Brian MacWhinney
Carnegie Mellon University

Title: Language Emergence

This handbook presents 27 chapters covering a wide variety of topics in the study of human language. The core idea uniting all of this work is that alternative levels of linguistic structure emerge from patterns of usage across time. Emergentist analyses of this type are grounded on three core frameworks deriving from adaptive systems theory. The first is the Darwinian theory of evolution based on proliferation, competition, and selection. The second is the analysis of complex systems as structured hierarchically into levels, such that the properties and structures of higher levels of complexity are not fully predictable from properties on lower levels. The third is the theory of timeframes which holds that processes on different levels are linked to very different timescales that mesh together through competition in the present. These three frameworks are not unique to linguistic analysis. In fact, they are fundamental to scientific investigation of all physical, biological, and social processes.

This introduction contains five parts. First, we will describe how these three frameworks apply to the study of language. Second, we will consider how the overall emergentist framework relates to more specific explanatory linguistic frameworks, such as functionalism, cognitive linguistics, connectionism, embodied cognition, usage-based linguistics, and competition theory. Third, we will examine some of the specific emergentist mechanisms postulated by these various formulations. Fourth, we will contrast the program of Emergentism with the program of Universal Grammar (Chomsky, 1965) in terms of their respective analyses of ten core issues. Finally, we will examine how each of the 26 chapters in this volume contributes to our understanding of the overall emergentist program.

1. Frameworks Supporting Emergentism

This section examines the ways in which Emergentism relies on the three frameworks of natural selection, complexity theory, and timeframes.

Competition

Competition is fundamental to biological processes. Darwin (1859) showed how the evolution of the species emerges from the competition between organisms for survival and reproduction. The three basic principles Darwin identified are proliferation, competition, and selection. Proliferation generates variation through mutation and sexual recombination. Organisms with different compositions then compete for resources or rewards such as food, shelter, and the opportunity to reproduce. The outcome of competition is selection through which more adaptive organisms survive and less adaptive ones disappear.

The combined operation of proliferation, competition, and selection is the major engine driving change in all biological and social systems. Emergentist approaches to language (MacWhinney, 1999) also view linguistic structures as arising from the processes of proliferation and competition. For the organism as a whole, the fundamental functional pressure is to reproduce. For language, the fundamental functional pressure is to communicate efficiently in ways that allow the listener to efficiently and accurately decipher the message. As MacWhinney, Bates, and Kliegl (1984) noted, “the forms of natural languages are created, governed, constrained, acquired and used in the service of communicative functions." Bates and MacWhinney (1982) noted that this functionalist position can be dissected into three separate claims. The first is that language change across generations is determined by communicative function; the second is that language acquisition in the child is shaped by communicative function; and the third is that language form in real time conversations is controlled by communicative function. On all three levels, the facilitation of communicative function is viewed as depending on the availability of supporting neural mechanisms.

The handmaiden of competition is cooperation. As Bates and MacWhinney (1982) noted, humans have a great many ideas that they would love to express all at once. But language only allows us to say one thing at a time. One way in which language addresses this problem is by allowing motives to form coalitions. Bates and MacWhinney (1982) analyzed the possible solutions to competition as: (1) peaceful coexistence, (2) divide-the-spoils, and (3) winner-take-all.

We can illustrate these solutions by looking at subject marking in English. In the unmarked active transitive clause, the subject expresses a coalition of motives including agency, perspective, givenness, and topicality. This construction represents *peaceful coexistence* or coalition between the motives, because they all point in the same direction. In the vast majority of cases, these motives do in fact cooccur yielding the active clause as the dominant form for transitive verbs. Peaceful coexistence depends on natural patterns of cooccurence in the real world. For example, the properties of solidity, boundary, and firmness tend to cooccur for objects. Similarly, in animals, properties such agency, movement, warmth, and directed attention all tend to cooccur. When speakers of a language choose to emphasize one of the features in a peaceful coalition over others, the coalition can break down, precipitating a *divide-the-spoils* solution. For example, English uses the passive construction as a way of dividing the spoils between the topic/perspective that wins the main prizes of subject position and agreement and the agent which is awarded the "consolation prize" of placement in a by-clause. An alternative to the divide-the-spoils approach is the *winner-take-all* solution in which one motivation overrides the others. For English transitive verbs, this solution gives rise to the truncated passive. In that solution, the agent is not expressed at all.

Hierarchical Structure

Complexity arises from the hierarchical recombination of small parts into larger structures. For biological evolution, the smallest parts are the genes. For the brain, the smallest parts are the neuronal assemblies that generate competing ideas (Campbell, 1960). In his seminal article entitled "The Architecture of Complexity", Simon (1962) analyzed higher-level cognitive processes as hierarchically-structured combinations of elementary information processes. These elementary pieces are configured in modules whose structure is (only) partially decomposable.

A Simple Example

These basic architectural principles can be illustrated by the four levels of structure that emerge during protein folding (MacWhinney, 2010b). In this process, the *primary structure* of the protein is determined by the sequence of amino acids in the chain of RNA used by the ribosome as the template for protein synthesis. This sequence conveys a code shaped by evolution; but the physical shape of a specific protein is determined by processes operating after initial RNA transcription. The next structure to emerge is a *secondary structure* of coils and folds created by hydrogen bonding across the amino acid chain. These forces can only impact the geometry of the protein once the primary structure emerges from the ribosome and begins to contract. After these second structures have formed, a *tertiary structure* emerges from hydrophobic reactions and disulfide bridges across the folds and coils of the secondary structures. Finally, the *quaternary structure* derives from the aggregation of polypeptide subunits based on the ternary structures. It is this final structure that allows each protein to serve its unique role, be it oxygen transport for hemoglobin or antigen detection for antibodies. In this partially decomposable emergent system, each level involves a configuration of components from lower levels, but the biochemical constraints operative on each level are unique to that level and only operate once that level has emerged during the process of folding. If a given protein operates successfully, it promotes the adaptation of the whole organism, eventually leading to evolutionary selection for the DNA sequence from which it derives. This can be viewed as a type of backwards or downwards causality between levels (Andersen, Emmeche, Finnemann, & Christiansen, 2000).

Epigenesis

Our bodies are formed from the proteins that emerge from patterns in the genome. However, the actual work of triggering the construction of the right proteins for the right structures is determined by epigenesis, which involves the expression of patterns in the DNA at particular times in particular tissues during development, both before and after birth. The human genome contains 3 billion base pairs. The human genome has only 20,000 protein-coding genes, and over 98% of the genome is dedicated to sequences controlling gene expression during epigenesis. The informational content of DNA is simply too small to fully specify the shapes of the many complex structures in the human body. Instead, we can view the genes as providing control parameters that serve as specific constraints on local processes of self-organization *(Kelso, 1995; Murray, 1988)*. Although DNA itself only responds to environmental pressures through natural selection, epigenetic processes are highly sensitive to the actual configuration of body parts during both embryogenesis *(Fernandez-Sanchez, Serman, Ahmadi, & Farge, 2010)* and later tissue replacement *(Chan, Hinz, & McCulloch, 2010)*.

In terms of complexity theory, what this means is that the hierarchy of structures emerging from the four level of protein folding interlocks with an emergent hierarchical structure for individual tissues. Within the brain, gene expression is heavily dependent on induction by local structures (human.brain-map.org). The resulting complexity achieved by the interlocking of the basic hierarchical code with additional hierarchical structures during epigenesis is enormous.

Interlocking Linguistic Hierarchies

These principles of elementary units, partial decomposability, level-specific constraints, and backwards causality also apply to the study of language, where the interactions between levels and timeframes are so intense. For language, there are six major, partially independent, hierarchies: auditory phonology, articulatory phonology, lexicon, syntax, embodied roles, and communicative structure. Each of these systems is represented in partially distinct neuronal areas (MacWhinney, 2009), and each displays hierarchical composition between levels. For example, lexical items are composed of syllables that are then further grouped into prosodic feet to produce morphemes. Morphemes (Racz et al, this volume) can be combined to produce compounds, derivations, and longer formulaic strings (Sidtis, this volume). Articulatory form is composed hierarchically from motor commands that are grouped into gestures (Donegan, this volume) that eventually produce syllabic structures. Syntactic patterns can be coded at the most elementary level in terms of item-based patterns, which are then grouped on the next level ob abstraction into constructions, and eventually general syntactic patterns. At the most elementary level, communicative structures involve speech acts that can then be grouped into adjacency pairs from which higher level structures such as topic chains and narrative structures can emerge. Each of these hierarchies is tightly linked to others. For example, syntax and lexicon are tightly linked on the level of the item-based pattern and also in terms of the local organization of parts of speech in the lexicon (Li, Zhao, & MacWhinney, 2007). Given the interactive nature of these interlocking hierarchies, full decomposition or reductionism (Fodor, 1983) is clearly impossible (McClelland, 1987). Instead, the primary task of systems analysis is to study the ways in which the various levels and timeframes mesh. Stated in the terms of the Competition Model (MacWhinney, 1987), analysis is a matter of measuring the strength of competing forms or patterns and their interactions during both online and offline processing (Labov, 1972).

Timeframes

To understand the mechanics of pattern combination, we must examine inputs from processes operating across contrasting timeframes (MacWhinney, 2005, 2013). Broadly speaking, we can distinguish four major timeframes:

1. **Processing**. The timeframe of processing occurs at the moment of speaking. Here, psycholinguists have focused on the neural basis for online processing of words and sentences during production and comprehension, whereas conversation analysts have focused on the social basis for the ways in which we take turns and share ideas.
2. **Consolidation**. Online processing leads to the storage of experiential traces in memory. Some of these traces last for only seconds, others persist across decades. Memory processes can also support the emergence of higher levels of structure through generalization that vary through the course of a human lifespan.
3. **Social Diffusion**. Linguistic forms diffuse through processes of social memesis (Mesoudi, Whiten, & Laland, 2006) across interactional networks. Sociolinguists have shown that the changes triggered by these processes can extend across days or centuries.
4. **Genetic Diffusion**. Within timeframes ranging from decades to millenia, we can trace the diffusion and consolidation of genetic support for producing spoken and written language (Arbib, this volume).

For convenience, we refer to these as "timeframes", although it would be more accurate to call them "space-time frames" because they involve both unique spatial configurations and unique temporal configurations. For example, social memesis can arise either within the spatial frame of face-to-face interaction or the spatial frame of communication over the Internet and differences in these spatial frames can also impact the immediacy of the timeframes involved.

Within each of these four major timeframe divisions, there are many individual timeframes with their own unique ways of achieving processing, consolidation, and diffusion operations on structures at the various linguistic levels. What is crucial is that the structures emerging on all of these timeframes must be able to exert some impact on language use at the moment of speaking. Sometimes, the relevant structures may lie dormant for months or years before achieving activation. For example, the *what's X doing in Y* construction found in *what is this fly doing in my soup* (Kay & Fillmore, 1999) only surfaces rarely. When it occurs, it expresses a unique configuration of shock or pretended shock regarding some untoward condition, and either enough social solidarity to withstand the intended irony or else a power differential that allows for expression of some level of approbation or even accusation. In order to operate effectively, this pattern must have been consolidated into long-term memory in a way that permits efficient retrieval when this unique situational configuration arises. The various sociolinguistic and affective assignments needed to activate this pattern depend on the computation of the status of personal relations as they have developed across days, months, and years. These computations must then be linked to more immediate practical judgments regarding the unexpected nature of the condition (i.e., the fly in the soup). If the relevant, but rare, preconditions are not fulfilled, we may select a more neutral statement, such as "Oh goodness, there is a fly in my soup."

