CHAPTER 1

A tale of two paradigms

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The modern study of language, particularly as practiced in the Anglophone community, can be viewed as the tale of two competing paradigms: Universal Grammar (UG) and emergentism. These two paradigms take fundamentally different positions on these eight core issues: competence-performance, the centrality of recursion, the sudden evolution of language, the genetic control of language, the idea that speech is special, critical periods for language learning, neurological modules supporting language, and the poverty of the stimulus to the language learning. For researchers in the UG tradition, the vision of a recent evolution of language triggered by mutation in a few select genes predicts the formation of language modules, structures supporting recursion, and critical periods. Emergentists view language evolution as a gradual process based on dozens of mutations that impact general purpose cognitive and physiological mechanisms in many flexible ways. For emergentists, recursion and competence are not hard-wired facilities, but emergent abilities. Because of its greater complexity, the articulation of the emergentist position has depended heavily on advances in computer technology and the growth of multimedia databases, imaging technology, neural network modeling, and methods for dynamic assessment.

1. Introduction

The modern study of language, particularly as practiced in the Anglophone community, can be viewed as a tale of two competing paradigms. One of these paradigms is the discipline of generative grammar, as formulated by Chomsky and his coworkers. The goal of a generative grammar is the formulation of a device that can enumerate all grammatical sentences of a language and no ungrammatical sentences. Generative grammar broke onto the linguistic scene in 1957 with the publication of *Syntactic Structures* (Chomsky 1957) and Chomsky's (1959) devastating review of Skinner's *Verbal Behavior*. Later, Chomsky (1963) and Miller and Chomsky (1963) outlined the consequences of the approach for formal models of

language users. The paradigm achieved fuller articulation in subsequent formulations (Chomsky 1965, 1981, 1995; Chomsky & Lasnik 1993). These later versions of generative grammar emphasized the extent to which the core of language is identical across all humans. Chomsky referred to this as the theory of Universal Grammar (UG). Biological support for UG was presented in Lenneberg (1967), and Fodor's (1983) analysis of modularity of mind provided additional grounds for linking UG to cognitive science.

The second paradigm has developed more recently. It emphasizes the emergence of linguistic structure from natural processes in the brain, body, and society. This paradigm brings together work on cognitive linguistics (Langacker 1987), functional linguistics (Givón 1979), neural network modeling (Rumelhart & McClelland 1986), statistical learning (Aslin, Saffran & Newport 1999), data-driven corpus analysis (Bybee & Hopper 2001), embodied cognition (Barsalou 1999) and cognitive neuroscience (Edelman 1987). The goal of emergentism is the exploration of the biological and statistical mechanisms that create linguistic structure.

2. Eight core issues

Because these two paradigms have been in competition now for nearly 20 years, each has developed an internally consistent position regarding core issues in the study of language. Specifically, each paradigm has developed an approach to eight core issues. Of course, not all proponents adhere to a uniform view regarding each of the eight issues. However, across researchers and formulations, we can distinguish two competing, logically consistent approaches that provide a well-articulated approach to each of these eight issues. Let us begin by reviewing the position of UG on these eight core issues.

1. *Competence-performance.* The standard formulation of UG emphasizes the importance of basing linguistic theory on the competence of the ideal speaker-hearer, rather than diverse performances across variable speakers, situations, and dialects. This supposition of UG cannot be challenged, since it is a methodological preliminary rather than a testable empirical claim.
2. *Recursion.* The formulation of UG presented in the Minimalist Program (Chomsky 1995), emphasizes the role of recursion in characterizing the core nature of human language. Recursion involves the joining of linguistic units into a hierarchically ordered phrase structure, such as, "The man who built my house repaired Frank's car." Clauses can be recursively embedded inside other clauses, as in "The man who built the house that I sold you repaired Frank's car." It is this capacity for repeated recursion that underlies the essentially unlimited productivity of human language (Chomsky 1965).

