiatives to teach languages (and other subjects) for social justice (Glynn, Wesely, & Wessel, 2014; Osborn, 2006), since students' development of *critical cultural awareness* as part of intercultural citizenship (Byram, 2008) goes hand in hand with their understanding of social justice issues. By fostering our students' curiosity and a questioning attitude, we help them pose important questions about the world in which they live. More importantly, we provide tools for learners to judge events critically, based on specific evidence, and to take *action in the world*, which means tools to promote peaceful resolutions for growing conflicts around the world, as we have shown in recent projects (for an overview see Byram, Golubeva, Han, & Wagner, 2016; Wagner, Perugini, & Byram, 2017). In developing such

projects further, we now see connections between education for ICit and educational applications of IH.

3 INTELLECTUAL HUMILITY

The conceptualization of IH draws on philosophical and psychological research literature on virtue epistemology, specifically the study of intellectual virtues that include IH. The definition and theoretical underpinnings of IH are still being developed and analyzed (see, e.g., Hazlett 2012; Kidd, 2016a; Whitcomb, Battaly, Baehr, & Howard-Snyder, 2017). According to Johnson et al. (2017), the current philosophical literature on IH can be separated into two different perspectives. One considers intellectual humility as one unified trait, while the other regards it as a collection of related traits. For example, on the one hand, Whitcomb et al. (2017) argue that intellectual humility consists in owning one's intellectual limitations. On the other hand, Tanesini (2016) discusses intellectual modesty and intellectual self-acceptance as the dimensions of IH and argues that IH is a cluster of different attitudes. However, in order to analyze the potential benefits of combining IH and ICit we use the following definition that comes from work of researchers at the University of Connecticut and is focused specifically on IH in public discourse:

Intellectual humility can be understood as involving the owning of one's cognitive limitations, a healthy recognition of one's intellectual debts to others, and low concern for intellectual domination and certain kinds of social status. It is closely allied with traits such as open-mindedness, a sense of one's fallibility, and being responsive to reasons. Philosophers from Locke to Rawls have seen these traits as being crucial to the kind of meaningful public deliberation that we associate with democracy. Such deliberation is rational: it responds to reasons, not force or manipulation ("What is intellectual humility," 2017, para. 1).

Research in the area of public discourse and deliberation looks into how IH (among other virtues) affects political and classroom discussions of controversial issues. Garcia and King (2016) explore patterns of thought

that hinder the quality of arguments in the classroom. They offer pedagogical approaches that foster IH (and other virtues) to support “genuine self-understanding, mutual understanding, and healthy civic discourse” (p. 219). In relation to this, one specific aspect that has received attention is the empathetic consideration of others’ perspectives to foster dialogue across disagreement. On the importance of empathy for productive conversations around differences, Johnson (2017) contends that one way to develop empathy is to be intellectually humble and to realize the gaps and limitations of our own experiences. Psychologists are also conducting studies that consider IH as a subdomain of general humility and relate it with negotiation of ideas. For example, Davis et al. have found that IH is associated with fair and inoffensive ways of negotiating (2016).

The link with education can be found, for example, in part of a compendium put together by Baehr (2016) on intellectual virtues and education dealing specifically with the role of IH in addressing educational concerns. In particular, Hazlett (2016) elaborates on the centrality of IH in education and Kidd (2016b) argues for the importance of finding ways to foster IH in the classroom.

IH development has also been linked to education that fosters critical thinking. In his extensive work on this, Paul made a crucial distinction between strong-sense and weak-sense critical thinkers (1990). The latter refers to critical thinking that is manipulative, selfish, and unethical. In contrast, Paul and Elder (2002) explain that the former strive to be fair-minded thinkers who consider the rights and needs of others who might hold differing points of view. Their presentation of the crucial components of critical thinking places IH at the core of good critical thinking practice, based on the notion that “[s]tudents who think critically routinely strive to apply intellectual humility. To develop intellectual humility, one must learn to actively distinguish what one knows from what one does not know” (Elder & Paul, 2012, p. 30). They formulated the following educational outcomes for IH (pp. 30–31):

1. Students demonstrate initial understanding of intellectual humility by stating, elaborating, and exemplifying the concept in numerous ways.

2. Students discover their own false beliefs, misconceptions, prejudices, illusions, and myths. They use this knowledge to gain better command of their minds.
3. Students suspend judgment about matters of which they are ignorant.
4. Students accurately distinguish what they understand about a subject from what they do not.
5. Students accurately articulate the extent of their ignorance.
6. Students avoid claiming to know what they have no defensible reason for claiming.
7. Students admit mistakes and change their views (when faced with reasoning superior to their own).
8. Students demonstrate awareness of and concern for the fact that they have been socially conditioned into the belief systems and worldview of their culture and nation (and naturally see their culture and nation as *correct* in its views). Students actively seek and carefully study the viewpoints of other cultures to gain new knowledge and insights.
9. Students demonstrate understanding of the importance of intellectual humility in thinking at a high level within any discipline and profession.

Thus, cultivating IH has an impact on two of today's crucial educational goals, namely, improving classroom discourse for productive conversations, and supporting critical thinking.

So far, we have shown how the two threads in our argument, namely theories of IH and theories of ICC and ICit, have developed independently of each other, with ICC and ICit perhaps more advanced in terms of operationalization in classrooms. In the following, we explore the relationships between the two, uncover the ways in which the theories presented thus far complement one another and show how this can be leveraged to enhance education for ICit and IH.

4 **MUTUAL ENRICHMENT OF EDUCATION FOR INTERCULTURAL CITIZENSHIP AND INTELLECTUAL HUMILITY**

4.1 **How can we operationalize IH by drawing from IComp, ICC, and ICit theories?**

As pointed out earlier, IH theory is evolving. As a consequence, operationalization and applications in the practice of education are less developed than those of ICit. In this section, we address our first research question regarding how ICit can be a locus of operationalizing IH through ICit education. For example, while both ICit and IH are concepts which are based on rationality and reasoning, the models of ICC and ICit include the operationalization of the dimension *attitudes* and *openness* and *curiosity*. In ICit this means that students are “willing to seek out or take up opportunities to engage with otherness in a relation of equality”, that they have an “interest in discovering other perspectives on interpretation of familiar and unfamiliar phenomena both in one’s own and in other cultures and cultural practices”, and that they have a “willingness to question the values and presuppositions in cultural practices and products in one’s own environment” (Byram, 2008, p. 238), which correspond closely with points 3, 4 and 5 of Paul and Elder’s list above.

The pedagogical activities resulting from these particular aspects of ICC and ICit theory have been implemented successfully in a number of transnational collaborative projects (e.g., Byram et al. 2016) as well as in foreign language education projects in compulsory schooling in the US (e.g., Wagner et al. 2017). In the projects described in these publications students applied the knowledge, attitudes and skills that are part of ICC and ICit in a variety of contexts. For example, students in elementary and middle school in Connecticut, USA, became curious about, and then critically examined, various means of transportation in Puerto Rico (Perugini, 2017), daily routines in Peru (Despoteris & Ananda, 2017), and houses around the world (Silvey & Gräfnitz, 2017). Examples of transnational projects reported in Byram et al. (2016) include middle school students in Denmark and Argentina applying their ICit knowledge, skills, and attitudes to collaboratively solve environmental problems (Porto, Daryai-Hansen, Arcuri, & Schiffler, 2016), or university students in South Korea and the USA collaborating to discuss issues of language teaching

(Peck & Wagner, 2016). A retrospective analysis of those projects would show how elements of IH were being operationalized *avant la lettre* as we will show briefly below. At the same time such analysis would also show how the projects could have included concepts from IH enriching the focus on the objectives of ICit.

Additionally, the comparative element of ICit through which students are asked to interpret and relate information from another language and culture to their own language(s) and culture(s) requires them to take a step back and assume that they do not know everything they need to know. This entails discovering “their own false beliefs, misconceptions, prejudices, illusions and myths”, point 2 in Paul and Elder’s list above. In ICit, students are asked to “a) identify ethnocentric perspectives in a document or event and explain their origins, b) identify areas of misunderstanding and dysfunction in an interaction and explain them in terms of each of the cultural systems present, and c) mediate between conflicting interpretations of phenomena” (Byram, 2008, p. 239). By emphasizing these interpersonal skills related to interpreting and relating in the model of ICit, students acquire skills necessary to (further) develop their IH as described in points 6 and 7 of Paul and Elder’s list.

Another important part of the comparative orientation of the ICit model is comparing and contrasting rhetorical devices and meanings of apparently equivalent words and phrases in different languages; this is more than just being aware of what is an objective *fact* and what is not. In this sense, point 8 above is relevant but also needs refining to include *the viewpoints of other cultures and languages*. For example, abstract concepts such as *democracy* (English) have different connotations in the USA than *Demokratie* (German) in Germany, just as concrete terms such as colors are not the simple equivalents one might find in bilingual dictionaries; *brun* (French) is not the same as *brown* (English). Thus, in comparing and contrasting as required for ICit, students learn to regulate in this intellectually humble way. Additionally, when students discover that there are different interpretations and connotations of apparently equivalent words in two languages, such understanding requires and fosters tolerance of ambiguity *without taking offence, even when confronted with alternative viewpoints*. A monolingual project can only offer glimpses into this aspect of IH. In order for students to apply their sociolinguistic and discourse competence they need to have a certain awareness of their

knowledge of similarities and differences between sociolinguistic and discourse-related aspects of communication in different cultural contexts in their language. For example, in taking turns in a conversation, what might be felt to be *interrupting* by one participant from one sociolinguistic background, will be experienced as *normal engaged interaction* by a participant from another. Similarly, where we include pertinent information in a conversation (at the beginning or at the end) might differ in various cultural contexts (see Scollon, Scollon, & Jones, 2011). Learning that there is considerable ambiguity due to linguistic and cultural differences may cultivate a more questioning and open attitude in general.

Finally, and most importantly, we suggest that the action component of the ICit model shows the biggest promise for enriching the implementation of IH in education as well as for ICit pedagogy to be enriched by focusing on aspects of IH theories. In the action orientation in ICit, students are asked to a) elicit from an interlocutor the concepts, values of documents or events and develop an explanatory system susceptible of applications to other phenomena, b) identify significant references within and across cultures and elicit their significance and connotation, and c) take *action in the world* which means in their ‘here and now’, in their local and/or international environment as an extension of their work in the classroom (Rauschert & Byram, 2017). At the same time, the work on IH in public discourse offers a refinement for ICit teaching. In the projects we have developed in classrooms, students are often led to engage with the public, for example in presenting their analyses of social issues done in the classroom to people in their community (Byram, Perugini, & Wagner, 2013; Porto & Yulita, 2016). The work of IH scholars on public discourse in the classroom needs to be applied also to such *actions in the world*, and this takes us to the enrichment in the opposite direction.

4.2 **How can IH enrich ICit education?**

Turning now to our second research question, we shall in this section give an overview in the form of a table, of how indicators from ICit can be enriched by indicators from IH, and then use an example from a research and curriculum development project to show how this might impinge on practice.

As discussed before, ICit education is developed and already includes many indicators corresponding to IH. Perhaps the most important contribution of IH in ICit education could be a conscious and more articulated focus on the students' development and awareness of the importance of IH. While there are a number of studies investigating the effects of IH on attitudes and skills, such as negotiations skills (Davis et al., 2016), the emphasis here is on connections with attributes of IH and how they can enrich ICit education. The main points of this section are summarized in Tables 1 through 5. The tables show different IComp, ICC, and ICit indicators and corresponding IH indicators. Following each table, we offer suggestions for the foci of intentional educational experiences that leverage from these associations. Due to space limitations, elaborating on these suggestions is impossible; however, in the example we strive to provide significant details on particular ways in which IH can enrich ICit education.

Table 1: Overview of IH indicators that enrich ICit linguistic competences

Indicators: IComp, ICC, ICit	Associated IH Indicators
<i>linguistic competence</i>	"The humble person will seek to engage in regular disciplined argumentation with others to honor their recognition that good conduct requires the contributions of other people" (Kidd, 2016a, p. 401)
<i>sociolinguistic competence</i>	
<i>discourse competence</i>	"The intellectually humble is associated with being a fair negotiator of ideas, objective, and willing to submit to a process for evaluating assumptions and limitations in one's ideas to correct for biases" (Davis et al., 2016, p. 3)

Note. IComp, ICC (Byram, 1997), ICit (Byram, 2008).