Timeframes for Processing

Fluent speech depends on a smooth temporal meshing of multiple neurolinguistic processes, each with its own timeframe. Speech relies on an loop (Feldman, 2006) for the repetitive production of syllables lasting about 150 ms each (Massaro, 1975). MacNeilage & Davis (1998) argue that the unmarked CV (consonant-vowel) structure of syllables is homologous to the lip-smacking gesture in other primates. In their frame-content theory, the positioning of the jaw and articulatory closures for the consonant constitutes the "frame" and the positioning of the tongue for the vowel constitutes the "content". The generation of these gestures is controlled by the *pars opercularis* (Bookheimer, 2007). This is the part of the inferior frontal gyrus closest to the motor cortex areas that control the tongue and lips. In a syllable-timed language like Spanish, this circuit produces a clear periodicity of syllabic gestures. We can think of this process as a wheel revolving with a periodicity of 150 ms. However, the output of this first wheel is then further modified by a second wheel that imposes syllabic stress. This second wheel operates not at the timeframe of the syllable, but at the slightly longer timeframe of the metrical foot. The imposition of stress on the syllabic chain can be based either on lexical signals or on conversational emphases. The wheels that drive these syllable-level activations must also be meshed with the wheels that link syntactic and lexical processing. The activation of words in temporal cortex must be gated by syntactic patterns represented in inferior frontal cortex. Usually, this gating meshes smoothly with the wheels driving syllable activation. However, if some information arrives late or is judged to be incorrect, speech errors can arise (Dell, Juliano, & Govindjee, 1993). Such errors can arise from the impact of neural and peripheral physiological factors, such as exhaustion, inattention (Donegan, this volume), drugs, lesions, or degeneration.

This meshing of processes for syllable production is only one of the ongoing timeframe synchronizations arising in language processing. Others involve monitoring of conversational sequencing for projected turn completion, topic continuation, alignment feedback (Hopper, this volume), gesture processing (Zlatev, this volume), and comprehension feedback (Clark, this volume). Still other meshed processes operate during language comprehension, as listeners attempt to use lexical items and syntactic cues to construct mental models (MacWhinney, 2008b) that mesh with ongoing input from the speaker and the situation.

Timeframes for Consolidation

The processes of speaking and listening leave traces in terms of patterns of connectivity in the brain. The ways in which these patterns are consolidated depend on biochemical processes at the level of the synapse, as well as larger patterns controlled by interactions between cortical areas. In order to understand how the brain consolidates inputs across diverse timeframes, it will help to take a detour into the simpler world of the honeybee. Menzel (1999) explains how honeybee cognition relies on five memory phases, each involving different cellular processes, different timeframes, and different environmental challenges. The first phase is early short-term memory (eSTM). When foraging within a single patch of flowers of the same type, bees are able to maintain attention on a pollen source through activity within an activated neural ensemble (Edelman, 1987; Pulvermüller, 2003) without consolidation. In the second phase of late short-term memory (lSTM), synthesis of the PKA protein kinase works to solidify the currently active circuit, as the bee shifts between contrasting pollen sources. The third phase of middle-term memory (MTM) spans a timeframe of hours and involves the formation of covalent modifications in the synapses between neurons. During these first three timeframes, bees have not yet returned to the hive, but are still processing flowers encountered during a single foraging bout. The fourth phase of memory consolidation relies on the formation of early long-term memories (eLTM) through the action of nitrous oxide (NO) and PKC1. This type of consolidation is important, because it allows the bee to return to remembered pollen sources even after a trip back to the hive. The fifth phase of consolidation in late long-term memory (lLTM) operates across a timeframe of over three days, using PKC2 protein synthesis for even more permanent memories regarding ongoing use of pollen sources. Thus, each of the five phases of memory consolidation is responsive to the nature of the memory that must be retained to allow the bee to continue successful foraging.

When the bee is trying to decide where to fly, her decision is impacted by an array of wheels that mesh in the current moment. Some of the wheels derive from the memories for pollen sources described above. Others derive from activities in the hive, including the dances of other bees. Still others relate to the season, the need to defend the hive, and so on. Bees have a evaluation neural module that works to mesh information from all of these sources, much as our language production device serves to mesh inputs from all sorts of memories and motives. For both the bee and the human speaker, this meshing of timeframes all occurs at the moment of deciding either where to fly or what to say.

This linkage between environmental tasks, timeframes, and neuronal processes is not unique to bees. However, these relations are particularly transparent in the honeybee, because of the way in which the distribution of flowers structures the bee's environment. We find the same five memory mechanisms operating across these timeframes in humans. However, for humans, there are additional mechanisms that support even more complex consolidation over longer timeframes for integrating increasingly complex memories. Many of these additional mechanisms rely on links between the hippocampus and the cortex (McClelland, McNaughton, & O'Reilly, 1995; Wittenberg, Sullivan, & Tsien, 2002), including episodic storage in the medial temporal lobes (Daselaar, Veltman, & Witter, 2004). In addition, the frontal lobes provide a hierarchical system of executive control involving increasingly complex and longer-term structures as one moves from the posterior to anterior frontal areas (Koechlin & Summerfield, 2007).

Consolidation impacts processing through connectivity and item strength. Consider the three stages in the learning of the English past tense as an example. During the first stages of learning, children pick up irregular past tense forms, by rote. In the second stage, they acquire the combinatorial past tense that produces forms, such as *jumped* and *wanted*. During this period, there is a competition between rote and combination (MacWhinney, 1975b). Because the combinatorial form gathers strength from its use across many verb types, it will occasionally win, leading to the production of **goed* and **falled*. In the third stage of learning, the child consolidates the representations of individual irregular forms such as *went* and *fell*, so that they can dominate when placed into competition with combinatorial patterns.

The role of consolidated pattern strength and specificity in governing such competitions is fundamental across all linguistic domains (MacWhinney, 1987), and the results of these competitions can be predicted quantitatively from experimental and corpus data (McDonald & MacWhinney, 1989). Both first (MacWhinney, 2014b) and second (MacWhinney, 2012) language learners begin with highly specific patterns and formulas (Sidtis, this volume) from which they then form higher-level generalizations. However, there are also many competitions between forms on the same level. For example, during comprehension of the word *candle*, there is a brief moment at word onset when *candle* competes with *candy*, *camera*, *calendar*, and other words beginning with *ca*- (Allopenna, Magnuson, & Tanenhaus, 1998).

Timeframes for Social Diffusion

Short-term processes must mesh with consolidated long-term processes. Typically, the consolidation of linguistic patterns depends on an interplay between neural and social encoding. Individual language users can only consolidate forms, if those same forms are also adopted by the wider community. In this sense, language can be viewed as a collection of social memes that are internalized by group members. Language includes internalized memes for controlling conversational sequencing, alignment, code-switching (Li, this volume), and many other social interactions. These social patterns must also mesh with individuals' motor control of physical systems for maintaining gaze contact, proxemics, and postural alignment. This means that social groups can only adopt patterns that also work out well for individuals in terms of both processing and consolidation.

Both sociolinguists (Poplack and Cacoullos, this volume; Foulkes and Hay, this volume) and typologists (Bybee and Beckner, this volume; Givón, this volume; Hawkins, this volume) examine patterns of language diffusion and change. Sociolinguists often focus on changes within a single language, whereas typologists are often concerned with comparisons of patterns of change across languages. By combining information from these two methodologies, we can derive an even more complete understanding of how forms diffuse, consolidate, compete, and decay within contrasting social groups across time.

Timeframes for Genetic Diffusion

The slowest moving biological timeframes are those that link to the DNA. Although modern human languages may derive from an ancestral language spoken in the Late Pleistocene, earlier changes in human physiology and neural circuitry going back to 300,000 years and more provided a platform for the more recent advances (Donald, 1991; MacWhinney, 2008a). Because language depends on such a great diversity of structures, abilities, and processes, individuals often suffer from developmental disabilities reflecting variations in the stability of genetic support for language (Kang & Drayna, 2011). Typically, these variations involve either sporadic mutations on specific genes (Fisher & Scharff, 2009), complex gene-gene interactions as in autism, or major errors in disjunction such as Down Syndrome or Williams Syndrome. However, there is virtually no evidence for differences between current human populations in terms of basic genetic support for language learning and production.

Epigenesis (Waddington, 1957, 1977) involves the expression of the genetic code during human development. The long-term instructions encoded in the DNA must mesh with the shorter-term processes of genetic regulation and expression that can be triggered by tissue structures and body plans, as well as environmental inputs such as stress, diet, or chemicals. To understand the meshing of timeframes during epigenesis, we need to develop increasingly detailed dynamic system models of brain-body interactions (Thelen & Smith, 1994), neurogenesis, lateralization, plasticity, disability (Bishop, 2013), and neural degeneration (Kempler & Goral, 2008).

2. Emergentist Approaches

Recent work in linguistics has produced a variety of theoretical frameworks with overlapping goals and assumptions. Among these are functionalism (Givón, 1979), Systemic Functional Grammar (Halliday & Matthiessen, 2004), Processing Emergence (Hawkins, 2004; O'Grady, 2005), Cognitive Grammar (Langacker, 1987), Usage-Based Linguistics (Bybee & Hopper, 2001), Variable Rule Analysis (Kay, 1978), the Competition Model (MacWhinney, 1987), Construction Grammar (Goldberg, 2006), Conceptual Metaphor Theory (Lakoff & Johnson, 1980), Blending Theory (Fauconnier & Turner, 1996), Optimality Theory (Bresnan, Dingare, & Manning, 2001; Kager, 1999), and the Neural Theory of Language (Feldman, 2006). In cognitive psychology, theories such as Parallel Distributed Processing (Rumelhart & McClelland, 1986), Self-Organizing Maps (Kohonen, 2001), Bayesian Modeling (Kemp, Perfors, & Tenenbaum, 2007), Information Integration Theory (Massaro, 1987), and Dynamic Systems Theory (Thelen & Smith, 1994; van Geert & Verspoor, 2014) provide quantifiable predictions regarding the outcomes of competition. In social psychology, theories such as Memetics (Mesoudi et al., 2006) and Social Priming (Bargh, Schwader, Hailey, Dyer, & Boothby, 2012) explain how memes diffuse and consolidate. In addition, formulations from neurolinguistics such as mirror neurons (Arbib, 2010), Mind-Reading (Mitchell et al., 2008), Embodied Cognition (Pecher & Zwaan, 2005), and Common Coding (Schütz-Bosbach & Prinz, 2007) link up well with many aspects of functionalist linguistics.

Faced with this embarrassment of theoretical riches, students often ask what is the relation between Emergentism and all these other approaches. The answer is that all of these approaches fall under the general category of emergentism, because all recognize the importance of the principles of competition, hierarchicality, and timeframes we have been discussing. Where these approaches differ is in terms of their *emphases*. For example, given a metaphor such as *choking poverty*, Embodied Cognition emphasizes mappings of this metaphor to the source domain of the body, Mind-Reading highlights ways in which this metaphor activates particular areas of the brain, usage-based analysis focuses on the conventionalization of the metaphor through usage, and memetics examines the spread of the metaphor across communities. Integration of these contrasting emphases can force us to refine our empirical analyses. For example, we may want to contrast the processing of conventionalized metaphors with those of more novel metaphors in terms of the ways in which they activate embodied representations.