3. *Evolution.* Because recursion plays such a central role in language structure, generative theory sees the emergence of recursion as constituting a crucial step in the evolution of human language. Moreover, this emergence is viewed as both sudden and recent. Hauser, Chomsky and Fitch (2002) distinguish the language faculty broadly defined from the language faculty narrowly defined. According to this recent account, many species have evolved special vocal forms and social support for communication, but only humans have achieved recursion. Moreover, the recent expansion of human material culture is taken as evidence that there was a recent, sudden evolution of the neural structures supporting recursion.
4. *Genetics.* UG accounts often claim that there has been a sudden, recent evolution of recursion that can be traced to a specific genetic basis for recursive control of language (Enard et al. 2002). In support of this analysis, speakers with specific language impairment (SLI) are expected to have deficits linked to this gene (van der Lely 2005).
5. *Speech is special.* Because of its general emphasis on a biological basis for language, generative theory has often been associated with the idea that, "speech is special." The idea is that processing phonemic distinctions such as that between *pin* and *bin* relies on methods that go beyond those available to nonhumans. However, the finding that chinchillas (Kuhl & Miller 1975) and even Japanese quail (Lotto, Kluender & Holt 1997) share these abilities with humans claim has tended to undercut this view. As a result, some recent formulations of the UG position on this issue (Hauser et al. 2002) place evolutionary adaptations for speech outside the language faculty narrowly defined.
6. *Critical period.* Proponents of UG have often emphasized the idea that there is an expiration date on the special gift underlying language learning and use. This gift is sufficient to support the smooth learning of language during early childhood. However, after the end of some critical period, the natural acquisition of a second language becomes difficult or impossible (Lenneberg 1967).
7. *Modularity.* UG accounts have consistently emphasized the modular composition of the grammar. Separate modules have been proposed for thematic role assignment, pronominal binding, argument chaining, and so on. In addition, large modules such as lexicon, phonology, and syntax are thought to minimize interactive communication (Fodor 1983).
8. *Poverty of the stimulus.* Analyses of language learning grounded on UG often hold that there is insufficient information in the input to the language learner to properly determine the shape of the native language (Piattelli-Palmarini 1980). Instead, language learning is guided by a rich set of innate hypotheses regarding the shape of Universal Grammar.

Emergentist studies have developed sharply contrasting approaches to each of these eight issues. Let us consider each of these alternative emergentist formulations.

1. *Competence-performance.* From the viewpoint of emergentism, the language variation revealed through performance is not something to be abstracted away. Rather, it is the core engine driving language change and much of language learning.
2. *Recursion.* Emergentist accounts also recognize the importance of recursion in supporting language productivity. However, they view recursion as arising from ancient, general-purpose mechanisms for the organization of space and action, as well as more recent systems for short-term memory storage (MacWhinney 2009).
3. *Evolution.* Emergentism stresses the gradual nature of the coevolution of language, gesture, and thought (MacWhinney 2008a).
4. *Genetics.* Emergentism points to the complexity of gene-gene interactions (Plomin & Rutter 1998) in complex systems such as human language.
5. *Speech is special.* Emergentist approaches to speech and phonological development 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).
6. *Critical period.* Emergentist accounts emphasize the gradual nature of the decline in language learning abilities over age. They attribute this decline to the entrenchment of the first language, the transfer of first language abilities, and the competition between the first and second language (MacWhinney, in press).
7. *Modularity.* Emergentist accounts emphasize interactivity between permeable, emergent modules (McClelland, Mirman & Holt 2006).
8. *Poverty of the stimulus.* Emergentist accounts emphasize the richness of the input to the learner and the role of item-based learning strategies in achieving effective learning of complex structures (MacWhinney 2005c).

Table 1 summarizes the positions of these two paradigms on these eight core issues.

Because UG is the older, more established, tradition, it has received relatively more attention, elaboration, commentary, criticism, and codification. Moreover, the logic underlying the linkage between the default UG view on each of these eight issues is generally well understood. In comparison, the logic of the emergentist approach to these eight issues has received less discussion. Therefore, we will devote the remainder of this paper to a consideration of the logic underlying emergentism.