4.2.1 Suggested foci for enrichment opportunities

To foster the linguistic aspects of intercultural communicative competence, educators can purposefully craft opportunities for students to use linguistic and communicative skills to engage in conversations with others who hold ideas that differ from their own. It will be important to provide students with specific scaffolding, for example to differentiate their own opinions from *facts*, they use phrases such as *in my opinion, I believe*,

etc., and to practice *empathy by analogy* to encourage dialogue (Johnson, 2017). Another skill students can learn in this context is to evaluate their own assumptions and those of others in fair-minded ways. In order to be able to do so in a language that is not their L1 they need to acquire communicative tools to intentionally seek or ask for sources that support their ideas, possible limitations of information, sources, etc. and potential biases they or their informants might hold.

Table 2: Overview of IH indicators that enrich ICit knowledge and attitudes dimensions

Indicators: IComp, ICC, ICit	Associated IH Indicators
<i>knowledge</i>	IH Outcome 5 (Elder & Paul, 2012, p.30) (see above) Those high in IH may readily put themselves in situations that challenge their thinking, including challenging dialogs that require high cognitive effort (Davis et al., 2016)
<i>attitudes</i>	IH appears to predict openness to experiencing different ideas and greater capacity to tolerate disagreement (Davis et al., 2016) The intellectually humble is aware of “the rights and needs of others who might hold differing points of view” (Paul & Elder, 2002, p. 40)

Note. IComp, ICC (Byram, 1997), ICit (Byram, 2008).

4.2.2 Suggested foci for enrichment opportunities

The knowledge dimension of ICit can be enriched with learning activities that allow students to challenge their own knowledge and that of others (Elder & Paul, 2012). Educators need to purposefully incorporate opportunities for students to productively criticize the extent of their knowledge of a certain topic and identify missing perspectives or gaps (Davis et al., 2016). These experiences should involve students doing this on their own as well as with their peers since such exposure has the potential to promote knowledge growth at individual and group levels.

To support the development of intercultural communicative competence skills, it would be important that educators intentionally expose students to ideas that differ from their own, providing opportunities to ease anxiety and/or overcome resistance to exploring contentious or sen-

sitive topics and develop a capacity for dealing with disagreement (Davis et al., 2016). Students need opportunities to become aware of their tendencies to prejudge and have biases towards views different from their own, and to be able to recognize the rights and needs of those whose perspectives might rival their own (Paul & Elder, 2002). Students should be guided to reflect on how those tendencies affect their learning processes and ways these can be handled positively.

Table 3: Overview of IH indicators that enrich ICit skills

Indicators: IComp, ICC, ICit	Associated IH Indicators
<i>skills of interpreting and relating</i>	IH Outcome 4 (Elder & Paul, 2012, p. 30) (see above) “People who are high in intellectual humility are attentive to limitations in the evidence for their beliefs and are aware that their ability to obtain and evaluate relevant information is limited” (Deffler, Leary, & Hoyle, 2016, p. 255)
<i>skills of discovery and interaction</i>	IH Outcome 2 (Elder & Paul, 2012, p. 30) “People high in intellectual humility are higher in epistemic curiosity, openness, and need for cognition, characteristics that are associated with the motivation to seek information and think deeply about topics. Such an epistemic approach should expose intellectually humble people to information that demonstrates the complexity and ambiguity of many issues and encourage them to question the veracity of their beliefs” (Deffler et al., 2016, p. 255)

Note. IComp, ICC (Byram, 1997), ICit (Byram, 2008).

4.2.3 Suggested foci for enrichment opportunities

Students’ ICit skills of interpreting and relating can be strengthened through IH by creating opportunities that encourage them to disentangle what is clear and what still needs further exploration (Elder & Paul, 2012). Learning activities should call for students to recognize and identify the risks in finding and assessing information (Deffler et al. 2016). With this understanding, students should be further encouraged to reflect on how these considerations impact their ability to interpret and relate the topic at hand.

Building on these considerations, educators can foster the skills of discovery and interaction by helping students to evaluate their knowledge limitations (Elder & Paul, 2012) to recognize how weaknesses that stem from biases and prejudices etc. affect the quality of a product, and by motivating them to seek further information (Deffler et al., 2016). Students should be led to identify potential weaknesses in their work and that of others. Here again, students should be encouraged to reflect on how this impacts their ability to make new discoveries and/or interactions.

Table 4: Overview of IH indicators that enrich ICit critical cultural awareness

Indicators: IComp, ICC, ICit	Associated IH Indicators
<i>critical cultural awareness</i>	IH appears to predict one's preference to sharpen the quality of ideas and base decisions on empirical information or reasoning rather than intuition (Davis et al., 2016) "A critical thinker does not blindly accept what he or she thinks or believes but cannot prove as true. A critical thinker realizes how easily we confuse intuitions and prejudices. Critical thinkers may follow their inner sense that something is so, but only with a healthy sense of intellectual humility" (Paul & Elder, 2002, p. 390)

Note. IComp, ICC (Byram, 1997), ICit (Byram, 2008).

4.2.4 *Suggested foci for enrichment opportunities*

In supporting critical cultural awareness, educators can help students by offering opportunities to identify potentially unfounded *intuitions* used as evidence in support of arguments and to reflect on how these intuitions affect the quality of the work at hand (Davis et al., 2016). These experiences should involve students in thinking critically about their own intuitions as well as those of their peers, and using this to revise work that may contain sub-optimal treatment of evidence, to sharpen the quality of ideas and/or to acknowledge places in their work where there might be potential for improvement.

Table 5: Overview of IH indicators that enrich ICit action component

Indicators: IComp, ICC, ICit	Associated IH Indicators
<p><i>ICit sample indicators with action orientation: grasp and take seriously the opinions and arguments of others, accord personal recognition to people of other opinions, put oneself in the situation of others, accept criticism, listen</i></p>	<p>IH Outcome 8 (Elder & Paul, 2012, p. 30) The IH person considers standpoints other than their own, extend and apply their knowledge with strong reasons and supports for their claims that are informed by thoughtful questions (Baehr, 2013) Coming full circle with IH means “[w]e also must be motivated by an intellectual sense of justice. We must recognize an intellectual responsibility to be fair to views we oppose. We must feel obliged to hear them in their strongest form to ensure that we are not condemning them out of ignorance or bias on our part” (Paul & Elder, 2002, p. 56) “society accepts among its social practices any form of slavery, torture, sexism, racism, persecution, murder, assault, rape, fraud, deceit, or intimidation, it is subject to ethical criticism. The question ceases to be one of social preference and relativity” (Paul & Elder, 2002, p. 264)</p>

Note. IComp, ICC (Byram, 1997), ICit (Byram, 2008).

4.2.5 Suggested foci for enrichment opportunities

Educators can reinforce the action component of ICit by helping their students become ambassadors of intellectually humble intercultural discourse on issues that affect the public good. This can be achieved by creating tasks that lead students to demonstrate awareness of and concern for the impact that their culture may have on their beliefs and actions (Elder & Paul, 2012) and to carefully consider the viewpoints of other cultures (Baehr, 2013). They should be encouraged to incorporate these thoughtfully into projects for taking action in the world and exhibit intellectual humbleness in their products (written and oral) when enacting their action projects for their school community, as well as other communities.

To illustrate how IH might refine the ways in which ICit is taught, we turn to a project in which university students in Argentina and England worked, through telecollaboration, to analyze an historical event – the war between Britain and Argentina about the Malvinas/Falkland Islands – and to become involved in *action in the world* (Porto & Yulita, 2016).

The project consisted in students first working together to establish the two differing national perspectives on the event, and then through comparison and analysis taking up a critical perspective from an *international* viewpoint, and finally planning and carrying out actions in their societies which presented this new international and critical perspective to other people in their communities.

The teachers based their work, *inter alia*, on Byram's (2008) model of ICit with particular reference to *critical cultural awareness* as defined above, and used this as a basis for evaluating their students' activities in the classroom and beyond. Had this been augmented by referring to IH theory and the definition juxtaposed with critical cultural awareness as in Table 1, the teachers would have been able to look for specific evidence corresponding to this indicator, and would thereby have gained a more nuanced analysis of students' responses whether in terms of what they said or in terms of how they acted.

4.3 **What is the role of foreign/world language education in fostering IH education?**

Finally, addressing our third research question, the investigation of the connections between theories of IH and ICC highlight the special status of foreign language education in our students' acquiring critical thinking skills as part of their development of IH. As discussed above (section 4.1), a linguistic analytical perspective can bring more depth to IH through the comparison of languages. The comparative orientation regarding rhetorical devices and language in general is a key element of the way in which language education relates to education for IH. A close attention to language *per se* and a comparative analysis of the way assertions and arguments are made in two or more languages introduces the critical awareness which is fundamental to the teaching of openness and curiosity, which are dispositions crucial to IH. We therefore believe that intercultural and linguistic comparisons support the goals of IH education through a thoughtful and systematic approach. It is with foreign/world language education that the action orientation of ICit is ultimately enacted, as a medium to question the interconnections of these comparisons, as the agency to deepen understanding of issues and develop action plans, and as the means to bring those plans to fruition. IH attitudes

and dispositions contribute to accomplishing this successfully and, when that is the case, it is through foreign/world language education that IH development is supported.

Furthermore, there is now convincing evidence of connections between being bilingual and the development of cognitive skills (Marian & Shook, 2012). Additionally, in the aging population, the use of more than one language has been linked to a reduced risk of developing dementia (e.g., Bialystok, Craik, & Freedman, 2007). These cognitive gains are supported by findings in neuroscience where studies have found positive effects of bilingualism on the structure of the brain as well as in neuronal activation (Marian & Shook, 2012). Based on our empirical work and the argument presented in this chapter, we believe that the study of connections between IH in combination with foreign language education can offer additional explanations for the potential effects of foreign languages on cognitive development. In other words, specific approaches to foreign language education proposed here can support and enhance students' IH and their critical thinking skills, and this might pave the way for research on the relationship between IH and bilingualism and language learning.

5 CONCLUSION AND FUTURE DIRECTIONS

Based on our empirical work in projects mentioned earlier and the argument developed here, we have demonstrated that there is considerable overlap between the theories of IH and ICit (which includes IComp and ICC). We have also shown how combining aspects of both theories can strengthen and enrich the implementation of ICit pedagogy in education. This can happen by strengthening overlapping concepts or adding components from IH into the different dimensions of ICC. We have also shown how ICit can operationalize theories of IH, which is still in the process of theoretical refinement. ICC/ICit can offer a pedagogy which is competence-based and which can make IH accessible and feasible for teachers in schools and other educational institutions. It can do so by creating a model of ICit/IH for pedagogical purposes.

The combination of teaching (foreign) languages for intercultural citizenship with insights from IH invites future research focused on another important comparison. Content and *Language Integrated Learning in Bilingual and Multilingual Education* (CLIL) as it is called in the European context is comparable to *Content-based Instruction* (CBI) in the US context in that both approaches foster learning objectives related to content as well as to proficiency in the target language. If the content is intercultural citizenship (which can be based on any problem and topic teachers or students choose to address) students can attain proficiency in the target language while developing the skills necessary to engage in intercultural public discourse, which we have argued above should be infused with the principles of IH.

A second opportunity for future research is in furthering the connection from foreign language education – refined in its aims with input from IH – to *intercultural service learning* (Rauschert & Byram, 2017) where there is explicit and deliberate creation of cooperation for students with non-governmental agencies in dealing with real world problems, particularly those where linguistic and intercultural (communicative) competence are a necessary tool for success. As we emphasized in the introduction, there are clear demands in the contemporary world for initiatives not only by politicians but above all by active citizens. Combining ICit and IH education, language proficiency, critical cultural awareness, and critical language awareness, we can prepare our students to go out into the community and to apply their intercultural competence right now which is urgently needed.

ACKNOWLEDGEMENTS

Work on this project was supported by Humility & Conviction in Public Life and the John Templeton Foundation.

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Frames, cognition, ideology. And Chomsky.