Although these various approaches all invoke concepts of competition and hierarchicality, they differ in terms of the specific quantitative methods they utilize. For example, Parallel Distributed Processing (Rumelhart & McClelland, 1986), Self-Organizing Feature Maps (Kohonen, 2001), and Dynamic Systems Theory (Thelen & Smith, 1994) all represent networks of connections, but differ in the ways in which algorithms operate on these connections. Underneath this apparent divergence, there is a core mathematical framework (Farmer, 1990) that derives from their shared reliance on emergentist principles. Similarly, Construction Grammar (Goldberg, 2006) is a direct outgrowth of work in Cognitive Grammar

(Langacker, 1987), differing largely in terms of the detail with which it analyses competitions between constructions.

Among the various emergentist approaches, there are three that have tackled the problem of understanding the meshing of timeframes. First, sociolinguistic analyses, such as those presented by Poplack and Cacoullos (this volume) that have succeeded in tracing changes and continuities in grammar and lexicon over decades and even centuries. Second, researchers such as Goodwin (2000), Sfard and McClain (2002), and Lemke (2000) have shown how the use of artifacts (tools, maps, books, color chips, computers) during interaction can provide links to long-term timeframes. Third, researchers in child language (Bates & Goodman, 1999) and second language (Verspoor, de Bot, & Lowie, 2011) have developed longitudinal corpora to trace the ways in which competing processes interact across several years. However, the full study of the meshing of alternative timeframes in linguistic analysis (MacWhinney, 2005, 2014a) remains a task for future theories, databases, and models.

3. Mechanisms of Emergence

The three major conceptual frameworks supporting Emergentism are competition, hierarchicality, and timeframes. To derive specific predictions and analyses from these frameworks, we need to link them to particular mechanisms of emergence. In this regard, it is helpful to survey some of the most important emergentist mechanisms that have been proposed.

1. **Proliferation**. Linguistic patterns are inherently variable both at the level of the community and the individual. Understanding the sources and results of this variation is a fundamental task for virtually every branch of language studies.
2. **Competition**. Individuals must continually make choices between alternative ways of expressing intentions. Psychological models of this process (Anderson, 1983; Ratcliff, Van Zandt, & McKoon, 1999) assume that the winners in this competition are the forms with microfeatures that most closely match the intended outcome. On the neuronal level, competition is implemented by summation of synaptic input across the neuron's cellular membrane.
3. **Generalization**. Emergentist accounts, such as PDP, Bayesian networks, the Competition Model, and Construction Grammar emphasize the ways in which generalizations emerge from the extraction of similarities across collections of more specific items or episodes. These accounts assume that, on the neuronal level, generalizations arise from shared patterns across items. Generalization plays a major role in theories of polysemy (MacWhinney, 1989), metaphor (Gibbs, in press), and prototype application (Taylor, in press). Some accounts also postulate multiple hierarchically-organized levels of generalization for syntactic constructions (Culicover & Jackendoff, 2005; McDonald & MacWhinney, 1991; Perfors, Tenenbaum, & Wonnacott, 2010) and categories (Kemp et al., 2007).
4. **Error correction**. Learning theories often emphasize the importance of corrective feedback for errors (Rumelhart & McClelland, 1987). However, this feedback can also involve failure to match self-imposed targets, as in the DIVA model of phonological learning (Guenter & Perkell, 2003).
5. **Self-organization**. Mechanisms such as the self-organizing feature map (Kohonen, 2001) provide alternatives to mechanisms based on error correction. An important assumption of these models is that the brain prefers to establish connections between local units, rather than between distant units (Jacobs & Jordan, 1992).

6. **Criticality**. There is increasing evidence (Shew & Plenz, 2013; Uhlig, Levina, Geisel, & Herrmann, 2013) that cortical circuits operate at criticality. This means that spike transmission depends on neurons being poised in dynamic equilibrium that allows maximally faithful information flow through quick phase transitions. Criticality is also maximized through the ways in which neural networks are self-organized. Criticality can also play a role in higher level structures, including the dynamics of interpersonal communication.
7. **Memory consolidation**. Repeated use of a muscle or bone will lead to its growth and strengthening. Language functions in a similar way. Each use of a sound, word, or construction in a particular context strengthens the memory for that form and increases its ability to compete with alternative forms. As we noted in our discussion of memory consolidation in honeybees, consolidation processes are sensitive to the relevance of memories in alternative timeframes (Squire, 1992). These alternative methods of consolidation rely on an array of biochemical processes and patterns of connectivity between the hippocampus and the cortex (McClelland et al., 1995; Schmajuk & DiCarlo, 1992; Wittenberg et al., 2002). Consolidation operates initially within individuals, but then extends over time to impact wider social and dialectal groups.
8. **Structure mapping**. Theories of metaphor, metonymy, and analogy in Cognitive Linguistics often assume some method of mapping from the structure of a source domain to a target domain (Gentner & Markman, 1997). Mechanisms of this type can also be used to account for convergence between cognitive systems (Goldstone, Feng, & Rogosky, 2004).
9. **Embodied representations**. The representations and schemata used in Cognitive Linguistics align well with neurolinguistic theories of body image (Knoblich, 2008), embodied perspective-taking (MacWhinney, 2008b), empathy (Meltzoff & Decety, 2003), situated spatial processing (Coventry, this volume), and motion processing (Stefanowitsch, this volume).
10. **Common ground**. The establishment of embodied representations benefits from the fact that we all share the same body type, thereby allowing physical mirroring (Arbib,this volume). On a still higher cognitive level, we also construct shared mental representations of places, events, goals, and plans that provide common ground, upon which language structures and conversational patterns can depend (E. Clark, this volume).
11. **Conversational pressures**. Linguistic structures adapt to frequent conversational patterns. For example, Du Bois (1987) has argued that ergative marking emerges from the tendency to delete the actor in transitive sentences, because it is already given or known. Similarly, Donegan (this volume) and Bybee and Beckner (this volume) explain how a loosening of demands for precision can stimulate lenition processes in phonology that eventually lead to further grammatical changes.
12. **Item-based patterns**. The theory of item-based patterns (MacWhinney, 1975a, 1982; Tomasello, 2000) provides an underpinning for Construction Grammar (Goldberg, 2006), as well as solutions to the logical problem of language acquisition (MacWhinney, 2004).
13. **Composition**. Syntactic theories must deal with the ways in which words cluster into phrases. Emergentist models of comprehension such as O'Grady (2005) show how this can be done in an incremental fashion. In this area, the emphasis in UG Minimalism on the Merge process (Chomsky, 2007) is compatible with emergentist accounts. However, compositionality is also required for basic action processing (Arbib, 2014; MacWhinney, 2009; Steedman, 2004), quite apart from its role in language.

14. **Perceptual recording**. Studies of infant auditory perception have revealed that, even in the first few months, infants apply general-purpose mechanisms to record and learn sequential patterns from both visual and auditory input (Thiessen and Erickson, this volume).
15. **Imitation**. Human children display a strong propensity to imitate gestures (Meltzoff & Decety, 2003), actions (Ratner & Bruner, 1978), and vocal productions (Whitehurst & Vasta, 1975). Imitation in both children and adults is the fundamental mechanism postulated by usage-based linguistics.
16. **Plasticity**. Children with early left focal lesions are able to recover language function by reorganizing language to the right hemisphere. This plasticity in development is a general mechanism that supports a wide variety of emergent responses to injury or sensory disability (MacWhinney, Feldman, Sacco, & Valdes-Perez, 2000).
17. **Physical structures**. Phonologists have shown that the shape of the vocal mechanism has a wide-ranging impact on phonological processes (Ohala, 1974). The articulatory system can be characterized as an assemblage of springs and dampers whose functioning is expressed through sets of differential equations (Boersma & Hayes, 2001; Story, 2002). For example, when singers use vibrato, they set up a resonance at 5-6 Hz, between the cricothyroid and thyroartenoid muscles. This resonance can be modeled by the vibrating string formula, as applied to the underlying dynamic mechanical system (Titze, Story, Smith, & Long, 2002). Rather than stipulating phonological rules or constraints (Bernhardt & Stemberger, 1998) for phonological patterns, we can view them as emergent responses to underlying physical pressures (Donegan, this volume). Further physical effects on emergent processes include coupling of the vocal cords to jaw movements (Iverson & Thelen, 1999), diffusion reactions during epigenesis (Murray, 1988), and many others.
18. **Epigenesis**, **Homeostasis and Homeorhesis**. Earlier, we discussed ways in which brain and body structures arise during epigenesis. To understand the organic basic of language disorders, we need to trace through the ways in which relevant brain and body structures emerge during neurogenesis. It is likely that many forms of disability arise from errors in patterns of connectivity between language processing areas during embryogenesis. However, even after the brain is formed, epigenetics continues to determine neural support for language through the homeostasis and homeorhesis. Homeostasis is the ability of the body to maintain structures despite cell loss. Homeorhesis is the ability of the body to maintain ongoing processes, despite perturbations. Both of these abilities arise from epigenetic control of gene expression, which is in turn sensitive to physical and chemical pressures from existing structures and processes.

This is a very incomplete listing of the many mechanisms and pressures that shape the emergence of language. Understanding how these mechanisms and others related to them mesh across timeframes to produce complex language structures is the major task facing emergentist approaches to language.

4. Emergentism and Universal Grammar

The modern study of language can be viewed as the tale of two competing paradigms: Universal Grammar (UG) and Emergentism. Over the last two decades, the dialog between Emergentism and UG has focused on ten core issues. Let us consider how UG and Emergentism approach each of these issues.

1. *What is Language?* UG focuses its attention on a narrow definition of language (Hauser, Chomsky, & Fitch, 2002) that involves the recursive application of rules in modules of the

syntactic component. This emphasis leaves large areas of lexicon, phonology, dialog, meaning, and interpretation outside of the domain of the language faculty. In contrast, Emergentism treats all of the components of human language, including those controlling communication, as parts of a interlocking, unified system.

