

Swarthmore College

## Works

---

Linguistics Faculty Works

Linguistics

---

Spring 2007

## Language As An Emergent System

K. David Harrison

*Swarthmore College*, [dharris2@swarthmore.edu](mailto:dharris2@swarthmore.edu)

E. Raimy

Follow this and additional works at: <https://works.swarthmore.edu/fac-linguistics>



Part of the [Linguistics Commons](#)

Let us know how access to these works benefits you

---

### Recommended Citation

K. David Harrison and E. Raimy. (2007). "Language As An Emergent System". *Soundings*. Volume 90, Issue 1/2. 77-90.

<https://works.swarthmore.edu/fac-linguistics/15>

This work is brought to you for free and open access by . It has been accepted for inclusion in Linguistics Faculty Works by an authorized administrator of Works. For more information, please contact [myworks@swarthmore.edu](mailto:myworks@swarthmore.edu).

LANGUAGE AS AN EMERGENT SYSTEM

Author(s): K. David Harrison and Eric Raimy

Source: *Soundings: An Interdisciplinary Journal*, Vol. 90, No. 1/2, Emergence Theory (Spring/Summer 2007), pp. 77-90

Published by: Penn State University Press

Stable URL: <http://www.jstor.org/stable/41179192>

Accessed: 04-10-2017 18:46 UTC

**REFERENCES**

Linked references are available on JSTOR for this article:

[http://www.jstor.org/stable/41179192?seq=1&cid=pdf-reference#references\\_tab\\_contents](http://www.jstor.org/stable/41179192?seq=1&cid=pdf-reference#references_tab_contents)

You may need to log in to JSTOR to access the linked references.

---

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact [support@jstor.org](mailto:support@jstor.org).

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <http://about.jstor.org/terms>



JSTOR

*Penn State University Press* is collaborating with JSTOR to digitize, preserve and extend access to *Soundings: An Interdisciplinary Journal*

# LANGUAGE AS AN EMERGENT SYSTEM

*K. David Harrison and Eric Raimy*

**H**UMAN LANGUAGE IS a biological system: All humans are neurologically predisposed to acquire whatever language they are exposed to in their early years. Language itself is socially transmitted. A rich interaction between genetic structures and social learning gives rise to what linguists call a “grammar,” which is the knowledge — part innate, part learned — of language complexity found inside the brain of every speaker. The ambition of linguistics, properly a sub-field of neurobiology in our opinion, is to describe and explain the complex patterns found in all languages. Because this complexity can be shown to arise from simpler underlying components, human language is an emergent system par excellence. The paradigm of emergence set forth in this volume is very well-suited to the study of linguistic patterns on at least two distinct (though interrelated) levels.

Anyone who is familiar with our current scientific understanding of language knows that linguists have only been recently able to formulate good questions about the nature of language. Believing that we have a deep understanding of any aspect of language or any other cognitive function is sheer hubris. Our main goal of this chapter is to demonstrate how the fundamental methods of analysis in linguistics produce and reduce an emergent system. We note that although both authors are phonologists and focus on the sound pattern side of language, all of the arguments we present here hold for the other areas of linguistics including syntax, semantics, sociolinguistics, morphology, and so on. We focus our arguments in the area of phonology both because this is the arena with which we are most familiar and be-

K. David Harrison is Assistant Professor of Linguistics at Swarthmore College, and Eric Raimy is Assistant Professor of English Language and Linguistics at the University of Wisconsin, Madison.

*Soundings* 90.1-2 (Spring/Summer 2007). ISSN 0038-1861.

cause the chain of events from acoustic signals to lexical access which is covered by phonology is the best documented, and the basic cognitive components such as phonemes and syllables are well understood.

The fact that classic linguistic analyses such as those by the Prague School (for example Trubetzkoy, Jakobson and Halle among many others) are emergent approaches has only been recently acknowledged. Contemporary work represented by Juliette Blevins and Andrew Wedel reveals the full complexity of the independent forces that combine to shape both diachronic and synchronic aspects of language. The key aspect of these approaches is their emergent flavor; they favor explanations of complex phenomena where simple independent forces interact to account for the complexity. As part of this methodology, we are constantly attempting to jettison stipulated constructs if these can be derived more simply from the interaction of independent forces. In our mind, this is the core tenet of emergentism, and accounts for much of its explanatory appeal. It must be noted that this philosophy of emergence is by no means a new idea or approach and, as far as we can tell, derives from Occam's Razor which suggests that simpler solutions are to be favored when all other things are equal among the alternatives.