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ABSTRACT Within the field of cognitive linguistics, *Frame Semantics* and *Conceptual Metaphor Theory* are two major and influential players. While Charles Fillmore created his approach to provide a model for how knowledge is stored interdependently in our minds via *frames*, George Lakoff further developed this model to the level of metaphors and gave it a political dimension. He linked metaphors and frames to ideology and the struggle for power, epitomized by his engagement in shaping the discourse used by US Democrats in their struggle for interpretative dominance against their Republican counterparts. In showing how the use of images and frames is connected to both experience and worldview, Lakoff managed to further deconstruct the idea of language as a neutral way of representing reality and showed its contested role in the struggle for political power. Due to Lakoff's own political investment, however, he is highly critical of conservative discourse, but less so regarding the problematic aspects of liberal discourse. It took another prominent linguistic figure and political activist, Noam Chomsky, to redirect the discussion not to right vs. left or conservative vs. liberal, but to just vs. unjust and to contextualize and challenge it in terms of vested interests of people in positions of power. In this chapter, I propose that the three approaches by Fillmore, Lakoff and Chomsky are compatible, even complementary, despite, or rather, because of their differences, with regard to the light they shine on the understanding of the public impact of political discourse from different angles. In order to illustrate this, the chapter aims to highlight one part of the development of research areas

attempting to connect cognitive linguistics to politics and ideology, and argues for a combination of the Chomskyan knowledge-based approach to criticism of political discourse and Fillmore's and Lakoff's theories on the cognitive implications of language use and ideology.

KEYWORDS conceptual metaphors, Frame Semantics, ideology, metaphorical framing, political discourse

1 INTRODUCTION

The naturalistic view that language's main purpose is to reflect and describe reality (Hall, 1997) has long been discarded. This has, however, not necessarily resulted in a comprehensive theory about the nature of language and of why and how words have meaning. The axiomatic, Saussurian view (de Saussure, 2006) that language is a system and that words, as part of the system, gain their meaning through complex relations to other words has greatly inspired linguistic research. An aspect, however, that was long ignored was that of language as a cognitive phenomenon, an expression of our subjective perception of the world, and therefore of an entity informed, and limited, by what George Lakoff calls our *embodiment* – and the boundaries this sets on our cognition (1999) – as well as by our everyday experience.

When Charles Fillmore created *Frame Semantics* (Fillmore, 1976), he did this in consideration of language as a mental phenomenon, and with a focus on the experience-based nature of language and our interpretation of it. With his groundbreaking approach, he managed to show how the comprehension and interpretation of language draw on previous experiences coherently organized in our minds, and are thus closely tied to our cognitive capabilities and processes. One of his earliest followers and colleagues, George Lakoff, used Fillmore's cognitive approach as a basis for his theory of conceptual metaphors and metaphorical frames, which Lakoff claimed were not merely linguistic phenomena, but fundamentally cognition-based: the mind's way of making sense of the abstract nature of many concepts by relating them to concrete life experiences.

Lakoff was also one of the most prominent linguists to give linguistic research a political dimension by pointing out the importance of metaphors and frames used in political discourse because of their relation to the workings of the mind as they activate certain schemas in our minds which influence the way we perceive and reason about an issue. Even though his cognitive approach to political discourse proved very enlightening in explaining the success of dominant frames over alternative frames, his clear political affiliation with the US Democrats arguably made it difficult to apply his theory to question political discourse in itself as a means to establish, reinforce, and monopolize power. While many scholars from the field of *Critical Discourse Studies* and beyond have made an effort to deconstruct political discourse, a unique and frequently quoted approach is that of the political activist Noam Chomsky. Chomsky critically analyzes and dissects political discourse irrespective of its leaning by not only discussing the language used, which may vary, but also by involving sociopolitical factors such as power and elite interests to show how framing on all sides is a mere tool obscuring often similar political and economic interests.

The objectives of this chapter, therefore, are twofold. The first is to outline an important stage in the development of cognitive linguistics by presenting selected aspects of Fillmore's and Lakoff's theories. The second is to present how cognitive linguistics can be applied to explain relationships of power as well as the maintenance of power, while contemplating ways to combine this approach with Chomsky's ideas of elite interests – the vested interests by people who wield social, political, or economic power – that unite political discourse throughout the ideological spectrum.

2 FRAME SEMANTICS AND COGNITION

Every memorable experience occurs in a meaningful context and it is memorable precisely because the experiencer has some cognitive schema or frame for interpreting it (Fillmore, 1976, p. 26).

Charles Fillmore devised his Frame Semantics approach in the early 1970s, while working on his theory of case grammar, with which he attempted to classify verbs according to the roles (or cases) they occur with, such as agent, theme, or instrument (Andor, 2010). It was a response to what he saw as an unsatisfactory explanation for the meaning of linguistic forms “being represented in terms of a checklist of conditions that have to be satisfied in order for the form to be appropriately or truthfully used” (Fillmore, 1975, p. 123). He proposed instead a merger between two new and upcoming theories at the time: *prototype theory* and *frame theory*. Neither restrict a word’s meaning in terms of necessary and sufficient conditions, but rather attempt to describe it in relation to ideal examples or prototypes – for entities, states, actions, situations – that are or become mentally ingrained based on acquired knowledge, and which “impose structure or coherence on some aspect of human experience” (Fillmore, 1975). For Fillmore, frames can be defined as “any of the many organized packages of knowledge, beliefs, and patterns of practice that shape and allow humans to make sense of their experiences” (Fillmore & Baker, 2009, p. 314). By encountering a particular linguistic form in the right context, a specific frame gets activated in the speaker’s mind (Fillmore, 1976), to the effect that a complete understanding of a form depends on the speaker’s ability to invoke all aspects of the frame it comprises. For example, it would be difficult to think of a university without at the same time thinking of what the purpose of a university is, who the actors are, what their roles are, and what properties and provisions we would expect to encounter at such an institution.

For Fillmore, frames are intrinsically cognitive because they draw on existing knowledge for the interpretation of meaning. Some “may be physiologically built in [...], others may owe their existence to perceived constant cause-effect relationships in the world, while still others may depend for their existence on symbolization” (Fillmore, 1976, p. 25).

A Frame Semantics description of language focuses on how the interpreter of a particular discourse creates a complete image of what is being said during the process of text interpretation despite the fundamental underdetermination (Sperber & Wilson, 1986) of semantic content. According to Fillmore, this missing information is filled in through the activation of frames. In one of his famous examples, Fillmore (1982) juxtaposed the two sentences *I spent two hours on land this afternoon*

and *I spent two hours on the ground this afternoon*. From a formal semantic point of view, these sentences are synonymous as they both have the same truth conditions. From a frame semantic vantage point, however, they mean different things because they evoke different frames that complement missing information differently. *On land* is interpreted horizontally, in opposition to *the sea*. We would assume that the person uttering this sentence must be on a ship. *On the ground*, conversely, is interpreted on a vertical scale, and in opposition to *in the air*. We would hence interpret this sentence as being uttered by somebody who usually spends his or her time on a plane. *Land* and *ground* thus belong to different frames, and their usage evokes these frames, which accounts for the difference in meaning between the aforementioned sentences.

This exemplifies another important feature of frames, namely that they frequently can refer to the same situation, but from different perspectives. They are therefore partisan in that invoking a particular frame necessarily enforces a certain vantage point, such as the word pairs *go* and *come* or *bring* and *take*, or the phrases *from shore to shore* versus *from coast to coast*, the former of which locates the speaker on the water, while the latter locates the speaker on the land. We can also speak of either a *terrorist* or a *rebel* or a *freedom fighter*, which may each be synonymous in a given context except for the perspective that is taken. This feature is highly useful in public and political discourse as it allows a speaker to frame an issue by rendering their reasoning as the natural way of perceiving a state of affair, without running the risk of lying (Kahnemann & Tversky, 1984). As soon as the frame is adopted, the perspective entailed is also adopted, mostly without being conscious of it, which makes the intentional use of frames a powerful tool.

3 GEORGE LAKOFF, METAPHORS AND EMBODIMENT

In the late 1970s, George Lakoff, inspired by Fillmore's ideas, went on to discover the anchoring of another phenomenon within cognition. He found that metaphors – contrary to common understanding – are not merely fancy, flowery expressions we use in (mainly literary) language for a particular effect, but that our minds are largely governed by meta-

phorical thinking, most of which happens on an unconscious level (Lakoff, 2014). In his breakthrough work with Mark Johnson, *Metaphors we live by* (1980), he proposed that metaphors inform every aspect of our lives and that – borrowing Paul Watzlawick's famous axiom (Watzlawick, 1967) – we cannot *not* think metaphorically.

Lakoff determined that many of our basic expressions in language are fundamentally metaphorical, such as being *in love* (love as a bounded space) or *getting ideas across* (ideas as objects) or *defending an argument* (argument as war), where the source domain (e.g., *journey*) is usually more concrete while the target domain is more abstract (e.g., *life*). Arguably his most important finding was that metaphors are by no means random but systematic, and largely influenced, determined, as well as limited by the details of what he called *embodiment*.

One of the powerful, though unconscious, characteristics of metaphors is that they govern reasoning: the decisions and actions we perceive to be appropriate to take with regards to an issue or event. Once a metaphorical framework is established, the issue becomes meaningfully debatable only within this framework and following its logic. This is a consequence of the systematic mapping between the domains and of the coherent structure (source domain concepts and their entailments) that is thusly imposed on the target domain (Lakoff & Johnson, 1980). For example, by adopting a disease or cancer metaphor (e.g., *to contain, to spread, to metastasize, to infect*) when talking about particular social or political groups or movements, the reasoning regarding the course of action is predetermined. Cancer needs to be *cut out*, a disease needs to be *eradicated*. It would be odd, within this metaphor, to suddenly suggest negotiations or compromise, as this is not a meaningful course of action within said metaphorical framework. Something similar can be argued with regards to the so-called *War on Terror*, in which the war metaphor was applied to a psychological state (*terror*), and within which frame negotiations are reserved for the losing party, thus laying the groundwork for a war without end (Steuter & Wills, 2008).

The impact of metaphors on reasoning was also well illustrated in a series of studies conducted by Thibodeau and Boroditsky (2011), in which they confronted participants with two texts about crime which were identical except for the metaphors they used, one being *Crime is a virus*, the other being *Crime is a beast*. While in the first study the met-

aphor was explicitly mentioned in the texts, the degree of explicitness decreased with each iteration until eventually only one trigger word (such as, e.g., *devour*) was left to suggest the metaphor. Participants were then asked to propose a solution to the crime problem. Those presented with the virus metaphor were consistently more likely to propose tackling the root causes and implementing social reforms, while participants faced with the beast metaphor had a greater tendency to suggest harsher law-enforcement measures. This, the authors argued, was in line with the metaphorical framework in which a virus can only be tackled by locating its source, while a beast needs to be hunted down and locked away or eliminated.

The notions of frames and metaphors are closely related, because similarly to using frames, in using a metaphor, a particular image or situation is invoked, including location, props, actors, actions and purposes. Following Fillmore, Lakoff suggested that many frames that shape our daily experiences are also metaphorical, and that these frames confer, impose and reinforce certain world views, as they take a certain perspective (Lakoff, 2004, 2009), while at the same time prescribing certain courses of action that are meaningful within the metaphor and its frame. An example would be the phrase *tax relief* (Lakoff, 2004). The word *relief*, as Lakoff suggests, evokes a certain frame with certain roles, such as an afflicted person, an affliction and somebody who relieves the afflicted from the affliction. Additionally, the person who relieves is normally seen as a good person, even a hero. When this term is combined with tax, it presents taxes as an affliction, and thus makes the expression metaphorical. It also implies that taxes are something inherently negative and therefore a government that reduces taxes is a good government. Such is the nature of the frame, which makes it very difficult to adopt this frame and argue against the reduction of taxes, as being against *relief* would be either conceived as nonsensical within its logic or as associated with the antagonist's role. In some cases, such metaphorical frames can also be misleading. In the case of Brexit, Britain's exit from the European Union, Lakoff argues, the discussion rests on the metaphor that states are locations, which is that the political entity of the EU is a location one can enter and exit, and that by exiting, one would return to the same place one came from. For Britons, this may have led to the assumption that by leaving the EU, their country would return to its original state before they

joined, an assumption that may turn out to be very wrong, as “[t]hings changed radically while they were in the EU” (Lakoff, 2016, para. 12).

Such guided reasoning makes (metaphorical) frames an ideal tool in political discourse, where the purpose is to present an issue in such a way that makes one’s own approach appear to be the only meaningful one (e.g., ameliorating the affliction of taxes), while rendering all other approaches nonsensical (e.g., arguing for taxes as a necessary tool to maintain social services). Recognizing the importance of frames in public and political discourse, Lakoff set out to use his research to raise awareness as to how frames impact our thinking, and how to reframe political debates.

