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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.

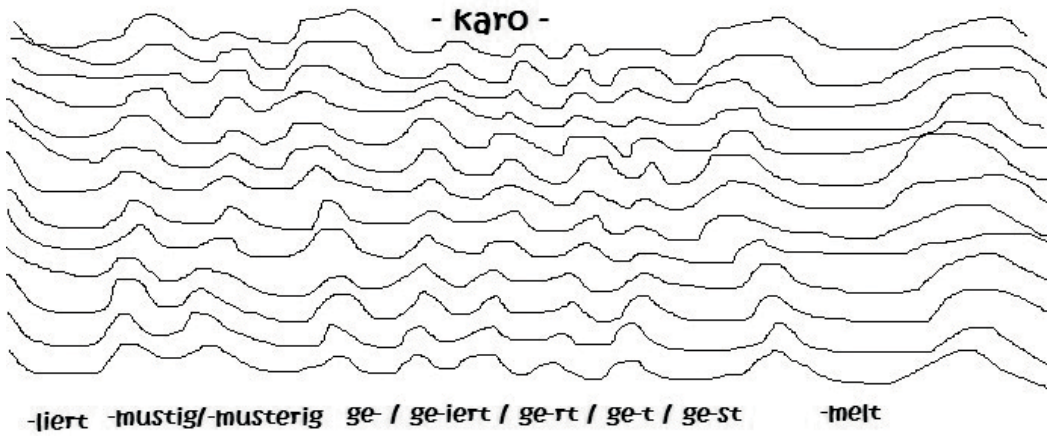

Figure 1. Pooled epigenetic morphological landscape of German L1 learners of the adjective 'kariert' (checkered).

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 instable 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-

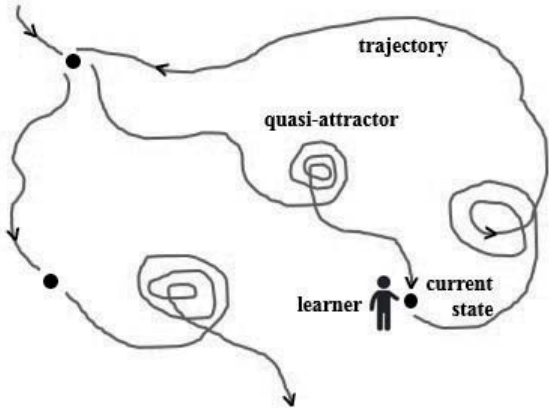

Figure 2. Schematic drawing of chaotic itinerancy, closely adapted from Tsuda (2001, Figure 4, p. 799): overall state space comprising regions of low dimensionality (quasi-attractors surrounded by attractor ruins) connected by regions of high dimensionality (trajectories) through which a learner itinerates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

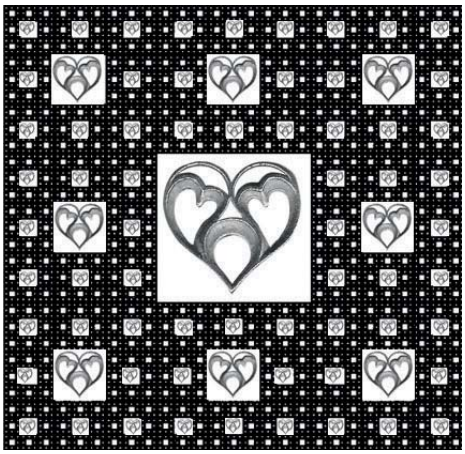

Figure 3. "Liebe Annemarie! Ich 'karoliere' Dir von ganzem Herzen zu Deiner Pensionierung!" — Annette

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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