2. *The Uniqueness of Recursion.* UG (Chomsky, 1995) and Emergentism (MacWhinney, 1987) both recognize the central role of recursive combination in producing sentence and discourse structure. However, UG holds that syntactic recursion is a criterial and unique feature of human language, linked specifically to the language faculty (Hauser et al., 2002). In contrast, Emergentism views recursion as arising from the combined activities of memory, lexicon, discourse, and role activation (MacWhinney, 2009).
3. *Rules vs. Cues.* A fundamental claim of the Emergentist program is that linguistic structures emerge from patterns of usage. This emphasis arose in reaction to the emphasis in earlier UG theories on large systems of ordered rules (Chomsky & Halle, 1968). These stipulated rule systems were formulated without any linkage to functional motivations. In later UG formulations (Chomsky, 1981; Chomsky & Lasnik, 1993), rules gave way to principles, parameters, and constraints. In contrast, emergentist analyses have focused on understanding how patterns arise from usage, generalization, and self-organization (MacWhinney, Malchukov, & Moravcsik, 2014).
4. *Irrelevance of E-Language.* UG seeks to base linguistic theory on the competence of the ideal speaker-hearer. This competence is characterized as I-Language (internal language) in contrast to E-Language (the external language of the community). Emergentism rejects the decoupling of I-Language and E-Language, as well as the attempt to separate competence and performance. Instead, it views the individual's linguistic abilities as emerging from interactions with the wider social community. It is through such interactions that we develop structures that achieve conceptual consensus (Goldstone et al., 2004; Wittgenstein, 1953).
5. *The Sudden Evolution of Language.* UG holds that language evolved recently as a way of supporting more elaborate cognition, rather than for purposes of social interaction. In contrast, Emergentism views language as deriving from a series of neurological and physical adaptations (Arbib, this volume), driven by a adaptation of the human species to a specialized niche involving upright posture, control in large mobile social groups (Geary, 2005), and support for delayed infant maturation (MacWhinney, 2008a).
6. *Simple Genetic Determination.* UG seeks to link the appearance of language to very specific genetic changes (Fisher & Scharff, 2009) in the last 70,000 years, perhaps involving one or two genetic changes. Emergentism views language as grounded on a wide-ranging set of genetic adaptations across millions of years.
7. *Speech is Special*. Generative theory has often been associated with the idea that, in terms of auditory processing, "speech is special" in the ways that innate faculty-specific abilities guide phonological development and structure. In contrast, emergentist approaches emphasize the role of physiological mechanisms in controlling articulation (Oller 2000). They also view auditory learning as governed by basic aspects of the auditory system and temporal processing constraints (Holt & Lotto 2010).
8. *A Critical Period for Language Learning.* Many UG formulations hold that there is an expiration date on the special gift underlying language learning and use (Lenneberg 1967). Emergentist accounts attribute the gradual decline in language learning abilities to entrenchment of the first language, parasitic transfer of first language abilities, and social isolation (MacWhinney, 2012).

9. *Modularity of Mind.* UG emphasizes the encapsulated, modular composition of grammar (Fodor 1983). Emergentist accounts emphasize interactivity between permeable, emergent modules (McClelland, Mirman & Holt 2006).
10. *Poverty of the Stimulus.* UG holds that there is insufficient information in the input to the language learner to properly determine the shape of the native language (Piattelli-Palmarini 1980). As a result, language learning is guided by a rich set of innate hypotheses regarding the shape of Universal Grammar. Emergentist accounts emphasize the richness of the input to the learner and the role of item-based (MacWhinney 2005c) and distributional (A. Clark, this volume) learning strategies in achieving effective learning of complex structures

The fact that the two approaches offer such different analyses for such fundamental issues has been a major impetus to ongoing empirical and theoretical work in each of these ten areas. However, the focus of work in Emergentism is now shifting away from the debate with UG toward the detailed articulation of an explanatory account of language structure based on the integration of the principles of competition, hierarchicality, and the meshing of processes across timeframes.

5. Applying Emergentism

This volume presents 27 chapters that explore the application of Emergentism to various aspects of language structure and development. The chapters are organized into five major sections: basic language structures, language change and typology, interactional structures, language learning, and language and the brain. Let us take a brief look at the core issues addressed by the chapters in each of these sections to see how their findings relate to the overall program of Emergentism.

Section 1: Basic Language Structures

This section examines the emergence of linguistic structures. In the first chapter, **Jay McClelland** reviews the highly productive connectionist approach to language emergence. Connectionist models view language structure as emerging from distributed patterns in neural networks, rather than from symbolic units and rules. McClelland illustrates the pervasive role of quasi-regularity in phonology, inflectional morphology, derivational morphology, spelling, lexical fields, and constructions. He argues that the continuous variation and the quasi-regularity present on every linguistic level are best captured in systems that allow for gradient representation and competition. Accounts that allow for both rules and gradient representations fail to explain why exceptions to rules are themselves quasi-regular. Although neural networks have provided empirically accurate emergentist models for detailed patterns of acquisition and language change without resorting to stipulation of rules and innate constraints, most previous work has relied on small input corpora and stipulations regarding input units. However, newer lines of neural network research are quickly overcoming these limitations.

In the next chapter, **Patricia Donegan** contrasts the conventionalized historical processes found in morphophonology with the automatic natural processes involved in phonology. Whereas morphophonological rules are sensitive to morphological factors such as morpheme boundaries, affix types, and word class, phonological processes are sensitive just to phonetic features. This contrast between the two levels of phonological control shows how articulatory patterns that are operative within the processing timeframe become lexically-specified patterns within the consolidation timeframe. Donegan's chapter also displays the fundamental competition between the motives of efficiency and accuracy (MacWhinney et al., 2014), with the former producing lenitions that optimize feature combinations, and the latter producing fortitions that enhance the characteristic properties of individual segments.

Maryellen MacDonald challenges the assumption that sentence processing biases originate from constraints in comprehension. Examining in detail the literature on relative clause and verb ambiguity processing, she proposes that these biases may emerge from the fact that certain structures are produced more easily and hence are more frequent in the input to the comprehension mechanism. In particular, she shows how the well-documented strategies of Easy First, Plan Reuse, and Reduce Interference generate biases in comprehension as well as production. One possibility is that the interchangeability of speaker and hearer (Hockett, 1960) means that both are subject to the same processing pressures, so that the three strategies MacDonald identifies for production may operate in similar ways for comprehension. Alternatively, these relations could emerge from the ways in which sentence producers engage in recipient design (Sacks, Schegloff, & Jefferson, 1974) to maximize accurate understanding of their message. At the same time, it would be a mistake to discount the role of statistical patterns deriving from production in shaping comprehension biases. At a minimum, MacDonald's analyses require us to consider the ways in which production and comprehension are coupled or entrained.

In contrast, **William O'Grady** focuses on ways in which biases emerge from processing pressures in the course of comprehension. In accord with extensive evidence demonstrating the incremental nature of sentence comprehension, O'Grady proposes that the processor attempts to resolve the referential dependencies of reflexive pronouns immediately and locally by linking to arguments in the current clause. This is done with reference to the argument structures that are an integral part of semantic representations, without reference to the syntactic structures adopted in traditional work on generative grammar (Chomsky, 1981). O'Grady also notes that young children also manifest a competing pragmatic strategy for linking reflexives to the perspective (Clackson, Felser, & Clahsen, 2011). It appears that these two strategies remain in competition, even in adulthood, but that the first strategy dominates whenever it has a chance to apply, because it is higher in cue validity and aligns so well with the basic sentence processing mechanism. Viewed in this way, O'Grady's analysis demonstrates ways in which language structure emerges from processing biases operating in competition and cooperation across slightly different timeframes.

Péter Rácz, Janet Pierre-Humbert, Jennifer Hay, and **Viktória Papp** (RPH&P) treat morphological systems as emergent generalizations across lexical items. The development of these higher-level patterns sets up a fundamental opposition between rote retrieval and combinatorial formation. RPH&P note that even long common forms may be stored by rote (Van Lanckner Sidtis, this volume), whereas others are produced by combination. How this works out for an individual speaker is entirely a function of that speaker's experience, as well as ongoing social changes, with the result that there is significant variation in morphological knowledge and use (McClelland, this volume). Looking at work on changes in the morphology of Early Modern English, they note that women led in some of these changes and men in others, depending on the exact nature of the social message being conveyed in the change (Helmbrecht, 2013). RPH&P also review recent work designed to illustrate the emergence of morphology through computational modeling. This work simulates the emergence of shared meaning-form relations through repeated communication attempts. Within these models, there is a proliferation of possible methods for expressing morphological concepts (see also Everett, this volume). As learning progresses, some of these forms win out in the competition over others, eventually emerging as new grammatical morphemes.

Zoltán Kövecses surveys the application of emergentist concepts to the study of metaphor. Conceptual Metaphor Theory (CMT) argues that metaphors emerge as projections from pre-existing cognitive structures (Lakoff, 1987), many of which involve the human body (Gibbs, 2005). However, in accord with Sanford (2012), Kövecses argues that metaphors themselves can function as the sources for the emergence of these schemata. This usage-based approach sees the production of novel metaphors as arising from processes such as generalization or extension that we see elsewhere in language and cognition. Moreover, it allows us to view both novel and conventionalized metaphors as responsive to situational and social aspects of particular communications. Kövecses focuses on the complexity, flexibility, and variability of the forces creating the source-target linkages underlying metaphors. An example of this is the metaphorical observation that the cyclist Lance Armstrong will need to confront "mountain stages" during his attempt to recover from his doping scandal. Such novel metaphors illustrate the interaction of recent timeframes with longer-term timeframes within the general source domains of JOURNEY and STRUGGLE. Further use of novel metaphors or clusters of similar metaphors will then lead to consolidation and conventionalization of projections from sources to targets. Metaphors provide an excellent arena for the study of timeframe interaction in terms of processing frames (Glucksberg, Brown, & McGlone, 1993), consolidation frames, generalization, and memetic spread.

Finally, the chapter from **Nick Ellis, Matthew O'Donnell,** and **Ute Römer** (EO&R) reviews the ways in which corpus-based research can provide empirical grounding for Construction Grammar analysis. They begin with a general review of emergentist approaches to language structure, including Zipfian distributions, prototypicality, cue reliability, embodied cognition, entrenchment, and construction grammar. They then demonstrate these principles through an analysis of the distribution in the British National Corpus of 23 verb argument constructions (VACs) out of the larger set of 700 identified by the COBUILD project. This analysis shows that the verbs in these constructions have a Zipfian distribution and that individual verbs are closely tied to particular constructions (Goldberg, Casenhiser, & Sethuraman, 2004). For example, *give* is linked to the ditransitive, whereas *leave* is more closely associated with the intransitive or simple transitive. Moreover, verbs in a given construction share common meaning profiles, as indicated through WordNet. They argue that these patterns of VAC distribution work together to promote learnability.

Section 2: Language Change and Typology

In the second section, **Joan Bybee** and **Clay Beckner** apply the theory of attractor dynamics to the two areas of sound change and grammaticalization. They view attractors in sound systems as emerging from the competing motives of maximizing perceptual contrast and minimizing articulatory cost (MacWhinney et al., 2014). However, there are a variety of solutions to this competition, and specific sound inventories involve detailed phonetic realizations that are not predicted from this competition alone, involving additional inputs from palatalization, glottalization, and nasalization processes, as well as perceptual effects. Furthermore, these pressures impact vowels and consonants differentially. Consonants are largely subject to weakening or lenition effects, whereas a vowel may begin to drift through vowel space, opening up a gap that can then lead to a "pull chain" or other vowels. Looking at the process of grammaticalization, we also see hot spots or attractors emerging from the competing motives of maximizing accurate communication and minimizing formal complexity. For tense and aspect, grammatical markers commonly arise from items such as "going to" or "finish". The pathways of change, reflecting dynamic aspects of language use, then involve chunking, meaning drift, bleaching, and phonetic reduction. Although these same processes recur across languages, the actual steps in the changes vary from case to case, depending on initial conditions and pressures from other parts of the system (Cristofaro, 2014; Malchukov, 2013).