4 **POLITICAL FRAMING**

It has been understood since the early days of public relations in the 1920s, that the main path to reach the public and convince it of the value of one’s own policies, is not so much through facts and reason, but by appealing to people’s instincts and emotions. Walter Lippmann, pioneer of public opinion research, wrote in his book *The Phantom Public* that the art of creating a common will

consists essentially in the use of symbols which assemble emotions after they have been detached from their ideas [...]. The process, therefore, by which general opinions are brought to cooperation consists of an intensification of feeling and a degradation of significance (Lippmann, 1927/2015, pp. 37-38).

Lakoff seems to partly agree that appealing to people’s emotions is more important than arguing facts when he identifies one major issue in the debate on *Obamacare* (a national healthcare plan passed during the Obama administration) in the US: Democrats were discussing “policy details” while Republicans were “arguing their values” (2012, p. 7), which in turn activated certain emotions. The major issue for Lakoff is that the Democrats appear to be arguing in the established conservative frame, thus making their arguments ineffective as they belong to a different frame

to begin with. This, he maintains, is due to *hypocognition*, which means a lack of ideas to express what you wish to convey concisely (Lakoff, 2004). He argues that, while conservatives can rely on an array of fixed frames that have become established in recent decades (due to intensive funding from conservative think tanks), progressives lack such frames, and thus are left with either longish explanations of their viewpoints or with adopting the conservative frame and arguing against it from within the frame. According to Lakoff, both have proven unsuccessful because the frame, once activated, rejects any ideas that are inconsistent with its inner structure, which has become neurally instantiated (Lakoff, 2004). On the other hand, by simply negating or arguing against their frame, the frame is only reinforced because any invocation of the frame, even by negation, activates it (Lakoff, 2004).

With books such as *Don't think of an elephant!* (2004) or *The Little Blue Book* (2012), Lakoff has become one of the main linguistic thinkers of the Democratic Party. Based on his research, he identifies the main difference between Democrats and Republicans in their different frame models regarding family. While Republicans in general subscribe to a strict father model, Democrats' policies are infused by the *nurturant parent model* (2004), and people relate to either one of them through their own metaphorical frames of the family based on their values and experiences. Funneled through a very basic metaphor conceptualizing the nation as a family (e.g., the Founding Fathers, our nation's sons and daughters, the state taking care of its citizens), this explains – in Lakoff's view – why the two parties have such different policies on issues such as the death penalty, welfare or abortion. This is because in the strict father model children need to be punished when they have been bad (death penalty or harsh prison sentences in general) and should not receive rewards if they have not worked hard to earn them (welfare), while in the nurturant parent model, it is the role of the parents (i.e., the state) to teach their children compassion and to help them when they do not manage on their own.

However, the strict father model seems to be the more dominant and wide-spread frame in the US context, as is also exemplified by the most archetypal American narrative – the idea of *rags-to-riches*, also known as the *American Dream*. It states that everyone, even the poorest person, can be successful, can become rich, if they only try hard enough. By ex-

tension, this implies that if someone does not succeed, they did not try hard enough and therefore deserve their fate – and do not deserve to be helped by others. This basic metaphorical mindset is currently epitomized by US President Donald Trump, who, to a much greater extent than his predecessors, is seen to draw his rhetoric from the strict father model, in which he represents “the ultimate authority. Father knows best. He gets his authority from the claim to know right from wrong, and what he says is by definition always right. His word is law and needs to be strictly enforced through strength – swift painful punishment” (Lakoff, 2017, para. 15). Proponents of the nurturant parent model, therefore, would seem to be at a serious disadvantage, as the dominant Republican frame appears to reverberate more with what could be called *the American spirit*. In arguing against this very fundamental strict father frame, hence, Lakoff maintains that progressives are bound to fail as their arguments run counter to the dominant frame and thus to those cognitive structures through which many Americans make sense of the world around them (Lakoff, 2004, 2009; Lakoff & Wehling, 2012). A side effect of this dominance, as Lakoff perceives it, is that the Republicans get to determine the narrative, as it is their own framings that are firmly in place in public discourse.

Lakoff persuasively argues for a different language to counter the power of such frames. His claim is that it is no use to debate Republicans on their own terms by adopting their language, such as *tax relief*, *tax cuts*, *tax havens*, all of which imply that taxes are bad. Thus he suggests reframing taxes to *revenues*, that is, to frame the same entity not in terms of where the money comes from but what it is used for (Lakoff & Wehling, 2012). In doing so, he maintains, Democrats can reframe debates and argue against Republicans on their own terms.

Lakoff's insights into metaphors and framing have certainly proven invaluable, especially because he argues from a cognitive point of view, tracing the impact of certain frames to their neural instantiations – or lack thereof. Additionally, it is clear that his concise analysis of the fundamental differences in metaphorical frames to conceptualize the nation state and the role of the government in it are crucial to understanding the variety of seemingly incoherent standpoints from both sides of the political spectrum in the US and beyond. However, while it is clear that no one can analyze discourse from a truly neutral perspective (e.g., van

Dijk, 1993), it is also clear that Lakoff's personal stake in the issue as an active supporter and linguistic expert for the Democratic Party has made it difficult for him to see that in certain other cases, the differences between Republicans and Democrats are actually not so great. Rather than being connected to different conceptualizations of values and different ideologies, they are at times merely in the language, because their fundamental interests – to gain power and to hold on to it; to support and be supported by lobbyists and other interest groups; to give priority to domestic economy over climate protection, human rights or democracy – essentially coalesce, in particular in view of foreign policies, a playing field which allows for the export of costs and conflicts and the import of cheap benefits at the expense of faraway countries. To put it bluntly: for all his merits identifying the effects of language on our thoughts and actions, and for all his efforts to infuse political language with more social and progressive values and frames, Lakoff seems to neglect what all in power have in common: vested interests.

5 **BEYOND PARTY INTEREST – NOAM CHOMSKY AND ELITE INTERESTS**

The casinos moved back into the country. Free health and free education were over. Big business returned with a vengeance. Democracy had prevailed (Pinter, 2005, para. 44)

Noam Chomsky was originally Lakoff's mentor and teacher, until in the early 1970s they got into an extended public debate about what linguists should concern themselves with: discovering the universal rules of syntax or understanding language concepts through discovering the workings of the mind (Bai, 2005). And while Lakoff was starting to build his reputation as a leading cognitive linguist, Chomsky increasingly moved away from linguistics proper towards a second career as a political activist, essentially attempting to find, as it were, the universal syntax to describe political agendas, by debunking the frames and narratives put forth by consecutive US administrations, both Republican and Democratic. Chomsky has repeatedly argued that both parties are heavily en-

tangled with private interests and therefore fundamentally pursuing the same goal, even if the methods and the intensity of investment may vary. In a 2010 interview with *The New Statesman*, he maintained that “in the US, there is basically one party – the business party. It has two factions, called Democrats and Republicans, which are somewhat different but carry out variations on the same policies” (McDonald, 2010, online, para. 13). Both parties, for example, reiterate America’s dedication to spreading *democracy* and *freedom*, when in fact their real geopolitical interest lies in gaining economic footholds around the globe, and *bringing democracy* has, for many nations striving for more economic independence, come to embody a threat.

Lakoff, in his works, attempts to focus on the frames that are used by politicians and on how they impact us based on cognitive science, and he does so from the implicit assumption that Democrats have the better policies; they only need to work on how they communicate them. Chomsky, on the other hand, is concerned with what is behind the meaning of certain words with a high symbolic character used equally by both parties, such as *democracy* or *terrorism* or *free market*, and with the difference between these words’ dictionary definitions and what he calls their technical definitions, namely the way a word is interpreted by people in power. For example, democracy, according to the technical definition proposed by Chomsky, would be a system that “is run by the business classes” (The Film Archives, 2012). By the same token, he suggests that a *peace process*, rather than having the general meaning of a process with the aim of leading to peace, is actually used to mean “whatever the US happens to be advocating at a particular moment” (The Film Archives, 2012). By employing this Orwellian doublespeak approach, Chomsky means to show how, behind the linguistic facade of political differences between the two US parties, the major interests driving and informing US policies, especially foreign policies, are largely the same.

In Lakoff’s argument, self-interest-centered foreign policies are mainly ascribed to the Republican Party and its strict father frame (Lakoff, 2004). As an example, he mentions the workings of the International Monetary Fund and its policies regarding developing nations, saying that “[i]f you are a strict father, you tell the children how to develop, tell them what rules they should follow, and punish them when they do wrong” (Lakoff, 2004, p. 11). In doing so, he associates neoliberal aus-

terity policies with conservative thinking, while stating that what progressives stand for are “nurturant values” (Lakoff, 2004, p. 13). Chomsky, however, is critical of such distinctions, outlining how both sides of the party spectrum resort to such policies of securing and protecting their economic interests.

Take Bill Clinton. He had a doctrine too, every president has a doctrine. He was less brazen about it than Bush, didn’t get criticized a lot, but his doctrine was more extreme than the Bush doctrine if taken literally. The official Clinton doctrine presented to Congress was that the United States has the unilateral right to use military force to protect markets and resources. The Bush doctrine said we’ve got to have a pretext, like we’ve got to claim they’re a threat. Clinton doctrine didn’t even go that far, we don’t need any pretext. With markets and resources, we have a right to make sure that we control them, which is logical on the principle that we own the world anyway so of course we have that right (cited in Shank, 2008, para. 19).

Thus, Chomsky sees the difference in language use on both sides as merely a smokescreen to obscure that the policies behind the veil are mostly identical, as they cater to the same market interests. The parties may invoke different frames or appeal to different worldviews, but the actions that are implicitly described are the same.

Another example is the discourse of *stabilization* in foreign policy, which Chomsky flatly debunks as “when we invade and destroy another country, that’s stabilizing, and if someone defends themselves that is destabilizing” (Chomsky, 2015, para. 19). In referring to the US-backed coup against Salvador Allende in Chile in 1973, he maintains:

The term “stability” is used here in its standard technical meaning: subordination to Washington’s will. There is no contradiction, for example, when liberal commentator James Chace, former editor of *Foreign Affairs*, explains that the United States sought to “destabilize a freely elected Marxist government in Chile” because “we were determined to seek stability” [under the Pinochet dictatorship] (Chomsky, 2008, para. 38).

The power of this discourse develops once the primary presupposition, which is that what the US is doing is indeed stabilization, has become accepted and axiomatic through constant repetition by authoritative channels such as the media. Once this has become common sense, the discussion no longer revolves around whether military actions in another country should be called stabilization or not, but around the question of how to perform better in the attempts to stabilize a region within the given and accepted framework.

The same can be applied to the concept of *humanitarian intervention*, which has seen a sharp rise in use since the collapse of the Soviet Union (Chomsky, 2008), and which officially designates the use of military force to protect civilians from violence by their own governments. As Chomsky outlines, however, it is in fact only used when the actor doing the intervention is a Western government (Chomsky, 2008). Its usage also presupposes that the intervention is actually undertaken with the main goal of saving civilian lives, to the effect that, once adopted, it limits the discussion only to whether the intervention was well-executed or blundered (as in the cases of the Iraq invasion of 2003 and Libya 2010), but effectively precludes discussions on whether the intervention was justified or not. After all, an intervention on humanitarian grounds is almost by definition justified. What these examples illustrate is the importance of going beyond a mere analysis of words, by deconstructing the myths that they both construe and represent.

The persuasive power of Chomsky's approach comes from his comprehensive historical knowledge and his remarkable skills in explaining and contextualizing complex events in world history. His linguistic background certainly does feature largely in his critical approach to US policies, as he attempts to deconstruct the use of certain buzz words – in essence not that different from Fillmore's and Lakoff's concept of frames – such as *democracy*, *stability*, or *humanitarian intervention*; Chomsky's main interest, however, lies in the juxtaposition of what is said with what is actually done (to the extent this can be perceived, e.g., via testimony or declassified documents). This becomes clear from a passage of a lecture given at the National Autonomous University of Mexico, in which he says that “it is wise to attend to deeds, not rhetoric and pleasant demeanor. Deeds commonly tell a different story” (Chomsky, 2009, online, para. 35). Of course, one might argue how deeds can be ascertained objective-

ly – they cannot – but this does not mean a relief from the obligation of holding those in power accountable for their actions, many of which are well documented, which is as close as one can get to accessing the facts on the ground. Chomsky's approach has considerable merit, in that it transcends the merely linguistic analysis of what is said and how this affects the audience, and instead shows that irrespective of political affiliation, the common denominator between people in power is their vested interests in business as it is business that keeps them in power. It need not be stressed that his class-based approach is in itself an ideology, but arguably free from the systemic vested interests that drive the dominant political forces.