Table 1. Positions of UG and emergentist approaches on eight core issues

Issue	UG approaches	Emergentist approaches
Competence-performance	Focus on competence	Rejection of the distinction
Recursion	Recursion is a specially evolved human capacity	Recursion arises from a network of cognitive abilities
Evolution	Language arose recently and suddenly	Language arose gradually through coevolution
Genetics	Language relies on specific genes	Language relies on general cognitive abilities
Speech is special	Speech production and audition rely on unique, recent human adaptations	Audition depends on general mammalian abilities; production is a recent adaptation
Critical period	L2 is fundamentally different from L1	L2 and L1 use the same set of abilities
Modularity	Language is processed in impermeable modules	Language processing is fundamentally interactive
Poverty of the stimulus	Language cannot be learned from the input	Language can be learned by bootstrapping from the input

3. Mechanisms of emergence

UG accounts place an emphasis on the recursive application of symbolic rules as characterizing the uniquely human capacity for language. The emergentist view counters this emphasis on innate constraints with an emphasis on dynamic, emergent processes. Some of these are the familiar processes of information-processing psychology, such as competition, strength, and reinforcement that are central to usage-based accounts such as the Competition Model (MacWhinney, in press) or Construction Grammar (Goldberg 2006). These competitive processes reflect the Darwinian emphasis on emergence from variation, adaptation, and selection (Edelman 1987). In addition, emergentist accounts emphasize the role of neurophysiological processes and constrains such as interactive activation (McClelland & Rumelhart 1981), memory consolidation (Wittenberg, Sullivan & Tsien 2002), reinforcement learning (Westermann & Miranda 2004), and a preference for short neural connections (Jacobs & Jordan 1992).

To illustrate how emergentism approaches issues in language learning, let us consider how the mechanism of entrainment or coupling can be used to account for aspects of the development of infant babbling. In 1794, Huygens demonstrated that two pendulums moving at different periods would couple together to find a single periodicity if they are mounted on a board with springs.

During this coupling, one pendulum serves as the strong attractor that entrains the other pendulum to its periodicity. This form of resonant coupling also seems to work within language learning. Studies of the mechanics of infant babbling have demonstrated that there is an early period when the child moves the jaw with a consistent rhythm (MacNeilage 1998). During babbling, the periodicity of this movement then serves to entrain a similar periodicity in the opening and closing of the glottis. The direct result of this coupling is the emergence of canonical babbling (Vihman 1996).

This simple illustration of an emergent process of language focuses on the linkage of the jaw to the glottis. However, emergent processes often function within more complex self-regulating feedback loops. For example, the Krebs cycle in cell metabolism relies on repeated catalytic reactions to construct adenosine triphosphate (ATP) for energy transfer. The cycle involves several feedback processes that make sure that ATP is not created in excess and that the original reactants (FAD and NAD+) are recreated to allow the cycle to continue. In this way, the catalytic nature of the cycle guarantees ongoing homeorhesis (stability during change) for cell construction and metabolism.

The hierarchical nature of emergent processes can be further illustrated by considering the determination of protein folding. The primary structure of a protein is determined by its sequence of amino acids, which is in turn a function of the order of amino acids in a codon of DNA. This is the structure that is directly controlled by evolutionary selection for mutations. The secondary structure of proteins involves coils, fold, and pleats that arise from the formation of hydrogen bonds between CO and NH groups along the polypeptide backbone. Tertiary structure, leading to the folding of single polypeptides, derives from hydrophobic interactions and disulfide bridges that produce bonding between side chains. Quaternary structure emerges from the aggregation of polypeptide subunits, as in the combination of four subunits in hemoglobin. Altogether "The specific function of a protein is an emergent property that arises from the architecture of the molecule" (Campbell, Reece & Mitchell 1999).