The fact that most contemporary linguists do not recognize themselves as practitioners of emergence is, in our opinion, very revealing about the role of emergence thought in our understanding of the world and human behavior. As papers in this volume of *Soundings* indicate, emergence cannot and should not be associated with a single field of study or a particular methodology. One specific aspect of our claim here is to note that emergence is not about using connectionist modeling or other specific approaches. Emergence is more about a philosophy of simplicity in analysis, a philosophy that can be found throughout history and for linguistics at least since the fourth century BC in the works of Panini the great Sanskrit grammarian. Consequently, we do not believe that emergent approaches to any phenomena will provide any arguments to distinguish between connectionist and classic Artificial Intelligence approaches to cognitive science.<sup>1</sup>

We view the benefits of emergent approaches to phenomena as a guiding principle that forces investigators to question

whether any complexity that is observed can be better understood as the result of interaction of simpler parts as opposed to some monolithic primordial complex entity. Part of this methodological approach is inherently reductionist in that any entity that can be derived from general principles or the interaction of other entities should be jettisoned. Radical reductionism as practiced by some connectionists is not justified as a useful interpretation of emergence, however, because it runs afoul of the second clause of Occam's Razor which requires all things to be equal when invoking simplicity to eliminate some entity. If the elimination of an entity reduces our understanding of the phenomenon itself or makes the analysis empirically inadequate, then the entity should be kept.

What follows is our particular view of how emergentism benefits and can benefit from our contemporary understanding of language and language acquisition. Although the historical chain of thought is not continuous, this view summarizes our particular synthesis and culmination of linguistic analysis of sound patterns from Panini, through the classic European historical linguists such as Wilhelm von Humboldt, Ferdinand de Saussure's formulation of *langue* and *parole*, the American Structuralists (Sapir, Bloomfield, etc.), to the Prague School (Trubetzkoy, Jakobson, and Halle), and contemporary generative phonology (see Chomsky, Chomsky and Halle, Halle and Vergnaud, and Kenstowicz). Please note that we recognize that our intellectual parents disagree with each other about many things and that our views, for better or worse, should be recognized as unique to ourselves, although we do believe that many linguists agree on many of the points we discuss.

#### LANGUAGE ACQUISITION

Language learners, beginning from birth and on through the language-learning years up to age seven or so, are confronted with massive amounts of complexity but never seem to assume that they must memorize verbatim all the linguistic forms that they hear. They will go for the abstract representation rather than the most direct, literal one. Thus, they never encode in their brain the world exactly as it occurs but rather assume the complexity they hear arises from an interaction of simpler underlying mechanisms.

We attribute this to the fact that the language faculty of the human brain contains statistical pattern detectors focused on analyzing language. Children are statistical virtuosos, and in acquiring language, they are able to map surface complexity of speech forms onto a more abstract set of representations to be memorized. Once they have the right abstract representations in their brain, speakers have achieved competence, the ability to both parse and generate limitless numbers of completely novel words, phrases, and sentences.

Our empirical research program seeks to infer what types of statistics the language faculty is able to compute and over what kinds of representations it computes them. Once we have useful answers to these questions, we can begin to find out whether the statistical pattern detectors or the representations computed are unique to the language faculty, or more general-purpose. To demonstrate this view of the human language faculty, we will discuss how emergent patterns in the pronunciation of different morphemes, pairings of a sound and meaning into an atomic unit stored in long term memory such as the plural suffix “-s” in English, are part of the process of language acquisition in Tuvan, a language spoken in central Siberia (see Anderson & Harrison, Harrison). Our analysis extends to all human languages.

Our research agenda makes a contribution to the understanding of emergence because we consider abstract symbolic representations which are normally eschewed in emergent analyses. We see no conflict of interest between emergence and symbolic representation because of complex surface patterns of data that are produced and accounted for in our analyses. As we discuss below, language acquisition provides excellent examples of how simple symbolic generalizations can interact to produce emergent phenomena.