6 CONCLUSION

It is clear that both Chomsky and Lakoff argue for social justice, but from two different ideological groundings and using radically different methods. However, it could be said that their approaches would be much more persuasive if combined, not just with each other, but also with other approaches. The goal should be to create a theory for political discourse analysis that takes into account the multidimensional aspects of discourse – interpersonal, cognitive, (con)textual, historical, ideological – in order to provide those interested with a toolset for analyzing and comprehending political discourse in its entirety, while shielding them from possible partisan effects by contrasting language with actions and by also studying omission in discourse. There is a great need for an analytical framework that not only relies on exploring the representation of language and ideology in a text, or on mental structures to account for the effect of ideological discourse on audiences, or on production processes to explain discourse constraints, but also questions the relationship between discourse and the deeds that follow. Focusing only on the language threatens to divert attention from the actions that political actors take, as well as detaches language entirely from the world it acts on. By relying solely on said actions, however, we run the risk of failing to explain why political actors get *cartes blanches* for these actions by employing language in a way that masks their ideological background, and why cer-

tain messages effectively shape, change and direct public opinion. Only by adopting a more global approach to analyzing political discourse that incorporates language use, language effects and an analysis of the actions that ensue, can a more complete understanding of the impact of politics on our lives be achieved.

What would be important is to merge some of the major existing approaches into a single universal theory that provides a toolkit for understanding, analyzing and inoculating against manipulative discourse. These approaches include the kind attempted, for example, by the Glasgow University Media Group's Thematic Analysis (Philo & Berry, 2011), which looks at media's production processes, linguistic strategies of representation as well as audience effects, juxtaposing media narratives with official and alternative narratives, but which lacks the cognitive depth of the news framing approaches by Robert M. Entman (e.g., 1993, 2004) or Dietram A. Scheufele (e.g., 2000), or the linguistic rigidity of Critical Discourse Studies (e.g., Fairclough, 1992; Reisigl & Wodak, 2001; van Dijk, 1993). Each approaches the topic from different directions, but none is comprehensive. Together, however, they have a large potential for critical synergy. Lakoff and Chomsky, here, cover important parts that would be vital for such an approach to be effective, but they arguably lose much of their potential effect because of their isolation from one another.

The importance of engaging in such a comprehensive critique, and doing this from a minority perspective, cannot be overestimated. In the status quo, the right is criticizing the left, for the sake of right-leaning audiences; the left is criticizing the right, for the sake of left-leaning audiences. Both are, in essence, preaching to their own choirs. Many of the resources of Critical Discourse Studies are devoted to exposing hypocrisy, sexism or xenophobia in right-wing groups and parties. The effect is merely to reinforce already existing beliefs about the *other* by reverberating with preexisting schemata and categorizations, or stereotypes. What is needed is to break one's own dominant frames, and question one's own stereotypes, hence a criticism of conservative discourse by and for conservatives and a criticism of progressive discourse by and for progressives. This could be achieved by questioning, as Chomsky does, how words conceal vested interest by decision makers revealed through deeds and by inquiring, as Lakoff does, what frames and metaphors do

to people and how to counteract those effects – not, however, in order to promote one part of the political spectrum, but instead to promote social justice for all. Otherwise, justice will remain merely a metaphor with an empty frame.

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Monats- und Wochentagsbezeichnungen im Wandel der Zeit

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KURZZUSAMMENFASSUNG Das vorliegende Kapitel befasst sich mit den Bezeichnungen für Monats- und Wochentage im Deutschen und deren etymologischer Herkunft. Es werden einerseits Begriffslisten vorgestellt und Namen erklärt, die in der Vergangenheit und/oder teils heute noch in Gebrauch sind. Andererseits werden die Bezeichnungen der vergleichenden sprachwissenschaftlichen Methode unterzogen, wobei auf deren Vorkommen in anderen (teils extinkten) Sprachen hingewiesen wird und im Weiteren die sprachlichen und lautlichen Veränderungen, die diese Begriffe durchgemacht haben, angeführt werden.

SCHLAGWÖRTER Ertag, Etymologie, Monatsnamen, Pfingstag, Wochentagsbezeichnungen

VORWORT

Sehr verehrte Frau Kollegin Peltzer-Karpf! Sie werden überrascht sein, von mir zu hören und zu lesen. Ich denke noch gerne an unsere gemeinsame Zeit in Graz zurück und freue mich außerordentlich, dass Ihnen ein Buch gewidmet wird und natürlich auch, dass ich dazu beitragen

darf. Hoffentlich erfreut Sie mein kleiner Beitrag etwas. Ich wünsche Ihnen alles erdenklich Gute! *Stets Ihr W.V.*

1 DEUTSCHE MONATSNAMEN

Verschriftlichte deutsche Monatsnamen findet man erstmals um das Jahr 800 in Einhards lateinischem *Opus Vita Karoli Magni*, das das Leben Karls des Großen behandelt (Weifert, 2003). Dazu gehören *wintarmanoth*, *hornung*, *lenzinmanoth*, *ostarmanoth*, *winnemanoth*, *brachmanoth*, *hewinmanoth*, *aranmanoth*, *witumanoth* und *heilagmanoth*. Diese Namen waren aber nicht mehr ursprünglich, sondern bereits durch den Einfluss des Christentums verändert worden. Zum Beispiel der neunte Monat (auch sogenannter *Herbstmonat*) und der *witumanoth* (*Holzmonat*) waren beliebig bestimmt worden. Im Angelsächsischen wurde dieser neunte Monat *halegmonadh* genannt (Beda Venerabilis, 725), der später unter Karl dem Großen zum zwölften Monat wurde.¹ Nach dem Vorsitzenden des Hamburger Vereins für Sprachpflege, Heinrich Heeger (1817–1885) tritt erst am Ende des Mittelalters die Bezeichnung „Mond“ an die Stelle von „Monat“ (Weifert, 2003). 1781 benannte Justus Friedrich Runde die Monate folgendermaßen:

Wintermonat, Hornung, Lenzmonat, Ostermonat, Wonnemonat, Brachmonat, Heumonat, Ähren- oder Erntemonat, Herbstmonat, Weinmonat, Windmonat und Heiligen- oder Christmonat

Diese Monatsnamenreihe hat Willkürlichkeiten Karls des Großen teils beseitigt, allerdings blieben noch gewisse Fehler bestehen. So war zum Beispiel der *Ährenmonat* falsch, da *aran* die alte Form für „Ernte“ ist. Im Jahre 1846 wurde von Friedrich Ludwig Jahn (1778–1852) der *Julmonat* als zwölfter Monat eingeführt (Weifert, 2003).

Am Ende des 19. Jahrhunderts waren unterschiedliche Monatsnamenreihen in Gebrauch, in denen eine Reihe an Namen erschienen

¹ Zur Zeit Karls des Großen war der Monat „manoth“ genannt; zum Ende des Mittelalters hatte sich die Bezeichnung zu „mond“ geändert (Janecke, 2017).

(siehe Tabelle 1). Hierbei sei erwähnt, dass einheitliche Monatsnamenreihen nicht möglich waren, da die deutschen Mundarten alleine an die 200 verschiedene Monatsnamen aufwiesen, die zeitlich und/oder örtlich begrenzt vorkamen (siehe dazu Weifert, 2003; Weinhold, 1861).

Tabelle 1: Monatsnamen des 19. Jahrhunderts

Monat	Bezeichnungen	Erklärung
1	Hartmond, Jenner, Hartung, Eismonat	Die Bezeichnung <i>Hartung</i> wurde 1893 von Hermann von Pfister-Schwaighusen aus der Umformung von <i>Hartmann</i> (entstanden aus der harten Erde und der Bezeichnung für „Mond“ <i>Man</i>) geprägt. Der <i>Hartmond</i> oder <i>Hartmonat</i> (althochdeutsch: <i>hertimanod</i> , mittelhochdeutsch: <i>hertemanot</i>) beinhaltet noch die Referenz zu hartem Eis, das im Wintermonat auftritt.
2	Hornung	Die Bezeichnung <i>Hornung</i> leitet sich vom althochdeutschen/mittelhochdeutschen <i>hornunç</i> ab, welches die Bedeutung von „Ecke“ (genannt Horn, vom Germanischen <i>hurna</i>) trägt. Die „im Eck gezeugten Kinder“ (d.h. die außerehelichen) wurden auch als „zu-kurz-gekommen“ (d.h. benachteiligt) bezeichnet, und der zweite Monat, als kürzester aller mit nur 28 oder 29 Tagen, weist darauf hin.
3	Lenz, Lenzmond, Lenzmonat, März, Spröckel	Die althochdeutschen Namen <i>lenzo</i> und <i>lengzo</i> bedeuteten „Frühling“ und wurden abgeleitet von der Bezeichnung für „länger“ in Referenz zu den länger werdenden Tagen des Frühjahrs.
4	Ostermond, April, Ostering (später Ostaring), Ostermonat	<i>Ostermonat</i> oder <i>Ostermond</i> nehmen Bezug auf die Himmelsrichtung Osten, die mit dem Sonnenaufgang zusammenhängt. Das steigende Licht und der wichtigste Fixpunkt im Sonnenverlauf – die Frühjahrs-Tag- und Nachtgleiche am 21. 3. – hatten maßgebliche Einflüsse auf diesen Monatsnamen. Das Osterfest wurde nach dem ersten Frühlingsvollmond gefeiert.
5	Wonnemond, Wonne- monat, Mai, Wundmond, Wunmonat	Diese Bezeichnungen gehen zurück auf das Althochdeutsche <i>winni-</i> und <i>wunnimanod</i> (ahd. <i>wunni</i> = „Freude“, „Lust“) und das Mittelhochdeutsche <i>wunne-</i> oder <i>winnemanot</i> (mhd. <i>wunne</i> = „Lust“, „Weideplatz“), und demzufolge wurde der fünfte Monat auch Weidemonat genannt. Das gotische <i>winja</i> bezeichnet „Weide“ und „Futter“ und ist bedeutungsverwand mit den germanischen <i>wunjo</i> oder <i>wun</i> , welche „zufrieden sein“ bedeuten.

Monat	Bezeichnungen	Erklärung
6	Brachmonat, Brachmond, Linding, Wendert, Brachet (süddeutsche Kurzform)	Diese Bezeichnungen nehmen Bezug auf die Dreifelderwirtschaft und die Bestellung des Brachfelds im Juni.
7	Heumond, Heumonat, Juli, Heue(r)t	Im siebten Monat des Jahres fand üblicherweise die Heuernte statt.
8	Ähren- oder Erntemond, Augst, Auchst, August, Ernting, Erntemonat, Erntert	Die Bezeichnungen <i>Erntemonat</i> , <i>Erntemond</i> und <i>Ernting</i> wurden von Adolf Ferdinand Ludwig Reinecke (1893) geprägt und sind vom Wort „Ernte“ abgeleitet, das sich auf die althochdeutschen <i>arnoti</i> und <i>ar(a)n</i> (d.h. „Ernte“) zurückführen lässt (Weifert, 2003). In diesem Monat fand die Getreideernte statt.
9	Herbstmond, Herbstmonat, Herbsting, Scheiding, Arminsmonat	Die Bezeichnungen <i>Herbstmond</i> , <i>Herbstmonat</i> und <i>Herbsting</i> gehen auf Adolf Reinecke (1893) zurück und weisen auf den Herbstbeginn am 23.9. hin, an dem es auch zur Herbst-Tag- und Nachtgleiche kommt (Weifert, 2003). Das Wort <i>Scheiding</i> könnte darauf Bezug nehmen, dass die warme von der kalten Jahreszeit geschieden wird (Weinhold, 1861), ist aber eher eine Neubildung aus dem nordhumbrischen <i>skeadhing</i> , welches „trennen“ bedeutet.
10	Weinmond, Weinmonat, Gilbhard, Freiheitsmonat	<i>Gilbhard</i> ist ein Neologismus, der auf die Bezeichnungen <i>gilb</i> für „gelbes Herbstlaub“ und dem germanischen <i>hart</i> für „Bergwald“ zurückgeht. Der Name wurde von Pfister-Schwaighusen geprägt, von späteren Germanisten allerdings als willkürlich abgelehnt (Weifert, 2003). Die Namen <i>Weinmonat</i> und <i>Weinmond</i> sind Ableitungen vom lateinischen Wort <i>vinum</i> für „Wein“ und <i>demere</i> für „abnehmen“, und beinhalten Referenzen zur Weinlese (auch <i>Weinlesemonat</i> genannt).
11	Windmonat, Wintermonat, Nebelung, Laubriß, Nebelmonat, Nebelmond	Aus volksetymologischer Sicht geht auch der <i>Windmonat</i> auf den <i>Weinmonat</i> (zehnter Monat) zurück. <i>Nebelmonat</i> und <i>Nebelmond</i> und das von Pfister-Schwaighusen geschaffene <i>Nebelung</i> nehmen Bezug auf die nebelige Jahreszeit des elften Monats (Weifert, 2003). Im Französischen wird der zweite Monat des republikanischen Kalenders der Französischen Revolution <i>brumaire</i> (d.h. <i>Nebelmonat</i>) genannt, und die deutschen Bezeichnungen <i>Nebelmonat</i> und <i>Nebelmond</i> könnten dem Französischen gefolgt sein.
12	Weihnachtsmond, Weihnachtsmonat, Jul, Julmonat, Heiligen- oder Christmond, Christmonat, Wending	<i>Julmond</i> kommt aus dem Schwedischen und leitet sich von <i>jul</i> (= „Rad“) ab. Jul ist das germanische Fest der Wintersonnenwende (21. 12.) und geht auf altnordischen <i>jol</i> zurück. Heute heißt der Monat <i>Dezember</i> , abgeleitet vom lateinischen <i>decem</i> , was auf die ursprüngliche römische Zählweise der Monate mit Dezember als 10. Monat hinweist.