Biological systems depend heavily on *homeorhetic* systems for the preservation of life. These systems maintain balance for hormone levels, ion transport, metabolites, immune functioning, and cell growth. In language, homeorhesis operates on physiological, neurological, and social levels. Conversation itself can be viewed as a homeorhetic process in which speakers maintain the floor and confirm interaction through ongoing attentional signaling and interactional markers. Biological systems also display various types of loose coupling (incomplete penetrance, weak canalization, pleitropy) in the expression of the genetic code (Waddington 1957). Emergentists see these loose couplings as evidence for the non-modular and emergent nature of neural control of language. For

example, the KE family studied by Gopnik and Crago (1990) has an inherited dominant mutation in the Fox2P gene that has an impact on motor functioning generally, leading to problems with chewing, drooling, and articulation. These articulatory problems then result in difficulties in producing final syllables in forms such as "jumped." In this case, the primary deficit is a motor disorder which then has indirect, loosely coupled effects on some aspects of the grammar. Table 2 summarizes the various mechanisms of emergence discussed above.

Table 2. Mechanisms of emergence

Mechanism	Description
Strength	Synaptic connections grow in strength, based on usage and cue validity.
Competition	Neurons integrate across inputs, so that stronger cues dominate over weaker cues.
Reinforcement	Hebbian learning – neurons that fire together wire together.
Memory consolidation	The hippocampus supports longterm encoding of patterns with strong associations and high cue validity.
Spreading activation	The spread of activation generates associations, activates local maps and gangs, and facilitates recall.
Lateral inhibition	Within local maps, the best match comes to inhibit its competitors.
Interactive activation	Major areas communicate interactively through white matter connections.
Short connections	Local connections are preferred over more expensive distant connections. This produces a weak form of modularity.
Entrenchment	Processes of self-organization in local maps become less flexible over time, leading to decreased plasticity.
Item-based learning	Concepts and lexical items serve as centers for other learning.
Serial ordering	Concepts and lexical items specify order relations with other items.
Generalization	Item-based patterns can join into larger groups and types.
Analogy and transfer	Patterns from a first language will be transferred to second languages.
Proceduralization	Repeated use of specific serial patterns leads to automatization supported by the procedural learning system.
Coupling	Resonant communication between modules is facilitated by isomorphic mapping based on embodied codes.
Embodiment	Language adapts to the shape of the vocal tract and body.
Homeorhesis	Neural and conversational patterns continue in a constant form unless redirected.

4. Seven timeframes

Language is grounded on levels of emergent structure very analogous to those involved in protein folding or catalytic processes such as the Krebs cycle. The brain, the vocal tract, and the body are themselves biological systems that help to shape the bases for language. Just as we can distinguish levels of protein folding, we can distinguish seven markedly different timeframes for emergent linguistic processes and structures (Lorenz 1958).

1. *Phylogenetic emergence*
   The slowest moving emergent structures are those that are encoded in the genes. Changes across this timeframe – which involves millennia rather than minutes – are controlled by natural selection (Darwin 1871). The core engine of emergence is the generation of variation through mutation, followed then by natural selection through both mate choice and differential mortality. Natural selection utilizes the possibilities for reorganization shaped by the DNA and the interactions of polypeptides that it specifies. The unevenness of this underlying landscape makes some mutations more probable and frequent than others, leading to a reliance on the reuse of old forms to serve new functions. Emergentist accounts in this area have emphasized the ways in which language, society, and cognition have undergone coevolution (MacWhinney 2008a) based on the linking of dynamic systems. To trigger this coevolutionary advantage, changes in linguistic abilities must arise in parallel with advances in cognitive or social abilities. Moreover, both effects must interact at the moment of speaking. When this happens in a way that favors reproductive fitness, the mutation will be preserved.
2. *Epigenetic emergence*
   The codification of information in the DNA represents a precise meshing between the slow moving process of evolution and the faster-moving process of epigenesis (Waddington 1957). Embryologists have shown us that biological structures emerge from processes of induction between developing tissue structures in the embryo. The shape of these interactions is not hard-coded in the DNA. Instead, the DNA encodes information that can push the process of differentiation in particular directions at crucial epigenetic choice points. The precursors of autism in the embryo can be traced to particular epigenetic effects, as can the formation of stripes in the tiger. Epigenetic emergence does not cease at birth. To the degree that the brain maintains a level of plasticity, epigenetic processes allow for recovery of function after stroke through rewiring and reorganization. Before birth, epigenetic interactions with the environment are confined to forces that impinge on the

uterus and the embryonic fluid. After birth, the environment can trigger a wide variety of variations in gene expression from diabetes to brain reorganization for language in the deaf (Bellugi, Poizner & Klima 1989).