#### EMERGENT PROPERTIES OF MORPHOLOGY

Suffix morphemes in Tuvan are an example of the type of surface complexity confronting language learners. Some morphemes exhibit allomorphy, a chameleon-like quality in which they take on different pronunciations to match different environments. In other words, a morpheme that is memorized as a single entity in the mental lexicon may assume one of multiple different related pronunciations when a user actually utters the mor-

pheme. The task for the learner confronted with a suspected case of allomorphy is to decide whether there is just a single morpheme to be memorized (with its chameleon-like behavior accounted for by general rules of the language) or many distinct ones to be memorized separately. The decision is aided by speakers' general knowledge of sound patterns, and of how sounds affect other sounds when they appear in a particular environment. We argue, however, that it is the underlying pattern detection component of the language faculty that forces learners to do so. The system needs to derive abstraction from complexity so that a language, with its infinite combinatorial possibilities, can be stored in a finite brain.

Two suffix morphemes in Tuvan, a plural and an adjective marker, will illustrate this process. The plural suffix, added to nouns, has eight distinct allomorphs as presented in (1) (the suffix is italicized and set off by a hyphen for clarity).<sup>2</sup>

(1) Tuvan plural suffix with eight allomorphs

Noun + plural suffix	meaning
teve- <i>ler</i>	"camels"
ulu- <i>lar</i>	"dragons"
xep- <i>ter</i>	"clothes"
at- <i>tar</i>	"names"
xerel- <i>der</i>	"sunbeams"
aal- <i>dar</i>	"campsites"
xem- <i>ner</i>	"rivers"
xam- <i>nar</i>	"shamans"

The Tuvan adjectival suffix presents even greater complexity, with sixteen allomorphs (2).

(2) Tuvan adjective suffix with 16 allomorphs

teve- <i>lig</i>	"having a camel"
börü- <i>lüg</i>	"having a wolf"
ada- <i>lyg</i>	"having a father"
ulu- <i>lug</i>	"having a dragon"
xep- <i>tig</i>	"having clothing"
üş- <i>tüg</i>	"having three"
ât- <i>tyg</i>	"having a horse"
quš- <i>tug</i>	"having a bird"
xerel- <i>dig</i>	"having a beam of light"
xöl- <i>düg</i>	"having a lake"
aal- <i>dyg</i>	"having a campsite"
mool- <i>dug</i>	"having a Mongol"
xem- <i>nig</i>	"having a river"
xöm- <i>nüg</i>	"having leather"

xam-nyg  
qum-nug

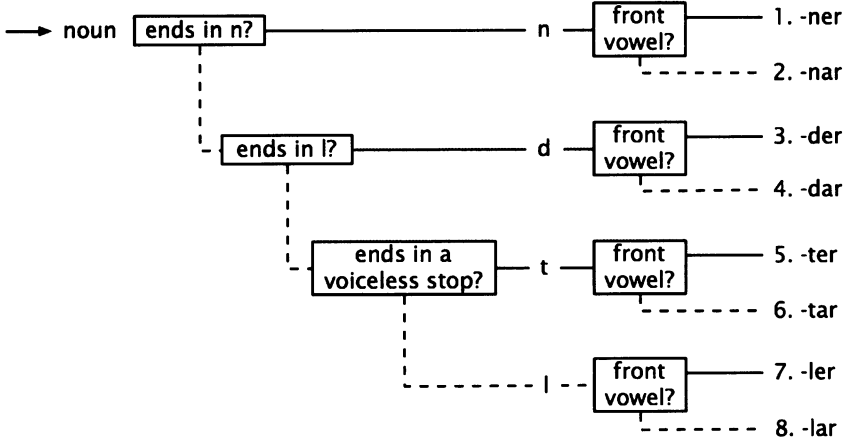
“having a shaman”  
“having sand”

What do Tuvan children learn when they encounter the sets of allomorphs in (1) and (2)? Although there are many different allomorphs of the plural and adjectival suffixes in Tuvan, learners do not have any problem in producing them in appropriate environments, nor in understanding that any and all of the allomorphs for plural and adjective have exactly the same meaning. Now we can sharpen our question: We can ask whether learners make any generalizations about the distribution of allomorphs. Do they commit to memory eight distinct forms of the plural in (1) with generalizations on what type of noun should occur with each allomorph? Or do they form a more abstract generalization?