Im 20. Jahrhundert wurden die Bemühungen fortgesetzt, Namensreihen der deutschen Bezeichnungen für die Monate zu erstellen. Zahlreiche Autoren haben sich daran beteiligt und folgende Namen können in diesen Listen gefunden werden (siehe Weifert, 2003):

Tabelle 2: Monatsnamen des 20. Jahrhunderts

Monat	Bezeichnungen
1	Jänner, Winter, Eismond, Horn, Hartmond, Hartung
2	Hornung, Sellemond, Selle
3	Lenz, Lenzmonat, Lenzing, März
4	Östring, Ostermond, Ostermonat, Oster
5	Wonnemonat, Wonnemonat, Weidemonat, Main, Maien
6	Brachmond, Brachet, Brachmonat, Sonnwend
7	Heumond, Heumonad, Heuet, Heuert
8	Aust, Ernting, Ernet, Erntemonat, Erntemonat
9	Herbst, Herbstmond, Herbstmonat, Herbsting, Scheiding
10	Weinmond, Weinmonat, Laubfall, Laubries, Heiligmond, Gilbhardt, Gilbhard, Gilbmond
11	Niblung, Nebling, Neblung, Nebelmond, Wintermonat, Wintermond, Laubris, Laubrost, Gilbhard
12	Jul, Julmonat, Julmond, Wihimanoth, Weihemond, Christmond, Christmonat, Heilsmond

Tabelle 3 präsentiert eine Übersicht der Monate des Jahres und ihrer wichtigsten und heute gängigsten Bezeichnung, basierend auf einer Zusammenstellung von Janecke (2017).

Tabelle 3: Etymologie der heute gebräuchlichen Monatsnamen

Monat	Heutiger Name	Ursprüngliche römische Bedeutung	Alte, deutsche Namen, die treffender erscheinen als die römischen
1	Januar	Göttin des Anfangs und des Neubeginns, <i>Janua Caeli</i> Später nach dem Gott <i>Janus</i> bezeichnet	<i>Hartung</i> = harte Erde (ahd. <i>hart</i> bedeutet auch „viel“) <i>Eismond</i> = Eismonat

Monat	Heutiger Name	Ursprüngliche römische Bedeutung	Alte, deutsche Namen, die treffender erscheinen als die römischen
2	Februar	Göttin <i>Juno Februata</i>	<i>Hornung</i> = im übertragenen Sinn „zu kurz gekommen“ (der kurze Monat mit 28 oder 29 Tagen)
3	März	Kriegsgott <i>Mars</i> War der erste Monat des frühen römischen Kalenders (<i>Mart, Mars</i>)	<i>Lenzing/Lenzmond</i> = „länger“, verweist auf die Verlängerung der Tage
4	April	Vom lateinischen <i>aprire/Aprilis</i> Zeit, in der sich Erde und Knospen öffnen	<i>Ostermonat/Ostermond</i> , Tag- und Nachtgleiche am 21. Tag
5	Mai	Göttin des Frühlings und des Wachstums <i>Maia/Maya</i> , bedeutet germanisch „jung“, „jugendlich“	<i>Wonnemonat/Wonnemond</i> = Beginn der Wonne der warmen Jahreszeit, Weidemonat für das Vieh
6	Juni	Römische Göttin <i>Juno</i>	<i>Linding, Sonnenwendmonat</i> <i>Rosenmond</i> <i>Brachet</i> = Zeit des Umbruchs der bis dato ruhenden Scholle der Dreifelderwirtschaft
7	Juli	Geburtsmonat des <i>Julius Cäsar</i> , der das Jahr - bisher 10 Monate - in 12 Monate und 365 Tage gliederte	<i>Sommermond</i> <i>Heumond, Heuert</i> = Zeit des ersten Grasschnitts, abgeleitet von <i>hauen</i> , d.h. Abtrennen der Halme
8	August	Orakelgöttin <i>Juno Augusta</i> Später nach Heiligem Augustus benannt, möglicherweise: <i>Kaiser Augustus</i>	<i>Ernting/Erntemond</i> = Einbringen des Getreides/der Ernte
9	September	Nach römischem Kalender der siebte Monat, lat. <i>septem</i> („sieben“). Im römischen Kalender begann das Jahr mit März, sodass September der siebte Monat war	<i>Scheidung</i> = Abschied vom Sommer, Tag- und Nachtgleiche am 23. 9.
10	Oktober	Nach römischem Kalender der achte Monat, lat. <i>octo</i> („acht“)	<i>Gilbhart</i> = viel vergilbtes (d.h. gelbes) Laub, ahd. <i>hart</i> bedeutet „viel“ <i>Weinmonat/Weinerntemond</i>
11	November	Nach römischem Kalender der neunte Monat, lat. <i>novem</i> („neun“)	<i>Nebelung</i> = der nebelreiche Monat Windmonat
12	Dezember	Nach römischem Kalender der zehnte Monat, lat. <i>decem</i> („zehn“)	<i>Julmond</i> = Monat des Julfests (Wintersonnenwende, 21. 12.), schwedisch „Rad“: Zyklus, ein Neubeginn <i>Christmond</i> = Monat der Geburt Jesu Christi <i>Weihnachtsmond; Wending</i>

2 WOCHENTAGSBEZEICHNUNGEN

Im zweiten Teil dieses Beitrags werden nun die Wochentagsbezeichnungen vorgestellt. Zunächst werden die alten deutschen Bezeichnungen beschrieben, gefolgt von den lateinischen Begriffen.

2.1 Alte deutsche Bezeichnungen

Eine Reihe an alten deutschen Bezeichnungen für Wochentage lassen sich in der Literatur finden. Der Wochentag *Montag* wurde auch als *guter tag* oder *mentag* bezeichnet. Für den *Dienstag* gab es eine Vielzahl an (teils dialektalen) Ausdrücken, unter anderem *eritag*, *irchtag*, *irrtag*, *zinstag*, *zistag*, *cistag*, *aftermontag*, sowie auch für den *Mittwoch* (*wodenstag*, *gudenstag*, *mitticher*, *mittichen*, *michten*). *Donnerstag* war auch als *phincztag* oder *durnstag* bekannt, und für *Freitag* existierte die Bezeichnung *fridach*. Die Tage des Wochenendes wurden auch als *sater-tagsnavend*, *sneund* oder *unsen abend* (*Samstag*) und *sonnentag* (*Sonntag*) bezeichnet.

2.2 Lateinische Bezeichnungen

Für jeden lateinischen Wochentagsbegriff gibt es ein entsprechendes Planetensymbol, welches man gelegentlich in Kirchenbüchern findet.

Tabelle 4: Lateinische Herkunft der Wochentage mit Planetensymbolen

Tage	Symbole	Lateinische Herkunft
<i>Montag</i>	☾	dies lunae (Mond), feria secunda, dies secunda
<i>Dienstag</i>	♂	dies martis (Mars), feria tertia, dies tertia
<i>Mittwoch</i>	☿	dies mercurii (Merkur), feria quarta, dies quarta
<i>Donnerstag</i>	♃	dies jovis (Jupiter), feria quinata, dies quinta
<i>Freitag</i>	♀	dies veneris (Venus), feria sexta, dies sexta
<i>Samstag</i>	♄	dies saturni (Saturn), dies sabbatinus, feria septima, dies septima
<i>Sonntag</i>	☉	dies solis (Sonne), dies dominica (Tag des Herrn), dominica, feria prima, lux domini

2.3 Entwicklung der Wocheneinteilung

Der erste Tag der Woche ist offiziell Montag, laut eines UNO Beschlusses zur internationalen Normierung von 1978. Deutschland führte bereits 1976 den Montag als Wochenbeginn ein. Allerdings wird in vielen Regionen weiterhin auf althergebrachte Weise gezählt und die Woche offiziell mit Sonntag begonnen (Jepsen, 2004). Die Einteilung der Woche in sieben Tage ist zurückzuführen auf den natürlichen Mond-Monat, der sich im Rhythmus von 28 Tagen bewegt. Die vier Mondphasen (d.h. Vollmond, abnehmender Mond, Neumond, zunehmender Mond) legen den Grundstein für eine Einteilung der 28 Monatstage in vier Wochen zu je sieben Tagen (Schreiber, 1957).

Die Platzierung der Wochentage und deren ursprüngliche Namen gehen auf eine antike Regel zurück, welche über babylonische, altindische, jüdische und dann griechisch-römische Wege nach Nordeuropa kam (Brodersen & Zimmermann, 2016). Das geozentrische Weltbild befindet sich im Zentrum dieser Regel, bei dem sich alle Gestirne um die Erde drehen. Sieben wandelnden Himmelskörpern sind Götter zugeordnet, die sich in der Reihenfolge mit zunehmender Geschwindigkeit auf einem Kreis im Uhrzeigersinn drehen: *Saturn, Jupiter, Mars, Sonne, Venus, Merkur, Mond* (Bergmann & Stricker, 2016). Pro Tagesstunde gibt es einen sogenannten „Stunden-Herrscher“; nach dem ersten Stundenherrscher des Tages wird dann der Tag benannt. Beginnt man mit der Sonne als Herrscher der ersten Stunde, so heißt dieser Tag *Sonntag*. Zählt man nun 25 Stunden weiter, gelangt man zum ersten Herrscher des nächsten Tages, dem *Mond*.

Die Gestirne bei den Römern waren mit römischen Götternamen benannt, so dass die Germanen zur Bezeichnung ihrer Wochentage ihre eigenen germanischen Götter (welche römische Entsprechungen hatten) wählten (Weinhold, 1861). So ist der Sonntag nach der Sonne benannt und dies war schon bei den Römern so (lat. *dies solis*). Der Tag wurde im Althochdeutschen als *sunnuntag* bezeichnet und bis heute konnte sich keine andere Bedeutung durchsetzen (Weinhold, 1861). Seit dem Jahr 321 n. Chr. ist der Tag ein Feiertag, was seine sekundäre, christliche Bezeichnung als *Tag des Herrn* (lat. *dies domini*) erklärt.

Die Bezeichnung für Montag verweist auf den *Mond* und ist bei allen germanischstämmigen Völkern als Übersetzung des lateinischen *dies*

lunae erhalten geblieben. Der Mond ist hier der Herrscher der ersten Stunde des Tages und gibt dem Tag somit den Namen. Die Mondgöttin Luna überwacht diesen Tag. Zu früheren Zeiten galt Montag als Tag des Unglücks (Schreiber, 1957).

Der Dienstag ist entweder nach dem Kriegsgott Mars benannt (lat. *dies martii*) oder das Wort leitet sich vom norwegischen *tyrsdag* ab. Der Gott Tyr war der Vorsitzende der nordischen Gerichtsversammlung und wurde auf Latein *Mars Thingsus* genannt. Im Schwäbischen ist der Dienstag auch als *Aftermontag* bekannt (König & Schrambke, 1999).