3. *Developmental emergence*
   Jean Piaget's genetic psychology (Piaget 1954) was the first fully articulated emergentist view of development. Impressively complete in its coverage, it failed to specify details regarding mechanisms of development. To provide this missing mechanistic detail, current emergentist accounts of development rely on connectionism (Quinlan 2003), embodied cognition (Klatzky, MacWhinney & Behrmann 2008), and dynamic systems theory (Thelen & Smith 1994). Emergentist theory has been used to characterize two different, but interrelated, aspects of development. The first is the learning of basic facts, forms, relations, names, and procedures. Connectionist and usage-based models of language learning, such as those that deal with learning of the past tense (MacWhinney & Leinbach 1991), syntactic patterns (Waterfall, Sandbank & Edelman, in press), or word segmentation (Monaghan & Christiansen, in press) often focus on this type of development. A second type of development involves the learning of new strategies and frameworks that can alter the overall shape of language and cognition, often through cue focusing and bootstrapping (Regier 2005; Smith & Colunga 2003).
4. *Processing emergence*
   The most fast-acting pressures on language form are those that derive from online processing constraints (MacWhinney 2008c). These pressures arise from the limitations of memory mechanisms, attentional focusing, coordination of sentence planning, code switching between languages, and motor control. When bilinguals switch from English to Spanish, the initial moments of speaking in Spanish are still under the influence English neural activation until the alternative Spanish patterns become fully active (Grosjean & Miller 1994). Many of these online pressures are themselves driven by long-term processes. For example, a child's failure to understand the meaning of the word "dependability" in a discussion of the reliability of batteries (MacWhinney 2005a) may be the result of problems in understanding previous classroom and computerized lessons on numerical distributions. Similarly, the failure in lexical retrieval that occurs in aphasia is driven by changes to neural tissue subsequent to a stroke. Thus on-line processing emergence can reflect the status of long-term developmental, neuronal, and physiological processes.
5. *Social emergence*
   Many of the pressures that operate during face-to-face conversations derive from long-term social commitments. Our choice of vocabulary, slang,

topics, and even language is determined by the status of our social relations to the people we meet. We can select particular linguistic options to emphasize solidarity, impose our power, or seek favors. The time course of these social commitments is often measured in years or decades (Labov 2001). Some basic social commitments, including those forced by gender and race, can never be fundamentally altered.

6. *Interactional emergence*
   Apart from our long-term commitments to dialects, languages, and subgroup themes, we also make more short-term commitments to ongoing social interactions. For example, we may engage a real estate agent to help us buy a house. Our linguistic interactions with this agent are then shaped by the status of the buying process. Even after we complete one set of transactions with this agent, we will maintain an ongoing relation that will then shape our further interactions, days or weeks later (Keenan, MacWhinney & Mayhew 1977).
7. *Diachronic emergence*
   We can also use emergentist thinking to understand the changes that languages have undergone across the centuries (Bybee & Hopper 2001). These changes emerge from a further complex interaction of the previous levels of emergence.

With these seven timeframes in mind, we can construct a revised interpretation of the traditional question "Is it innate or learned?" What this question really means is "Across what timeframe does this ability emerge?"

5. Why the paradigm shift?

Given the dominance of emergentist thinking in the biological and physical sciences, one may well ask why the various disciplines studying language have taken so long to explore emergentist accounts. The primary reason for this delay has been the lack of the methodological tools needed to construct and test emergentist accounts. Many of the methods needed to build an empirical basis for emergentism in language studies have only become available during the last decade. We can point to six major methodological and empirical advances that have now made emergentism accessible to wide groups of scientists.