Tom Givón uses relative clause formation to demonstrate how a language's synchronic structure emerges from its diachronic history in response to adaptive pressures that constrain human communication. The first pathway, illustrated by Bambara and Hittite, involves simple combination of two independent clauses, possibly with separate intonational contours and possibly with a merged intonational contour. In the next stage of this first pathway, the second of the two clauses joined under a single intonational contour may drop a pronoun. The second pathway, illustrated by German, uses demonstrative pronouns deriving from articles to serve two functions. At the beginning of a single clause, they can mark the topic. When clauses are combined, they begin the second clause and now function as a relativizer introducing a restrictive relative clause. Although Modern German then further adjusted the placement of the tensed verb in the relative clause to final position, the basic order and shape of the earlier paratactic pattern was preserved. The third pathway, illustrated by Ute, involves the conversion of a nominalized subordinate clause to function as a relative clause. The fourth pathway, illustrated by English, involves the development of relative clauses introduced by *wh*-question words (what, who, where, why, how) from sentences in which the *wh*-question word is the head of a clause that is the complement of the verb, as in *he saw how to solve it*. The idea is that this form then licenses *he saw the way how to solve it*, thereby allowing the *wh*-word to take on a relativizer function. Givón's analysis of these four pathways illustrates nicely two of the points made by Bybee and Beckner (this volume). First it appears that there is a strong attractor that leads languages to create a relative clause structure that can refine referent identification. Second, the exact shape of this construction depends on the initial state of the language, thereby illustrating the ways in which long-term timeframes mesh in language structure.

John Hawkins views conventionalized syntactic structures as emerging from usage preferences during processing. For example, the universal preference for definite over indefinite subjects becomes grammaticalized in some languages, whereas it remains a soft constraint in others. As in the work on the Competition Model, Hawkins examines the relative strengths of preferences through both experimentation and corpus analysis. However, he advances this method further by linking typological variation to differences in these observed processing preferences within individual languages. He presents 10 examples of such preferences, ranging from relative clauses and Wh-movement to number marking, and shows how these preferences emerge from processing efficiency constraints. The processing constraints he invokes include minimizing connections between forms (MiD), minimizing formal length (Zipf, 1949), minimizing variation within form categories (MiF), and maximizing the smooth online generation of properties that facilitate grammatical assignments (MaOP). Hawkins then shows how the proliferation of alternative forms of expression, often triggered by language contact and bilingualism, can result in a competition between forms with varying degrees of support from these underlying processing principles. Although this places his analysis close to O'Grady's in mechanistic terms, Hawkins argues that one cannot attribute everything to the workings of the processor and must preserve a role for an autonomous syntax. Within the framework of the wider Emergentist Program that we have been discussing, it is possible that this debate between

Hawkins and O'Grady over the autonomy of grammar (see also Newmeyer, 2013) will boil down to a consideration of the ways in which consolidation timeframes mesh with syntactic processing timeframes.

Terry Regier, Charles Kemp, and **Paul Kay** apply the theory of competing motivations (informativeness vs. simplicity) to explain the emergence of lexical categories. The three lexical fields they examine are color, kinship, and an abstract field represented as a set of binary feature vectors. Their account is grounded on a model in which speakers seek to minimize the error involved in the reconstruction of their message, while still maintaining simplicity. Like Bybee and Beckner (this volume), they note that there are both universal attractors and significant local variation modifying universal tendencies in the color domain. Their basic empirical prediction is that color naming systems are nearly as informative as theoretically possible for a given level of complexity. This prediction is supported, both for color and kinship, although there are some non-optimal systems that may represent languages in transition. For color terms, all of the options were given a similar need probability, which is probably only a bit off the mark. For kinship terms, need probability was estimated through corpus counts of kinship terms in English and German. However, these counts do not reflect distinctions such as younger vs. older sibling, parallel vs. cross cousin, or matrilineal vs. patrilineal relation that play no role in English or German. Hopefully, future corpus work with languages like Chinese or Turkish can refine these analyses.

Section 3: Interactional Structures

In the third section, **Shana Poplack** and **Rena Torres Cacoullos** (P&T) show how the methods of sociolinguistics add crucial empirical content to Emergentism. Fittingly enough, they refer to sociolinguistics as "language emergence on the ground," because of the richness of its observational data relating to language usage and change. In accord with the other chapters in this section, they show how situating newly emerging forms in the social and linguistic contexts in which they are embedded helps us pinpoint the operation of the mechanisms involved in emergence. A core insight of this approach to language is that form-function mappings are inherently variable, thereby producing exactly the type of proliferation required by Darwinian theory. To illustrate the importance of looking at actual variation in usage, P&T consider the alternation between the subjunctive and indicative in complement clauses in French. In the corpus they examine, the single verb *falloir* 'be necessary' accounts for nearly 2/3 of all the governors of the subjective and 3/4 of all tokens. Such results call into question numerous attempts to provide deep semantic characterizations of subjunctive use and point instead to a conventionalized lexical pattern with diminishing productivity. Looking next at the use of *bin* in Nigerian creole to express anterior aspect, P&T show that, although this form is used less than six other forms with which it competes, when it is used it is almost always to express anterior aspect. This suggests that it may be a newly emerging form for this function. In the case of Québec French, P&T are able to combine the use of spoken and written materials to trace the evolution of certain patterns of grammatical variation across centuries. For example, they can show how the interrogative particle *est-ce que* was introduced to French in the 16th century, but was rare in the 17th century French transplanted to Canada. However, in the late 20th century it began to spread in the upper classes as a way of emulating the prestige dialect of Metropolitan French.

Paul Foulkes and **Jennifer Hay** extend the reach of Emergentism to the sociophonetic level with a specific focus on the ways in which sociophonetic preferences and effects emerge across the lifespan through socialization and language use in social contexts. Beginning even before birth, babies become attuned to their mothers' prosody, pitch and other features of the native language. Later, parents give children rich input regarding register and dialect variations in games and role playing. Some of the many phonetic features that sociophoneticians track include rhoticity, glottalisation of /t/, vowel shifts, vocal fry, etc. Other features extend into morphology, as considered in the chapter by Rácz et al. (this volume). Learning of new phonetic patterns continues into adulthood with no evidence for a critical period after which individuals' phonetic productions become frozen. These various changes are heavily influenced by the timeframes of changing social alliances, new roles at the workplace, and incoming fads in language production. The diffusion of these new patterns can be traced through social networks, including those evolving in on-line social networking communities. Underlying all of these patterns of variation is the basic desire of the speaker to "index" their own personal identity in terms of age, gender, demographic background, attitudes, and emotions (Mead, 1934).

These two chapters demonstrate how, across five decades of research, sociolinguists have identified hundreds of instances of grammatical competitions, isolated the relevant competing motivations, and shown how they mesh quantitatively, using logistic regression. Frequently, sociolinguists have been able to track changes across long timeframes, sometimes extending to centuries. Most recently, the rapid development of sociophonetics has been supported by the availability of increasingly accessible methods for acoustic (Boersma & Weenink, 1996) and quantitative analysis. Given these various advances, sociolinguistics is becoming one of the most empirically and theoretically advanced applications of Emergentism to language.

Paul Hopper extends the notion of "emergence on the ground" to the study of the realtime creation of utterances in authentic conversations. In accord with his original ground-breaking analyses (Hopper, 1988), Hopper shows how grammatical structure emerges as an utterance proceeds, rather than being preconstructed and precompiled. The impact of on-line planning is demonstrated by utterances with retraces, expansions, pivots, and other emergent structures. Structures such as expansions may serve a variety of online purposes, such as further specification of referents, emphasis of points, hedging, metacommentary, evaluation, and others. Simply portraying the resultant organization of the utterance in tree diagrams misses large segments of the meaning being conveyed. Apart from this utterance-internal evidence, the dialogic nature of speech (Bakhtin, 1986) means that speakers are continually monitoring the status and reactions of their interlocutors to refine and reorder ideas to maximize recipient design (Sacks et al., 1974). Often this involves the use of projective devices such as *what will happen is* or *what we need to do is* as well as more basic devices such as *when* or *if*. Together, all of these illustrate the importance of taking the temporality of spoken language seriously (Auer, 2000).

Eve Clark examines a related area of online conversational processing – the co-construction of common ground between parent and child. Her analysis considers four space-time frames for the construction of common ground: local, personal, communal, and specialized. Local common ground emerges in the current conversation; personal common ground involves dyadic relations that may continue across interactions; communal common ground is tied to larger social groups; and specialized common ground is unique to groups with specialized knowledge such as hobbies or professions. Clark explains how common ground becomes solidified through assertions, acknowledgement, coreference, repetition, and nonlinguistic means. For infants, common ground is first established through the gestures, pointing, copresence, and reciprocal games involved in everyday settings and routines. Once they acquire some basic language, children use repetitions to express common ground and their parents provide expansions, corrections, and other forms of scaffolding to widen the scope of common ground. Experiments with two-year-olds show that they are good at assessing the other person's knowledge and adjusting their actions, pointing, and language to their understanding of that knowledge. Some basic aspects of this skill are even present as early as 12 months. By age 4, children begin to understand communal common ground in terms of understanding linked to age, status, or bilingualism. They also begin to acquire basic forms of specialized common ground for skills such as naming dinosaurs, birds, or play figures. In this way, children show a gradual expansion of common ground timeframes from local and personal to communal and specialized.

Dan Everett's chapter concludes this section with a examination of language-culture relations based on his extensive field data from Pirahã – an isolated Amazonian group that stresses communication based on immediate experience of the here and now. Following Sapir (1929), Everett argues that culture shapes language structure in significant ways on all levels. He points to the fact that, although Pirahã allows for combination of lexical items into phrases and arguments of the verb, it does not allow for clausal recursion through complementation or clause embedding. As such, it constitutes a stark exception to Chomsky's (2010) claim that syntactic recursion is the defining feature of human language. Everett argues that, if this were so, it would be strange to find a human language that does not have this property. Of course, the functions served by devices such as relativization, movement, and complementation can also be achieved through juxtaposition or parataxis (Givón, this volume; Mithun, 2009) between clauses, as Everett illustrates through citations of Pirahã texts. Turning his attention then to phonology, Everett shows how unique features of Pirahã culture are reflected in a sound system that has only three vowels and eight consonants. What Pirahã lacks in terms of a segmental inventory it makes up for in terms of prosodies that help support the additional channels of hum speech, yell speech, musical speech, and whistling.

Section 4: Language Learning

The fourth section presents eight chapters dealing with the emergence of language structures in first and second language learning. The section begins with a chapter from **Alexander Clark** that advances the thesis that rich classes of grammars can be acquired through distributional learning. He warns that learnability theory is not designed to provide a detailed account of the actual course of language learning; rather it is designed to investigate the conditions under which certain types of language can, in principle, be learned at all. For decades, the negative learnability results reported in Gold (1967) have been used to support a rich, domain specific program of UG. However, more recent learnability analyses considering the use of distributional and probabilistic information have produced positive results showing that one cannot argue for any version UG beyond one that is both small and domain-general. The ongoing challenge is to provide a model that aligns even more closely with what we know about the learner and the input.

The next chapter examines perceptual development and statistical learning. **Erik Thiessen** and **Lucy Erickson** (T&E), distinguish two basic classes of statistical learning: conditional and distributional. Conditional learning, which could also be called sequential learning, involves learning transitional probabilities between items. For example, in a phrase such as *the baby*, there is a high likelihood that *the* would precede *baby*, but a lesser likelihood that *baby* would follow *the*. T&E show how learning of prosodic patterns can facilitate word segmentation. Distributional learning, on the other hand, relates to learning about variation and constancy across the various exemplars of a given word, phoneme, syllable, or other form. One aspect of distributional learning the T&E explore in depth is the inability of 14-month-olds to consistently distinguish minimal pairs such as *bih* and *dih*, even when they can distinguish these sounds in real words. T&E suggest that this represents incomplete exposure in these young children to contexts such as *daddy* vs *tiger* in which the /t/ and /d/ acquire distinctiveness in terms of the further elements with which they combine. Within their extraction and integration framework, Theissen, Kronstein, & Hufnagle (2013) show how sequential learning and distributional learning work together to achieve segmentation and lexical learning.