Für Mittwoch war die Bezeichnung *Wodanstag* (was sich heute noch im englischen *Wednesday* finden lässt) bis zum 10. Jahrhundert gebräuchlich (Bergmann & Stricker, 2016). Wodan entspricht dem höchsten nordischen Gott Odin und heißt „der Wütende“. Odin wurde später mit dem römischen Gott Merkur gleichgestellt, da beide Götter als „Anführer der Seelen“ bezeichnet wurden. Es ist nicht klar, ob die lateinische Bezeichnung für Mittwoch, *dies mercurii*, namensgebend für den Mittwoch war. Es scheint eher, dass die Mitte der christlichen Woche den Ausschlag für den Namen gab (Weinhold, 1861).

Der germanische Gott Donar (d.h. die Entsprechung des nordischen Gottes Thor, des griechischen Gottes Zeus, und des römischen Gottes Jupiter) gab dem Donnerstag seinen Namen (Bergmann & Stricker, 2016). Die Referenz zu dem nordischen Gott Thor ist noch in der englischen Bezeichnung *Thursday* enthalten.

Der deutsche Name für den Freitag geht auf das altgermanische Wort *Freya* für Herrin zurück (Bergmann & Stricker, 2016), der nordischen Göttin der Liebe und der Fruchtbarkeit (die römische Entsprechung war die Göttin Venus). Im antiken Rom hieß der Tag *dies veneris*. In Altnordischen wurde der Tag auch *friggadagr* genannt.

Als Sabbat wird im Jüdischen der letzte Tag der religiösen Woche bezeichnet, auch auf Lateinisch *sabbata* genannt. Der sogenannte *dies sambati* im antiken Rom wurde von den Germanen als Lehnübersetzung *sambaztac* übernommen, wovon sich später die Bezeichnung *Samstag* ableitete. Die Römer nannten den Tag auch *dies saturnii*, benannt nach dem Gott Saturn, wovon sich Wurzeln noch im englischen *Saturday* oder im friesisch-westfälischen *Saterdag* finden lassen. Die Bezeichnung *Sonnabend*, die man in weiten Teilen Deutschlands heute finden kann, geht auf die Bezeichnung des Vorabends von Sonntag zurück.

Die Namen der Wochentage und ihre Bezeichnungen in ausgewählten germanischen Kulturen werden nun in Tabelle 5 dargestellt (siehe dazu Weinhold, 1861).

Tabelle 5: *Auswahl an germanischen Wochentagsbezeichnungen*

Wochentag	Althochdeutsch	Mittelhochdeutsch	Altnordisch	Altfriesisch	Dänisch/ Norwegisch
Sonntag	sunnuntag, frontag	suntac	sunnundagr	sunnandei	søndag
Montag	manetag	mantac	dróttingsdagr	monendei	mandag
Dienstag	zoistag	ziestac	tyrsdagr	tiesdei	tirsdag
Mittwoch	mittaweha	mitwoche	oðinsdagr, miðvikudagr	wonsdei	onsdag
Donnerstag	donarestag	donerstac	thorsdagr	thunresdei	torsdag
Freitag	friatag	vritac	friggadagr	frigendei	fredag
Samstag	samaztag, sunnunabend	sameztac, sunabent	laugadagr	saterdei	lørdag

3 REGIONALE BEZEICHNUNGEN

Es sollte erwähnt werden, dass es eine große Zahl an regionalen Bezeichnungen für diverse Wochentage gibt. So existiert im Schwäbischen der *Aftermontag* als Name für den Dienstag und im Friesisch-Westfälischen wird der Samstag auch *Satertag* genannt (Bergmann & Stricker, 2016). Im Altbayrischen findet man auch *Ertag* (für Dienstag) und *Pfnztag* (für Donnerstag), die beide auf altgriechische Quellen zurückzuführen sind (Kranzmayer, 1929). Im Folgenden wird kurz auf die Etymologie dieser beiden altbayrischen Ausdrücke eingegangen, um ihre Herkunft darzustellen.

3.1 Ertag

Der Tag zwischen Montag und Mittwoch wird in vielen Sprachen und Kulturen als Tag des Kriegsgottes bezeichnet (Simek, 2004). Die Römer

nannten ihn *dies martis* („Tag des Mars“), was später zum Italienischen *martedì* und dem Französischen *mardi* abgewandelt wurde. Die alten Griechen assoziierten ihren Kriegsgott Ares mit dem Tag, was von den Ostgoten, die damals am Schwarzen Meer das Nachbarvolk der Griechen waren, teils übernommen wurde. Das ostgotische *Areinsdags* lässt sich allerdings nicht nur auf Ares zurückführen, sondern beinhaltet auch einen Verweis auf den Presbyter Arius (†336), der als Begründer des Arianismus galt (Berndt & Steinacher, 2014). Als die Völkerwanderung begann, wurden die Goten zu Nachbarn der Baiern und übertrugen diesen den gotischen Tagesnamen *arjo*. Dieser wandelte sich zu *er* und später zu *ir* und resultierte im Wochentagsnamen *Irta* (auch *Iada*). Es entwickelten sich daraus weitere Formen, zum Beispiel *Eachda* nördlich der Donau oder *Eeschda*, *Ioschda*, *Iuchda* im südlichen Oberbayern. Im südwestlichen Altbayern gab es am Anfang des 20. Jahrhunderts noch *Mörchta*, *Mörada* oder *Mörda*, wobei das anlautende „m“ vom unbestimmten Artikel davor stammte (*am Erchtag* → *Merchtag*). Obwohl noch gebräuchlich in den 1920er und 30er Jahren, waren diese Begriffe aber damals schon vom sprachlichen Aussterben bedroht (Kranzmayer, 1929). Man findet sie heutzutage noch in Sammlungen bayrischer Dialektwörter (z.B. www.bairische-sprache.at).

3.2 Pfinztag

Der Tag vor dem Freitag wurde bei den Römern *jovis dies* genannt – Tag des Jupiter – und trug somit den Namen des höchsten Gottes. Die italienischen und französischen Begriffe *giovedì* und *jeudi* gehen darauf zurück. Die germanischen Entsprechungen von Jupiter waren Thor und Donar, und von diesen beiden Namen leiten sich die englischen und deutschen Begriffe für Donnerstag ab (Bergmann & Stricker, 2016). Das altbayrische Wort *Pfinztag* oder *Pfinzda* hat seine Wurzeln, ähnlich dem *Ertag*, auch im Griechischen und Gotischen (Weinhold, 1861). Nach der damaligen üblichen Einteilung der Woche, die mit dem Sonntag begann, war der Donnerstag der fünfte Tag. Daher bildet das griechische Zahlwort *pent* für *fünf* die Grundlage zur Wortentwicklung, die vom Griechischen über das Gotische zum Bairischen verlief und eine Lautverschiebung der Konsonanten *p* zu *pf* und *t* zu *ts* durchmachte (Goblirsch, 2005).

4 ABSCHLIESSENDE BEMERKUNGEN

Die Entstehung der heute üblichen Bezeichnungen für Wochentage und Monate ist eng verbunden mit religiösen Elementen verschiedener Kulturen, die sowohl zu den ursprünglichen als auch den später üblichen Namen beigetragen haben, und mit sprachwissenschaftlichen Prozessen, welche die Erscheinungsformen von Namen auf teils gravierende Art und Weise verändert haben (siehe *Pfingsttag*). Eng verwoben mit der Geschichte des Griechischen, Lateinischen und Altgermanischen, haben sich die heute gängigen Begriffe für die Wochen- und Monatsnamen entwickelt. Vergleichende Studien mit anderen germanischen Sprachen (zum Beispiel Englisch), sind notwendig, um zu zeigen, welche Einflüsse auf Sprachen gewirkt haben, und welche Konzepte mit Entlehnungen in andere Sprachen und Kulturen übernommen worden sind.

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Appendix



Annemarie Peltzer-Karpf: An Appreciation

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Be practical as well as generous in your ideals. Keep your eyes on the stars, but remember to keep your feet on the ground.

— Theodore Roosevelt

It is an honour to be asked by the editors of this volume to contribute to this celebration of Annemarie Peltzer-Karpf's career as a researcher and teacher. My contribution will differ from the others in this volume in that it will be of a more personal nature, and will aim to give the reader an understanding of some of the ways in which Annemarie has influenced the life of the Department of English Studies in Graz.

If asked to find a single word which encapsulates Annemarie as a colleague, it would be *generosity*, hence the quote from Theodor Roosevelt above. She has been a constant source of knowledge and advice not only to me but also to many of her colleagues and students. My fate as a linguistics teacher has been increasingly to teach classes which require knowledge of an uncomfortably wide range of topics in linguistics. Annemarie has on several occasions helped me by answering what must at times have seemed to be rather basic questions. I could always be sure that the responses I received were well considered and reflected the current state of research.

My experience of Annemarie's generosity with her time and knowledge has been shared by many of her students, particularly those who have worked with her on projects and as student assistants. She has written innumerable letters in support of students' grant and job applications, and is always willing to give time to students wishing to discuss their work with her. She is very interested in supporting the careers of particularly promising students and is always delighted to hear when any of these talented students succeeds in publishing a paper, completing a degree or securing a job. The support she gives to her students is summed up by one of her assistants as follows:

There have been many people who have influenced me and set great examples in my life but never have I met a teacher with a bigger heart than Professor Peltzer-Karpf. Not only is she supportive and understanding but she also has a great sense of humour.

Annemarie's dry sense of humour is legendary among her students, at least among those who can understand her somewhat oblique references. One of her less obscure wisecracks occurred the day after the last presidential election in the United States when she introduced her lecture with an approximation of these words: "Today we're going to talk about apes. Actual apes, that is. I don't like being political in classes."

Generosity not only pervades Annemarie Peltzer-Karpf's professional life but also her personal life. Her prodigious memory for birthdays and her impeccable taste in choice of gifts is legendary among her closest colleagues and friends. Rather than handing over the exclusive jewellery and cosmetics she has chosen, Annemarie prefers to leave an immaculately wrapped parcel on the desk of the fortunate recipient.

The other items which some of her colleagues have become used to finding on their desks are books, particularly crime novels. Over the years, a small coterie of crime enthusiasts has emerged in the department. We tend to keep quiet about our passion, but our enthusiasm is nevertheless sincere. Annemarie is a key player in this exclusive fan club and she tends to guide taste. Not for her the brutalities of North American crime! Instead she prefers the more orderly world of Anne Parry and Alexander McCall Smith, whose stories, in the words of P. D. James, confirm "our belief, despite some evidence to the contrary, that we live in

a rational, comprehensible and moral universe” (*Talking about Detective Fiction*, 2009, p. 19).

In keeping with many of us who enjoy detective fiction, she enjoys pinpointing the culprit and commenting on the plausibility of the detection process. Woe betide the poor author who dares to publish a story which does not correspond to her high standards! She experiences particular enjoyment when the recipient evaluates the author’s efforts according to a scale of 1–5, whereby 1 represents the highest grade possible. It has been known for her to distribute books to friends for vetting, and for her to reject any book which does not receive at least a 2.

The other kind of book which Annemarie deposits on colleagues’ desks represents more lightweight genres, or as some cruelly call them – rubbish books. I will not risk earning the wrath of publishers by naming any particular authors; suffice to say that such books tend to be given to colleagues who, in the opinion of Annemarie, require some light relief. She is sensitive to colleagues who are overworked, and her books perform a valuable service: a kind of literary valium which is less risky than the real stuff. However, it should be stressed that Annemarie’s taste in books is generally more highbrow and that she enjoys reading in several languages.

Her high standards do not only manifest themselves in her choice of books but also in her appraisal of classical music. She enjoys going to concerts and her tastes are quite broad in their scope, ranging from Mozart to the Armenian composer Komitas, and she requires a high standard of execution at all times. Fortunately, she lives in Graz, which offers a wide range of high quality performances throughout the year. Living in a cultural desert would be unthinkable for Annemarie.

So far, I have focused on Annemarie’s generosity to individual colleagues, friends and students. However, her generous spirit and willingness to embrace new ideas has also influenced larger developments within the department. Annemarie was the head of the departmental curriculum commission when the Joint Master’s programme started in 2007, and her guidance on matters of accreditation paved the way for the programme to become what it is today: a Master’s programme which allows its students to enjoy freedom in utilising the framework of the curriculum to develop their own interests.

From the very beginning, Annemarie understood that a Master's programme is a specialised degree and she appreciated the value of having students spend a semester at one of the partner universities in Bamberg, New York, Venice, Paris and Pécs. In contrast to previous practice in accrediting classes taken at foreign universities where course content was compared, Annemarie adopted a generous and pragmatic interpretation of equivalence, thus permitting students to pursue their interests without hindrance.