The key to the distribution of the allomorphs in (1) and (2) is that the suffix is predictable based on the phonemes (speech sounds) of the noun. We assume that this predictable aspect is statistically highly salient and thus readily identifiable by the learner. In a first pass of encoding, the predictability of the allomorphs for the plural and adjective suffixes in Tuvan can be represented by the decision trees in (3) and (4)

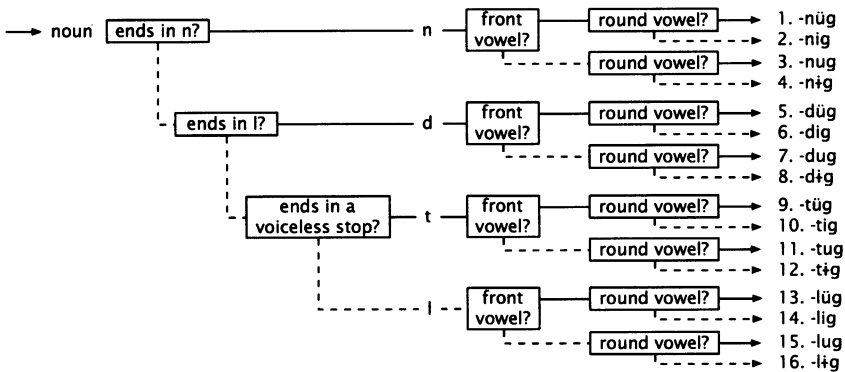
The decision tree for plural allomorphs in (3) encodes a generalization about the distribution of these allomorphs. The learner assumes eight distinct allomorphs, and must then decide how to select an allomorph to use with a given noun. The tree illustrates this decision process. Beginning from the left edge, the first branch queries whether the noun ends in a nasal sound (that is, with an “n” or “m” for the data set in (1) and (2)). If “yes,” then the learner has narrowed down the possible allomorphs to either #1 or #2. The next query is about the last vowel in the noun. If it is a front vowel (i, e, ü, or ö), then the learner selects allomorph #1 in (3) which is “-ner,” and if it is not a front vowel, then allomorph #2, “-nar,” is selected. The decision tree leads to the correct plural allomorphs out of eight possibilities, with a solid line indicating a “yes” answer to a decision box and a dashed line indicating “no.”





(3) Decision tree for Tuvan plural suffixes

The decision tree in (4) for the adjective suffix works in the same manner and produces the correct surface distribution of all sixteen allomorphs.

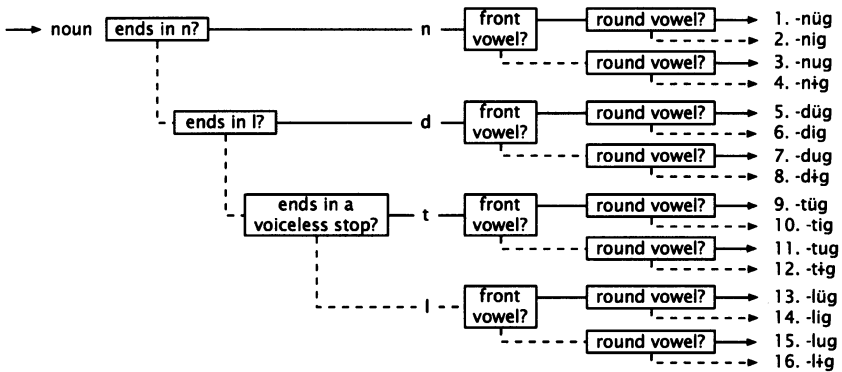


(4) Decision tree for Tuvan adjective suffixes

Although the decision trees in (3) and (4) represent enough information to predict the occurrence of the different allomorphs on different nouns, we do not believe the learner stops here. An important characteristic emerges if we consider the content of the two decision trees in (3) and (4). Within the decision trees themselves, there are deeper patterns that learners can detect. We see these patterns as informational redundancies in the trees. For example, the plural decision tree in (3) is wholly contained within the adjectival decision tree in (4). The only difference be-

tween the two trees is the additional bifurcation based on whether the vowel in the noun is round, that is, u, ü, o, ö, or “non-round” such as i, y, e, a vowel. This bifurcation occurs in the adjective tree but not the plural tree and the learner takes this distribution as evidence to extract the roundness sub-tree as a separate generalization.