Continuing on the same topic, **Stewart McCauley, Padraic Monaghan,** and **Morten Christiansen** (MM&C) present their PUDDLE and CBL models of early segmentation and syntactic learning. PUDDLE uses previous learned lexical items to leverage further boundary detection. A great strength of PUDDLE is its ability to reflect the growing shape of the lexicon during its operation. Whereas PUDDLE focuses on segmentation and word learning, CBL is designed to mimic full sentence comprehension and production in terms of constructing a shallow parse, based entirely on item coocurrence. The success of this model rivals that of shallow parser systems with far more structure that use part of speech information. This result strongly supports the idea that early syntactic learning relies primarily on item-based syntactic frames (MacWhinney, 1975a). MM&C note that, despite the empirical successes of PUDDLE and CBL, they do not yet fully model the process of early lexical and syntactic learning. The major future challenge here is the timeframes meshing problem – how to smoothly integrate these two processes along with realtime input of additional semantic and situational information (MacWhinney, 2010a).

Marilyn Vihman emphasizes the primacy of prosodic rhythm in early phonological perception and production. Within both modalities, children begin with certain universal dispositions or attractors. A perceptual example would be the categorical boundary between stop consonants at a voicing onset time (VOT) delay of +30 ms, and a production example would be the preference for initial CV (consonant plus vowel) structures over other syllable types. The shapes of these universal attractors are then adjusted (compare Bybee and Beckner, this volume and Regier, Kemp, and Kay, this volume) as the child attunes to the prosodies of the local language. Prosody influences children's encoding of new words by leading them to pay more attention to the details of stressed syllables. On the production side, children move quickly away from a universal reliance on the CV template to bring their early, simplified productions into accord with other templates in the target language, particularly VCV(C). Vihman concludes that the rhythmic patterns picked up through perception serve to entrain neurophysiologically based production rhythms to bring them into accord with those required by the target language.

Jordan Zlatev examines three views of the relation between gesture and speech: the deep linkage account of McNeill (2005), the interacting systems account of Kita and Özyurek (2003), and the interacting participants account of Goodwin (2000). He argues that only the latter two accounts can deal with the complexity and flexibility of the relations between speech and gesture during and across the timeframes of evolutionary consolidation (Arbib, this volume), developmental consolidation (Andrén, 2010), and the dynamic processing of face-to-face interactions (Charles Goodwin, 2000). Zlatev expands this argument in a detailed examination of the factors influencing early speech-gesture linkages, guided by the analysis of gestures on the levels of icon, index, and symbol (Peirce, 1932). He shows that iconic gestures begin as action schemas that develop into mimetic schemas operative in limited contexts, eventually undergoing symbolic distancing (Werner & Kaplan, 1963) to emerge as true iconic gestures.

Ben Ambridge and **Elena Lieven** (A&L) present a constructivist account of grammatical development that emphasizes the role of early generalization from rote-learned holophrases to item-based frames and then feature-based frames (MacWhinney, 1975b). They show how this approach can account for the acquisition of determiners, inflectional morphology, basic word order, and several more advanced constructions. Consider the problem of specifying the item-based frame for the indefinite article. It must allow for *a dog* and *a table*, but exclude *a sand,* or at least coerce a count noun interpretation (MacWhinney, 1989). Doing this requires a careful balancing of features to produce the correct inclusions and exclusions. A system of item-based generalization account provides better accounts of this process than competing categorial approaches. However, A&L realize that, to account for developmental patterns in full detail, we will need to construct computational simulations based on input from large corpora.

Work like that presented by Vihman, Zlatev, and Ambridge and Lieven responds in a productive way to the challenge of conducting "emergentism on the ground" issued by Poplack and Torres Cacoullos. Like the sociolinguists, emergentists working with child language are addicted to data, often collecting it very much down "on the ground" where children are playing with their toys. These data include audio and video linked closely to well-annotated transcripts; and these data are freely shared across the whole community (http://childes.talkbank.org) – a practice which we hope sociolinguists will also begin to adopt. Having these multimedia data publicly available allows us to conduct serious empirical tests of competing mechanistic accounts of emergence. This movement toward publicly available corpora and methods (http://talkbank.org) is also beginning to take hold in the study of second language learning, to which we turn next.

Ping Li begins his analysis by highlighting three factors that have stimulated the rapid recent surge of interest in bilingual and second language acquisition. These include reexamination of the notion of a Critical Period for second language acquisition, evidence for cognitive advantages conveyed by bilingualism, and increasing availability of neuroimaging data on bilingual processing. To these, he adds his own work in the construction of the DevLex neural network model of lexical and phonological acquisition in both monolingual and bilingual contexts. This self-organizing feature model (SOFM) does a particular good job in showing how both entrenchment of a first language and transfer from a first to a second language emerge from the basic operation of neural networks. Neuroimaging work has identified a distributed attentional network that supports bilingual code switching and other studies have demonstrated increased activation of certain areas for successful second language learners. In accord with the account of MacWhinney (2012), Li also shows how second language learners can deal with the learning problems posed by L1 entrenchment and transfer. These protective factors include strategies for maximizing comprehensible input, integrating with social groups, and engaging in resonant practice of new forms. Many of these strategies can be further supported through online media and adaptive computer tutors (Presson, Davy, & MacWhinney, 2013).

Paul van Geert and **Marjolijn Verspoor** (V&V) approach the study of language learning in terms of dynamic systems theory (DST) models with coupled attractors and generators that display emergent patterns when processing divergent inputs across timeframes. For example, van Dijk et al. (2013) show how patterns of CDS (child directed speech) lead to ongoing changes in child productions, which then lead back to new levels of CDS. In second language acquisition, Caspi (2010) showed how lexical acquisition drives subsequent syntactic acquisition with usage improving before accuracy. In accord with Darwinian theory, DST shows how periods of proliferation or instability can lead to developmental transitions and advances. Often, there are U-shaped curves with stability, then instability, and finally stability of higher usage patterns. These patterns are demonstrated across several studies of first and second language learners, with a focus on how developmental change can be quantified and described. Periods of increased variability indicate the coexistence of multiple competing strategies or waves (Siegler, 2006), some of which may eventually predominate, leading to new stability.

Section 5: Language and the Brain

The fifth and final section includes three chapters examining how neural functioning impacts language structure. The first, by **Gary Dell** and **Nathaniel Anderson** (D&A), considers several accounts of speech errors in people with aphasia. The first is the classic modular account of Lichtheim **(1885)** which treats Broca's aphasia as a loss of motor patterns in Broca's area, Wernicke's aphasia as a loss of auditory images in Wernicke's area, and conduction aphasia as a breakdown in the communication between these two areas. Modern computational models build on this original framework, but rely on connectionist computer modeling (McClelland, this volume) to derive more precise predictions regarding specific error patterns. These models support Freud's **(1891)** interactive view of processing, as opposed to accounts that assume no interaction between semantic, lexical, and phonological modules **(Levelt, Roelofs, & Meyer, 1999)**. D&A review three computational models implementing this assumption. The first is a dual-route interactive model that closely models aphasic error patterns using three lesionable parameters. The second model begins with a neural network trained to account for normal lexical retrieval in a sentential context. That model is then lesioned in ways that demonstrate aphasic performance. The third model also uses the method of lesioning a normal model, but in this case training allows for an emergent division of labor between dorsal and ventral neural circuits that arises during learning, before lesioning is applied.

Diana Van Lanckner Sidtis examines emergentist accounts of the production of formulaic language in both normal and disordered speech. The basic opposition here is between formulaic expressions, which are stored and accessed as single rote units, and productive forms, which are produced through combination. Formulaic expressions portray many unique psychological properties, including their ability to be recalled as a single chunk, higher levels of recall, and fuller encoding of emotional content. Evidence from child language acquisition indicates that formulas, unlike other lexical items, are often acquired through one-trial learning that maximizes the role of episodic encodings. Recent studies of patients with right hemisphere damage, Parkinson's disease, and Alzheimer's disease has provided a clearer understanding of the neural support for formulaic language. This evidence indicates right hemisphere structures organized to incorporate prosody and global encoding support the encoding of formulaic phrases, whereas subcortical structures such as the basal ganglia support the proceduralization of formulaic expressions.

The final chapter in this volume presents a comprehensive neurolinguistic emergentist approach to language evolution contributed by **Michael Arbib**. Arbib refers to this account as the Mirror System Hypothesis (MSH), because of the central role it assigns to the mirror neuron system in language acquisition. Arbib's position on six core debates or dichotomies regarding language evolution is much in accord with the analyses offered in section 4 above. In particular, he shows how language evolution depended on an emerging social/biological platform including motor neuron mirroring, imitation, gesture, paedomorphy, protosign, and holophrastic communication. He shows how imitation abilities build on the mirror neuron system, to create action schemas that ultimately lead to the sort of form-meaning mappings posited by Construction Grammar.

6. Conclusion

Together, these 27 chapters demonstrate the solid progress of the Emergentist Program, as a comprehensive, empirically-grounded, theory of language. By applying the concepts of competition, hierarchicality, and timeframe meshing, specific emergentist models have shown how mechanisms such as generalization, self-organization, establishment of common ground, competition, imitation, and embodiment can help us understand the complexity and diversity of human language, as well as the fact that language is learnable without depending on extensive detailed guidance from UG. The major challenge now facing this effort is to explain how these various processes mesh together in real time to determine language forms. Given our increasingly powerful access to tools for multimedia corpus creation, computational modeling, and neurolinguistic exploration, we can expect continued progress and refinement in this next phrase of the construction of the Emergentist Program.

Bibliography

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory and Language, 38*, 419-439.

Andersen, P., Emmeche, C., Finnemann, N., & Christiansen, P. (Eds.). (2000). *Downward causation: Minds, bodies, and matter*. Aarhus, Denmark: Aarhus University Press.

Anderson, J. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Andrén, M. (2010). *Children's gestures between 18 and 30 months*. Lund: Media Tryck.

Arbib, M. (2010). *Beyond the mirror: Evolving language and our social selves*. New York: Oxford University Press.

Arbib, M. (2014). Language evolution: An emergentist perspective. In B. MacWhinney & W. O'Grady (Eds.), *Handbook of Language Emergence*. New York: Wiley.

Auer, P. (2000). On line-Syntax - oder; was es bedeuten kennte, die Zeitlichkeit der mündlichen Sprache ernst zu nehmen. *Sprache und Literatur in Wissenschaft und Unterricht, 31*, 43-56.

Bakhtin, M. M. (1986). The problem of speech genres. In C. Emerson & M. Holquist (Eds.), *Speech genres and other late essays* (pp. 60-102). Austin: University of Texas Press.

Bargh, J., Schwader, K., Hailey, S., Dyer, R., & Boothby, E. (2012). Automaticity in social-cognitive processes. *Trends in Cognitive Sciences, 16*, 593-605.