With her retirement, our department will lose a committed researcher and teacher. What we will not lose, however, is a reliable source of wisdom and common sense, and a doyenne of good taste. The current volume constitutes an appreciation of Annemarie Peltzer-Karpf's long career in our department, of her distinguished contribution to research, and of the esteem with which she is held by those fortunate enough to have worked with her.

Index

A

- affective prosody 110, 127, 136, 139, 140, 143, 144, 145, 146, 154
- agentization 393, 397, 408, 412, 416, 417
- age of onset of acquisition 291, 292, 293, 294, 297, 298, 299, 300, 301, 303, 304, 305, 307, 308
- alphabetic languages 280, 281, 349
- animal communication 66, 68, 112, 117
- animal psychology 67
- animal vocalizations 105, 106, 107, 109, 118
- anthropomorphic mentalism 67
- ape language 66
- apes 29, 31, 36, 38, 39, 40, 42, 64, 66, 79, 80, 81, 82, 83, 85, 86, 89, 96, 97, 113, 170, 172
- aphasias 259, 260
- attractors 231, 236, 237, 238
- auditory deficit hypothesis 353
- Australopithecines 41
- autonoesis 240

B

- baby talk *see* infant-directed speech
- Bald's Leechbook 378, 380, 389
- basic emotions 106, 107
- behavioristic norm 57, 66, 67, 68, 70
- bilingualism 298, 425, 442
- biogenetic law 80, 93
- biological roots of music 129
- birdsong 57, 59, 62, 63
- birth of a word 239, 241
- bonobos 39, 81, 82, 98
- brægen 377, 378, 382, 385, 386, 387

- brain response 146, 273, 274, 276, 277, 280, 285, 298, 320
 - Broca's aphasia 32, 259, 260
 - Broca's area 30, 31, 32, 33, 35, 37, 38, 40, 42, 43, 45, 46, 93, 146, 257, 259, 284
 - Broca's cap 37, 43, 44
- ## C
- caregivers' phone engagement 219
 - Carl Wernicke 31, 32, 35
 - chaotic itinerancy 229, 230, 231, 236, 237, 239, 240, 241
 - Charles Fillmore 449, 450, 452
 - child development 196
 - child-parent interaction 196
 - chimpanzee 36, 37, 38, 39, 40, 42, 44, 62, 81, 82, 86, 89, 90, 91, 97, 98, 170, 174, 175, 176, 178, 179, 180, 182, 183, 184
 - choruses 112, 113
 - cognitive aptitudes 274
 - cognitive neuroscience 252, 323, 327
 - communicative competence 285, 426, 436, 437
 - comparative language discourse 57, 59, 61, 65
 - comparative psychology 59
 - conceptualizations of the brain 393, 413, 416, 417
 - conceptual metaphor theory 449
 - congenital amusia 116, 117, 127, 128, 130, 134, 135, 136, 139, 147, 153, 154
 - connectionists 241
 - cooperative behavior 86
 - core language areas 29, 30, 31, 33, 34, 35, 41, 42, 44

- corpus-based discourse analysis 395, 397
- CPH *see* critical period hypotheses
- critical cultural awareness 427, 428, 429, 439, 441, 443
- critical discourse studies 451, 464
- critical language awareness 428, 429, 443
- critical period hypotheses 293, 294
- cytoarchitecture 35
- D**
- de-personalization 393, 396, 405, 407, 416
- design properties of language 59
- developmental dyslexia *see* dyslexia
- developmental processes 128, 197, 234, 242, 286, 342
- Dictionary of Old English 377, 382
- dimensional emotion models 106
- distal pointing 87, 89
- DOE *see* Dictionary of Old English
- dogs 80, 85, 86, 87, 88, 89, 94, 96
- dual-pathway model 34
- duets 112, 113
- dynamical systems 231, 232, 233, 240, 242
- dyslexia 134, 139, 337, 338, 339, 340, 343, 344, 346, 347, 350, 354, 355, 360, 362, 363, 365, 366, 367, 368
- E**
- early childhood 198, 199, 284, 320
- early infant growth 170
- electro-encephalography 277
- embodiment 450, 453, 454
- emotional arousal in animal calls 109
- emotional communication 106, 108, 111, 112, 117, 118, 145
- emotions 92, 105, 106, 107, 111, 113, 114, 115, 116, 117, 140, 144, 145, 146, 200, 206, 207, 210, 291, 305, 307, 308, 309, 456
- endocasts *see* endocranial casts
- endocranial casts 41
- epigenetic landscapes 232
- epistemology 430
- ERP *see* event-related potential
- Ertag 469, 478, 479
- ESL classroom 284
- event-related potential 133, 146, 152, 273, 278, 280, 281
- explicit induction and rote learning 274
- F**
- facial emotions 117
- feeding independence 170, 171
- fluid intelligence level (gf) 260
- fMRI *see* functional magnetic resonance imaging
- foreign accents 318
- foreign/world language education 424, 425, 441, 442
- fractals 231
- fragmentation 393, 396, 399, 402, 404, 414, 416
- frames 231, 449, 450, 451, 452, 453, 455, 456, 457, 458, 459, 460, 461, 462, 464
- frame semantics 449, 450, 451, 452
- functional magnetic resonance imaging 277, 298, 327, 337, 338
- G**
- gaze following mechanism 87
- generative/minimalist models 253
- generativists 241
- genetics of language 45
- George Lakoff 449, 450, 453
- global citizenship 424
- grasping 79, 80, 81, 92, 94

growth model of language
development 234

H

handedness 39, 40, 44
 heafod 377, 378, 382, 383, 384, 385,
386, 388
 heteroecesis 240
 hierarchical dependencies 253
 holism 393, 396, 399, 400, 404, 414, 416
 Homo erectus 43
 Homo heidelbergensis 43
 Homo neanderthalensis 43
 Homo sapiens altai 43
 human cognitive ontogeny 95
 human emotions 107
 hypocognition 457

I

ICit *see* intercultural citizenship
 implicit inductive learning ability 274
 individual language aptitude 328
 infant development 169, 170, 171, 173,
174, 178, 184
 infant-directed speech 115, 144, 185
 infant nutritional development 169, 171
 intellectual humility 423, 425, 430, 433
 intentionality 66, 67, 68, 69, 70, 186
 intentional pointing 90, 91, 96
 intercultural citizenship 423, 424, 425,
426, 428, 429, 430, 432, 433, 434,
435, 436, 437, 438, 439, 440, 441,
442, 443
 intercultural (communicative)
competence 425, 443
 intercultural dialogue 423, 424, 425

J

joint attention 197, 234

K

Korbinian Brodmann 35

L

L1 influence 317, 318
 lactation 169, 170, 171, 173, 174, 176, 180,
181, 183, 184, 186
 Læceboec 378, 379, 380, 389
 language acquisition 112, 197, 199, 222,
229, 231, 241, 251, 259, 263, 274, 275,
276, 284, 291, 292, 322, 326, 328, 428
 language-brain models 30
 language disorders 251, 259
 language evolution 45, 70, 110, 111, 117,
257
 language processing 33, 34, 111, 253,
254, 259, 261, 262, 263, 274, 276,
278, 343
 language talent 327
 lexical tone 127, 148, 149, 150, 151, 153,
154
 linguistic ontology 59
 linguistic prosody 110, 136, 139, 140,
143, 144, 151
 LX attainment 291, 292, 293, 297, 302,
305, 307

M

manual gestures 65, 87
 maternal singing 115
 mentalism 67, 393, 394, 395, 396, 397,
404, 407, 410, 411, 413, 415, 416, 417
 metaphorical frames 450, 455, 457, 458
 metaphors 395, 402, 449, 450, 451, 453,
454, 455, 458, 464
 mirror neurons 37, 94
 mirror self-recognition 95
 mismatch fields 277, 279
 MMF *see* mismatch fields
 Monatsnamen 469, 470, 471, 473, 480
 motherese *see* infant-directed speech
 mother-infant interactions 181
 MSR *see* mirror self-recognition
 music 105, 106, 109, 113, 114, 115, 116,
117, 127, 128, 129, 130, 131, 134, 136,

137, 139, 140, 141, 142, 144, 145, 146,
147, 149, 150, 153, 154, 155
music and language 105, 106, 109, 114,
115, 117, 130, 144, 154
music-induced emotions 116
music processing deficit 131

N

native language magnet 300
native language mappings 279
nature-nurture debate 241
NDST *see* nonlinear dynamic systems
theory
nerve-growth factor 297
neural oscillations 251, 252
neural plasticity 235, 299, 317, 319, 322,
323, 324, 325, 328
neurobiology of language 30, 45
neurogenetics 45
neuronal plasticity 291, 292, 296, 297
neuroscientific discourse 395, 404
Noam Chomsky 449, 451, 459
nonlinear dynamic systems
theory 230, 231, 232, 235, 239, 245
non-tone language 128, 130, 131, 135,
136, 147, 148, 149, 150, 151, 153, 154,
155
nurturant parent model 457, 458

O

object choice tasks 85, 86, 89, 90, 96
Old English medical texts 377, 378,
382, 387, 389
origins of language 58, 112, 113, 144
oscillome 264

P

paleogenetics 45
paleoneurology 41
parental phone use 197, 198, 200, 220,
225

parental responsiveness 195, 196, 197,
198, 199, 200, 225
parent-offspring conflict theory 183
passivization 393, 397, 408, 412, 416,
417
personalization 393, 396, 405, 406,
407, 415, 416
Pfinztag 469, 478, 479, 480
phenomenology 231, 239
phonetic learning 317, 319, 322, 323,
326, 328
phonetic narrowing 321
phonological processing 127, 136, 137,
138, 149, 153, 338, 345, 356, 357, 362
phrase structure generation 252
physicalism 393, 394, 396, 397, 404,
407, 413, 415, 416, 417
Pierre Paul Broca 31
pitch processing deficit 131, 132, 135,
140, 143, 150, 152, 153
planum temporale 38, 39, 355
pointing gestures 80, 82, 85, 87, 88,
96, 98
pointing-like behaviors 80
political discourse 425, 449, 450, 451,
453, 456, 463, 464
pragmatic communication ability 274,
282
primate signals 62
pronunciation 139, 148, 291, 295, 296,
298, 300, 302, 317, 318, 319, 320, 322,
325, 326, 327, 329
properties of language 57, 58, 59, 65, 66
prosodic modulation 110, 111, 112, 113
public discourse 197, 400, 424, 430,
435, 443, 458

R

recursion 69, 252
recursive hierarchical phrase
structure 252
referential pointing 80, 96, 97, 98

relaxed selection conditions 97
rhythm processing 137, 143

S

scala naturae 60
second language acquisition 274, 275,
276, 281, 282, 284, 285, 291, 292, 293,
294, 295, 298, 299, 302, 303, 304,
305, 307, 308
self-organization 229, 230, 231, 233,
242, 243, 244
semantic categorization 343, 351, 360
shared acoustic correlates in music and
language 115
SLA *see* second language acquisition
smartphone use 196
social justice 429, 463, 465
socio-cognitive development 93
socio-emotional development 198, 222
spatial reference 82, 84
speech contrasts 279, 324
speech intonation 114, 127, 132, 140,
141, 142, 143, 151, 154
synchronized oscillations 253
syntactic spurt 235

T

temporo-parietal area 38
theory of mind 274, 282, 283, 284
tone language 127, 128, 130, 131, 132,
135, 136, 147, 148, 149, 150, 151, 153,
154, 155
Tpt *see* temporo-parietal area
transitional feeding 170, 171, 172, 174,
176, 178
traveling oscillations 251, 253, 254,
258, 260, 263
triangulation 412, 413

U

UG *see* universal grammar

ultimate attainment 291, 296, 300, 301,
302, 303, 304, 305, 307, 308, 319, 322,
326, 328
universal grammar 234, 241

V

vocabulary explosion 95

W

weakly coupled oscillators 251, 255
weaning conflict 171, 180, 181, 182, 184,
187
weaning process 171, 178, 179, 180
Wernicke-Lichtheim Model 33, 34
Wernicke's aphasia 32
Wernicke's area 30, 31, 32, 33, 34, 35,
38, 42, 43, 46, 284
whole-hand point 92
Wochentag 469, 475, 476, 478, 479

Z

zoomusicology 129

#

30 million word gap 197