5.1 Corpora

Perhaps the single most important advance in language studies has been the development of web-accessible corpora of language interactions through the CHILDES (Child Language Data Exchange System at http://childes.psy.cmu.edu), TalkBank (http://talkbank.org), and LDC (Linguistic Data Consortium at http://www.ldc.upenn.edu) systems. The CHILDES database provides data on first language acquisition and the TalkBank database (http://talkbank.org) provides data on second language learning. These databases include transcripts of learners' written productions, as well as spoken productions linked to audio and/or video. As these databases grow, we are developing increasingly powerful analytic and computational linguistic methods, including automatic part of speech tagging (Parisse & Le Normand 2000), dependency parsing (Sagae, Lavie & MacWhinney, in press) lexical diversity analysis (Malvern, Richards, Chipere & Purán 2004), and other analytic routines (MacWhinney 2008b).

5.2 Multimedia

The construction of an emergentist account of language usage also requires careful attention to gestural and proxemic aspects of conversational interactions (Goldman, Pea, Barron & Derry 2007). The last few years have seen a rapid proliferation of technology for linking transcripts to video and analyzing these transcripts for conversational and linguistic structures (MacWhinney 2007). Because video can be studied across multiple time frames (MacWhinney 2005b), it is particularly useful for articulating emergentist accounts of language structure and function.

5.3 Neural network models

The rise of connectionist modeling in the 1990s led to the formulation of a wide range of emergentist accounts for language learning. At one time, running these models required days of computation on mainframe computers. Now, researchers have the power of supercomputers on their desktop and these models have become increasingly powerful and accessible. The selection of possible models has also diversified, including important alternatives such as back propagation, self-organizing feature maps, adaptive resonance, and various recurrent networks.

5.4 Imaging

Before the recent period, our understanding of neurolinguistics was dependent primarily on data obtained from brain lesions that produced aphasia. This type of data led researchers to focus on localizing language in specific modules (MacWhinney & Li 2008). However, with the advent of fine-grained localization through fMRI imaging, researchers have been able to formulate emergentist accounts of neural functioning based on the dynamic interactions of functional neural circuits. In addition, it has been possible to use ERP methodology to study competition between languages in second language and bilingual processing (Tokowicz & MacWhinney 2005).

5.5 Neuroscience

Advances in neuroscience have begun to extend our understanding of cognitive function down to the level of individual cells and local cell assemblies. Although this level of detail is not yet available for imaging methods such as fMRI, ERP, or MEG, we are learning a great deal from the study of single cell recordings in animals (Rizzolatti, Fadiga, Gallese & Fogassi 1996) and humans undergoing surgery for epilepsy. This work has emphasized the ways in which the brain encodes a full map of the body, thereby providing support for the theory of embodied cognition (MacWhinney 2008c).

5.6 In vivo learning

Until very recently, it has been extremely difficult to study the learning of second languages in actual classroom contexts. Studies of this process have been beset with problems with random assignment, relevance to educational goals, and poor control of stimuli. However, using new web-based methods (http://learnlab.org and http://talkbank.org/pslc) it is now possible to study students' learning of French, Chinese, English, and Spanish on a trial-by-trial basis as they engage in exercises over the web. These exercises are providing us with direct empirical tests regarding theories such as the Competition Model (MacWhinney, in press) and the operation of graduated interval recall (Pavlik, in press; Pimsleur 1967). We are now able to track whole terms of online student responses during French and Chinese vocabulary training, pinyin dictation for Chinese, tone discrimination, sentence repetition in Japanese and Chinese, article use in English, and the acquisition of other basic skills in second languages.

6. Conclusion

This paper has presented a comparison of two paradigms. The older paradigm of universal grammar (UG) was formulated during the dawn of the cognitive revolution in the 1950s. UG accounts have produced major advances in our understanding of language and the mind. The mechanisms envisioned by this paradigm have focused on the stipulation of rigid modules, symbolic rules, sharp critical periods, and strict genetic determination. Sensing the limitations of this paradigm, researchers have begun to formulate accounts that view language as emerging from dynamic and competitive mechanisms operating across a diverse set of time scales. Recent advances in powerful computation, modeling, corpora, imaging, neuroscience, multimedia, and online instruction have made the construction of emergentist theories increasingly accessible. Using these new tools, students of language processing will be able to build accounts of language learning that are increasingly in line with those developed in the biological and physical sciences.

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