Bates, E., & Goodman, J. (1999). On the emergence of grammar from the lexicon. In B. MacWhinney (Ed.), *The emergence of language* (pp. 29-80). Mahwah, NJ: Lawrence Erlbaum Associates.

Bates, E., & MacWhinney, B. (1982). Functionalist approaches to grammar. In E. Wanner & L. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 173-218). New York: Cambridge University Press.

Bernhardt, B. H., & Stemberger, J. P. (1998). *Handbook of phonological development from the perspective of constraint-based nonlinear phonology*. San Diego: Academic Press.

Bishop, D. (2013). Developmental cognitive genetics: How psychology can inform genetics and vice versa. *The Quarterly Journal of Experimental Psychology, 59*, 1153-1168.

Boersma, P., & Hayes, B. (2001). Empirical tests of the Gradual Learning Algorithm. *Linguistic Inquiry, 32*, 45-86.

Boersma, P., & Weenink, D. (1996). Praat, a system for doing phonetics by computer *Tech. Rep. 132*. Amsterdam: Institute of Phonetic Sciences of the University of Amsterdam.

Bookheimer, S. (2007). Pre-surgical language mapping with functional magnetic resonance imaging. *Neuropsychological Review, 17*, 145-155.

Bresnan, J., Dingare, S., & Manning, C. (2001). *Soft constraints mirror hard constraints: Voice and person in English and Lummi.* Paper presented at the LFG01, Hong Kong.

Bybee, J., & Hopper, P. (2001). *Frequency and the emergence of linguistic structure*. Amsterdam: John Benjamins.

Campbell, D. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review, 67*, 380-400.

Caspi, T. (2010). *A dynamic perspective on second language acquisition*. Groningen: University of Groningen.

Chan, M. W., Hinz, B., & McCulloch, C. A. (2010). Mechanical induction of gene expression in connective tissue cells. *Methods in Cell Biology, 98*, 178-205.
Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.
Chomsky, N. (1981). *Lectures on government and binding*. Cinnaminson, NJ: Foris.
Chomsky, N. (1995). *The minimalist program*. Cambridge: MIT Press.
Chomsky, N. (2007). Approaching UG from below. In U. Sauerland & M. Gaertner (Eds.), *Interfaces + Recursion = Language?* (pp. 1-30). New York: Mouton de Gruyter.
Chomsky, N. (2010). Some simple evo devo theses: How true might they be for language. In R. Larson, V. Déprez & H. Yamakido (Eds.), *The Evolution of Language: Biolinguistic Perspectives* (pp. 45-62). Cambridge: Cambridge University Press.
Chomsky, N., & Halle, M. (1968). *The sound pattern of English*. New York: Harper and Row.
Chomsky, N., & Lasnik, H. (1993). The theory of principles and parameters. In J. Jacobs (Ed.), *Syntax: An international handbook of contemporary research* (pp. 1-32). Berlin: Walter de Gruyter.
Clackson, K., Felser, C., & Clahsen, H. (2011). Children's processing of reflexives and pronouns in English: Evidence from eye-movements during listening. *Journal of Memory and Language, 65*, 128-144.
Cristofaro, S. (2014). Competing motivationmodels and diachrony: what evidence for what motivations? In B. MacWhinney, A. Malchukov & E. Moravcsik (Eds.), *Competing motivations in grammar and usage*. New York: Oxford University Press.
Culicover, P., & Jackendoff, R. (2005). *Simpler syntax*. New York: Oxford.
Darwin, C. (1859). *On the Origin of Species*. London: John Murray.
Daselaar, S., Veltman, D., & Witter, M. (2004). Common pathway in the medial temporal lobe for storage and recovery of words as revealed by event-related functional MRI. *Hippocampus, 14*, 163-169.
Dell, G. S., Juliano, C., & Govindjee, A. (1993). Structure and content in language production: A theory of frame constraints in phonological speech errors. *Cognitive Science, 17*, 149-195.
Donald, M. (1991). *Origins of the modern mind*. Cambridge, MA: Harvard University Press.
Du Bois, J. (1987). The discourse basis of ergativity. *Language, 63*, 805-856.
Edelman, G. (1987). *Neural Darwinism: The theory of neuronal group selection*. New York: Basic Books.
Farmer, J. D. (1990). A Rosetta Stone for connectionism. *Physica, 42*, 153-187.
Fauconnier, G., & Turner, M. (1996). Blending as a central process of grammar. In A. Goldberg (Ed.), *Conceptual structure, discourse, and language* (pp. 113-130). Stanford, CA: CSLI.
Feldman, J. (2006). *From molecule to metaphor: A neural theory of language*. Cambridge, MA: MIT Press.
Fernandez-Sanchez, M.-E., Serman, F., Ahmadi, P., & Farge, E. (2010). Mechanical induction in embryonic development and tumor growth: Integrative cues through molecular to multicellular interplay and evolutionary perspectives. *Methods in Cell Biology, 98*, 295-321.
Fisher, S., & Scharff, C. (2009). FOXP2 as a molecular window into speech and language. *Trends in Genetics, 25*, 166-177.
Fodor, J. (1983). *The modularity of mind: An essay on faculty psychology*. Cambridge, Mass.: M. I. T. Press.
Freud, S. (1891). *Zur Auffassung der Aphasien: eine kritische Studie*. Vienna: Franz Deuticke.

Geary, D. (2005). *The origin of mind: Evolution of brain, cognition, and general intelligence*. Washington, DC: American Psychological Association.
Gentner, D., & Markman, A. (1997). Structure mapping in analogy and similarity. *American Psychologist, 52*, 45-56.
Gibbs, R. (2005). Embodiment in metaphorical imagination. In D. Pecher & R. Zwaan (Eds.), *Grounding cognition*. Cambridge: Cambridge University Press.
Gibbs, R. (in press). Metaphor. In E. Dabrowska & D. Divjak (Eds.), *Language emergence*. Berlin: De Gruyter Mouton.
Givón, T. (1979). *On understanding grammar*. New York: Academic Press.
Glucksberg, S., Brown, M., & McGlone, M. (1993). Conceptual metaphors are not automatically accessed during idiom comprehension. *Memory and Cognition, 21*, 711-719.
Gold, E. (1967). Language identification in the limit. *Information and Control, 10*, 447-474.
Goldberg, A. (2006). *Constructions at Work: The nature of generalization in language*. Oxford: Oxford University Press.
Goldberg, A., Casenhiser, D., & Sethuraman, N. (2004). Learning argument structure generalizations. *Cognitive Linguistics, 15*, 289-316.
Goldstone, R., Feng, Y., & Rogosky, B. (2004). Connecting concepts to each other and the world. In R. Zwaan & D. Pecher (Eds.), *The grounding of cognition: The role of perception and action in memory, language, and thinking*. Cambridge: Cambridge University Press.
Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of Pragmatics, 32*, 1489-1522.
Goodwin, C. (2000). Gesture, aphasia, and interaction. In D. McNeill (Ed.), *Language and gesture* (pp. 84–98). Cambridge: Cambridge University Press.
Guenter, F. H., & Perkell, J. S. (2003). A neural model of speech production and its application to studies of the role of auditory feedback in speech. In B. Maasen, R. D. Kent, H. Peters, P. van Lieshout & W. Hulstijn (Eds.), *Speech motor control in normal and disordered speech* (pp. 29-50). Oxford: Oxford University Press.
Halliday, M. A. K., & Matthiessen, C. (2004). *An introduction to functional grammar. 3rd revised edition*. London: Hodder Arnold.
Hauser, M., Chomsky, N., & Fitch, T. (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science, 298*, 1569-1579.
Hawkins, J. (2004). *Efficiency and complexity in grammars*. Oxford, UK: Oxford University Press.
Helmbrecht, J. (2013). Politeness distinctions in personal pronouns – a case study of competing motivations. In B. MacWhinney, A. Malchukov & E. Moravcsik (Eds.), *Competing motivations in grammar and usage*. New York: Oxford University Press.
Hockett, C. F. (1960). The origin of speech. *Scientific American, September*, 6-12.
Hopper, P. (1988). Emergent grammar and the apriori grammar postulate. In D. Tannen (Ed.), *Linguistics in context: Connecting observation and understanding* (pp. 117-134). Norwood, NJ: Ablex.
Iverson, J., & Thelen, E. (1999). Hand, mouth and brain. *Journal of Consciousness Studies, 6*, 19-40.
Jacobs, R. A., & Jordan, M. (1992). Computational consequences of a bias toward short connections. *Journal of Cognitive Neuroscience, 4*, 323-336.
Kager, R. (1999). *Optimality Theory*. New York: Cambridge University Press.

Kang, C., & Drayna, D. (2011). Genetics of speech and language disorders. *Annual Review of Genomics and Human Genetics, 12*, 145-164.
Kay, P. (1978). Variable rules, community grammar, and linguistic change. In D. Sankoff (Ed.), *Linguistic variation: Models and methods*. New York: Academic Press.
Kay, P., & Fillmore, C. J. (1999). Grammatical constructions and linguistic generalization: The "what's X doing Y?" construction. *Language, 75*, 1-33.
Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Cambridge, MA: MIT Press.
Kemp, C., Perfors, A., & Tenenbaum, J. B. (2007). Learning overhypotheses with hierarchical Bayesian models. *Developmental Science, 10*, 307-321.
Kempler, D., & Goral, M. (2008). Language and dementia: Neuropsychological prospects. *Annual Review of Applied Linguistics, 28*(73-90), 73.
Kita, S., & Özyürek, A. (2003). What does cross-linguistic variation in semantic coordination of speech and gesture reveal? Evidence for an interface representation of spatial thinking and speaking. *Journal of Memory and Language, 48*, 16-32.
Knoblich, G. (2008). Bodily and motor contributions to action perception. In R. Klatzky, B. MacWhinney & M. Behrmann (Eds.), *Embodied cognition*. Mahwah, NJ: Lawrence Erlbaum.
Koechlin, E., & Summerfield, C. (2007). An infromation theoretical approach to prefrontal executive function. *Trends in Cognitive Sciences, 11*, 229-235.
Kohonen, T. (2001). *Self-organizing maps (3rd ed.)*. Berlin: Springer.
Labov, W. (1972). *Sociolinguistic patterns*. Philadelphia: University of Pennsylvania Press.
Lakoff, G. (1987). *Women, fire, and dangerous things*. Chicago: Chicago University Press.
Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: Chicago University Press.
Langacker, R. (1987). *Foundations of cognitive grammar: Vol. 1: Theory*. Stanford, CA: Stanford University Press.
Lemke, J. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity, 7*, 273-290.
Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22*, 1-75.
Li, P., Zhao, X., & MacWhinney, B. (2007). Dynamic self-organization and early lexical development in children. *Cognitive Science, 31*, 581-612.
Lichtheim, L. (1885). On aphasia. *Brain, 7*, 433-484.
MacWhinney, B. (1975a). Pragmatic patterns in child syntax. *Stanford Papers And Reports on Child Language Development, 10*, 153-165.
MacWhinney, B. (1975b). Rules, rote, and analogy in morphological formations by Hungarian children. *Journal of Child Language, 2*, 65-77.
MacWhinney, B. (1982). Basic syntactic processes. In S. Kuczaj (Ed.), *Language acquisition: Vol. 1. Syntax and semantics* (pp. 73-136). Hillsdale, NJ: Lawrence Erlbaum.
MacWhinney, B. (1987). The Competition Model. In B. MacWhinney (Ed.), *Mechanisms of language acquisition* (pp. 249-308). Hillsdale, NJ: Lawrence Erlbaum.
MacWhinney, B. (1989). Competition and lexical categorization. In R. Corrigan, F. Eckman & M. Noonan (Eds.), *Linguistic categorization* (pp. 195-242). Philadelphia: Benjamins.
MacWhinney, B. (2004). A multiple process solution to the logical problem of language acquisition. *Journal of Child Language, 31*, 883-914.

MacWhinney, B. (2005). The emergence of linguistic form in time. *Connection Science, 17*, 191-211.
MacWhinney, B. (2008a). Cognitive precursors to language. In K. Oller & U. Griebel (Eds.), *The evolution of communicative flexibility* (pp. 193-214). Cambridge, MA: MIT Press.
MacWhinney, B. (2008b). How mental models encode embodied linguistic perspectives. In R. Klatzky, B. MacWhinney & M. Behrmann (Eds.), *Embodiment, Ego-Space, and Action* (pp. 369-410). Mahwah: Lawrence Erlbaum.
MacWhinney, B. (2009). The emergence of linguistic complexity. In T. Givon & M. Shibatani (Eds.), *Linguistic complexity* (pp. 405-432). New York: Benjamins.
MacWhinney, B. (2010a). Computational models of child language learning. *Journal of Child Language, 37*, 477-485.
MacWhinney, B. (2010b). A tale of two paradigms *Language Acquisition across Linguistic and Cognitive Systems* (pp. 17-32). New York: John Benjamins.
MacWhinney, B. (2012). The logic of the Unified Model. In S. Gass & A. Mackey (Eds.), *The Routledge Handbook of Second Language Acquisition* (pp. 211-227). New York: Routledge.
MacWhinney, B. (2013). Competition across time. In B. MacWhinney, A. Malchukov & E. Moravcsik (Eds.), *Competing motivations in grammar and usage*. New York: Oxford University Press.
MacWhinney, B. (2014a). Competition across time. In B. MacWhinney, A. Malchukov & E. Moravcsik (Eds.), *Competing motivations in grammar and usage*. New York: Oxford University Press.
MacWhinney, B. (2014b). Language development. In L. Liben & U. Müller (Eds.), *Handbook of child language development*. New York: Wiley.
MacWhinney, B. (Ed.). (1999). *The emergence of language*. Mahwah, NJ: Lawrence Erlbaum Associates.
MacWhinney, B., Bates, E., & Kliegl, R. (1984). Cue validity and sentence interpretation in English, German, and Italian. *Journal of Verbal Learning and Verbal Behavior, 23*, 127-150.
MacWhinney, B., Feldman, H. M., Sacco, K., & Valdes-Perez, R. (2000). Online measures of basic language skills in children with early focal brain lesions. *Brain and Language, 71*, 400-431.
MacWhinney, B., Malchukov, A., & Moravcsik, E. (Eds.). (2014). *Competing motivations in grammar and usage*. New York: Oxford University Press.
Malchukov, A. (2013). Resolving alignment conflicts: a competing motivations approach. In B. MacWhinney, A. Malchukov & E. Moravcsik (Eds.), *Competing motivations in grammar and usage*. New York: Oxford University Press.
Massaro, D. (1987). *Speech perception by ear and eye*. Hillsdale, NJ: Lawrence Erlbaum.
Massaro, D. (Ed.). (1975). *Understanding language: An introduction-processing analysis of speech perception, reading, and psycholinguistics*. New York: Academic Press.
McClelland, J. L. (1987). The case for interactionism in language processing. In M. Coltheart (Ed.), *Performance XII* (pp. 41).
McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review, 102*, 419-457.

McDonald, J. L., & MacWhinney, B. (1989). Maximum likelihood models for sentence processing research. In B. MacWhinney & E. Bates (Eds.), *The crosslinguistic study of sentence processing* (pp. 397-421). New York: Cambridge University Press.

McDonald, J. L., & MacWhinney, B. (1991). Levels of learning: A microdevelopmental study of concept formation. *Journal of Memory and Language, 30*, 407-430.

McNeill, D. (2005). *Gesture and thought*. Chicago: Chicago University Press.

Mead, G. (1934). *Mind, self, and society: From the standpoint of a social behaviorist*. Chicago: Chicago University Press.

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society of London B, 358*, 491-500.

Menzel, R. (1999). Memory dynamics in the honeybee. *Journal of Comparative Physiology A, 185*, 323-340.

Mesoudi, A., Whiten, A., & Laland, K. (2006). Towards a unified science of cultural evolution. *Behavioral and Brain Sciences, 29*, 329-383.

Mitchell, T. M., Shinkareva, S. V., Carlson, A., Chang, K.-M., Malave, V. L., Mason, R. A., & Just, M. (2008). Predicting human brain activity associated with the meanings of nouns. *Science, 320*, 1191-1195.

Mithun, M. (2009). Re(e)volving complexity: Adding intonation. In T. Givon & M. Shibatani (Eds.), *Syntactic complexity: Diachrony, acquisition, neuro-cognition, evolution* (pp. 53-81). Amsterdam: John Benjamins.

Murray, J. D. (1988). How the leopard gets its spots. *Scientific American, 258*, 80-87.

Newmeyer, F. (2013). Where do motivations compete? In B. MacWhinney, A. Malchukov & E. Moravcsik (Eds.), *Competing motivations in grammar and usage*. New York: Oxford University Press.

O'Grady, W. (2005). *Syntactic carpentry*. Mahwah, NJ: Lawrence Erlbaum Associates.

Ohala, J. J. (1974). Phonetic explanation in phonology. In A. Bruck, R. Fox & M. La Galy (Eds.), *Papers from the parassession on natural phonology* (pp. 251-274). Chicago: Chicago Linguistic Society.

Pecher, D., & Zwaan, R. (Eds.). (2005). *Grounding Cognition*. Cambridge: Cambridge University Press.

Peirce. (1932). *Language and context: Collected papers*. Cambridge, MA: Harvard University Press.

Perfors, A., Tenenbaum, J. B., & Wonnacott, E. (2010). Variability, negative evidence, and the acquisition of verb argument constructions. *Journal of Child Language, 37*, 607-642.

Presson, E., Davy, C., & MacWhinney, B. (2013). Experimentalized CALL for adult second language learners. In J. Schwieter (Ed.), *Innovative research and practices in second language acquisition and bilingualism* (pp. 139-164): John Benjamins.

Pulvermüller, F. (2003). *The neuroscience of language*. Cambridge: Cambridge University Press.

Ratcliff, R., Van Zandt, T., & McKoon, G. (1999). Connectionist and diffusion models of reaction time. *Psychological Review, 106*, 261-300.

Ratner, N., & Bruner, J. (1978). Games, social exchange and the acquisition of language. *Journal of Child Language, 5*, 391-401.

Rumelhart, D., & McClelland, J. (1986). *Parallel Distributed Processing*. Cambridge, Mass.: MIT Press.

Rumelhart, D., & McClelland, J. (1987). Learning the past tenses of English verbs: Implicit rules or parallel distributed processes? In B. MacWhinney (Ed.), *Mechanisms of Language Acquisition* (pp. 195-248). Hillsdale, N.J.: Lawrence Erlbaum.
Sacks, H., Schegloff, E., & Jefferson, G. (1974). A simplest systematics for the organization of turn-taking for conversation. *Language, 50*, 696-735.
Sanford, D. (2012). Metaphors are conceptual schemata that are emergent over tokens of use. *Journal of Cognitive Science, 13*, 355-392.
Sapir, E. (1929). The status of linguistics as a science. *Language, 5*, 207-214.
Schmajuk, N., & DiCarlo, J. (1992). Stimulus configuration, classical conditioning, and hippocampal function. *Psychological Review, 99*, 268-305.
Schütz-Bosbach, S., & Prinz, W. (2007). Perceptual resonance: Action-induced modulation of perception. *Trends in Cognitive Sciences, 11*, 349-355.
Sfard, A., & McClain, K. (2002). Special Issue: Analyzing tools: Perspective on the role of designed artifacts in mathematics learning. *Journal of the Learning Sciences, 11*, 153-388.
Shew, W., & Plenz, D. (2013). The functional benefits of criticality in the cortex. *The Neuroscientist, 19*, 88-110.
Siegler, R. S. (2006). Microgenetic analyses of learning. In D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology: Volume 2: Cognition, perception, and language* (pp. 464-510). Hoboken, NJ: Wiley.
Simon, H. (1962). The architecture of complexity. *Proceedings of the American Philosophical Society, 106*, 467-482.
Squire, L. R. (1992). Memory and the hippocampus: a synthesis from findings with rats, monkeys, and humans. *Psychological Review, 99*(2), 195-231.
Steedman, M. (2004). *Where does compositionality come from?* Paper presented at the Compositional connectionism in Cognitive Science.
Story, B. (2002). An overview of the physiology, physics and modeling of the sound source for vowels. *Acoustical Science and Technology, 23*, 195-206.
Taylor, J. (in press). Prototype effects in grammar. In E. Dabrowska & D. Divjak (Eds.), *Handbook of Cognitive Grammar*. Berlin: De Gruyter Mouton.
Thelen, E., & Smith, L. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.
Thiessen, E., Kronstein, A., & Hufnagle, D. (2013). The extraction and integration framework: A two-process account of statistical learning. *Psychological Bulletin, 139*, 792-814.
Titze, I. R., Story, B., Smith, M., & Long, R. (2002). A reflex resonance model of vocal vibrato. *Journal of the Acoustical Society of America, 111*, 2272-2282.
Tomasello, M. (2000). The item-based nature of children's early syntactic development. *Trends in Cognitive Sciences, 4*, 156-163.
Uhlig, M., Levina, A., Geisel, T., & Herrmann, M. (2013). Critical dynamics in associative memory networks. *Frontiers in Computational Neuroscience, 7*, 1-11.
van Dijk, M., van Geert, P., Korecky-Kröll, K., Maillochon, I., Laaha, S., Dressler, W., & Bassano, D. (2013). Dynamic adaptation in child–adult language interaction. *Language Learning, 63*, 243-270.
van Geert, P., & Verspoor, M. (2014). Dynamic systems and language development. In B. MacWhinney & W. O'Grady (Eds.), *Handbook of Language Emergence*. New York: Wiley.

Verspoor, M., de Bot, K., & Lowie, W. (2011). *A dynamic approach to second language development*. New York: John Benjamins.
Waddington, C. H. (1957). *The strategy of the genes*. New York: MacMillan.
Waddington, C. H. (1977). *Tools for thought: How to understand and apply the latest scientific techniques of problem solving*. New York: Basic Books.
Werner, H., & Kaplan, B. (1963). *Symbol formation: An organismic-developmental approach to language and the expression of thought*. New York: Wiley.
Whitehurst, G., & Vasta, R. (1975). Is language acquired through imitation? *Journal of Psycholinguistic Research, 4*, 37-59.
Wittenberg, G., Sullivan, M., & Tsien, J. (2002). Synaptic reentry reinforcement based network model for long-term memory consolidation. *Hippocampus, 12*, 637-647.
Wittgenstein, L. (1953). *Philosophical investigations*. Oxford: Blackwell.
Zipf, G. K. (1949). *Human behavior and the principle of least effort*. New York: Addison-Wesley.