The remaining decision tree, consisting of the consonant and front vowel decisions, can be further analyzed if we consider that Tuvan also has other suffixes which change their vowels but not their consonants. The possessive (3rd person) suffix in Tuvan has four allomorphs: /i/, /y/, /u/ and /ü/. For example, “*nom*” means “book” and “*nom-u*” means “his book.” Based on this extra information, the learner can separate the consonant decision from the front vowel decision. This last extraction provides the three decision trees that will generate all of the thirty-two possible forms of the plural, adjective, and possessive suffixes in Tuvan.



(5) Three decision trees for Tuvan: (a) consonant decision, (b) vowel frontness decision, (c) vowel roundness decision.

At this point, there are no further patterns to be extracted from the decision trees. The generalizations are as simple as possible, and this result has been driven by the statistical analysis of patterns in the data. There are two interesting aspects of this current situation. The first is that the three decision trees coincide with a traditional linguistic analysis of Tuvan as having three distinct phonological processes of “consonant dissimilation,” “backness harmony,” and “roundness harmony” (see Harrison, Anderson and Harrison). Each of these three processes is consid-

ered to be phonological and not morphological because the queries in each decision tree only refer to the sounds found in the noun to which the suffix attaches. The consonant dissimilation decision tree affects only the sound /l/ in Tuvan. The roundness harmony decision tree affects only the set of high vowels in Tuvan, while the backness decision tree affects all vowels in Tuvan. At this point, we can understand how the learner identifies the allomorphs for the plural and adjective suffixes in (1) and (2) as chameleons. The patterns that can be extracted from the distribution from these allomorphs do not coincide with lexical or morphological information. Indeed, the patterns range over the entire distribution of sounds in Tuvan. Because the pattern is not restricted to a particular word or morpheme, the learner need memorize just one of the surface allomorphs for the plural and adjectival suffixes. She may then allow the decision trees in (5) to modify the memorized morpheme to match specific sound environments.

A second interesting aspect of the decision trees in (5) is that relatively trivial transitional probability-based statistics are the only thing needed to identify these generalizations. It is well documented that infants as young as eight months are able to calculate transitional probabilities (see Aslin, Saffran, and Newport). So we are confident that we are not making unreasonable claims about the statistical abilities of humans. One aspect of statistical learning that is often glossed over, but which we feel is crucial to our analysis of Tuvan, is the question of what is done with the statistical knowledge gained by the learner. Statistical knowledge is useless in building words unless a decision is made based on it. We believe that the statistical analysis of the distribution of the plural and adjective suffixes in Tuvan provides the basis for decision-making. The learner makes sensible decisions about what to memorize as the underlying, mental representations for the morphemes in question and what phonological processes are present in Tuvan. Although the statistical analysis provides the source of the knowledge about the distribution of allomorphs in Tuvan, the learner makes a decision about whether to memorize a static representation or not. The static generalization based on a statistical decision encoded in the speaker's long term memory characterizes the speaker's grammar, not the statistics themselves.

The decision process aspect of statistical learning is the key, in our opinion, to understanding how and why we see complexity generated from simplicity in emergent systems. The language learner begins the task awash in the complex surface data of spoken language. At first, the only available option is to do raw statistical analyses. After sufficient statistical analysis, patterns emerge and the learner can decide which patterns merit generalization and which patterns do not. The positing of generalizations from the initial statistical parse of the data feeds back into the system to provide the learner with more information with which to work. Posited generalizations can be modified based on additional data and can be statistically analyzed as a source of new and ever more abstract generalizations. The overall effect of this feedback cycle of analysis and decision-making is the production of simpler and more parsimonious generalizations. The simplification of generalizations is a necessary condition for a statistical-based learning algorithm to be useful. If there is no pattern in the statistical distribution of a set of data that can be generalized in a manner that is simpler than the distribution of the data itself, then there is no motive to posit that generalization. Thus, any memorized generalization must be simpler than the distribution of the data itself. This generalization condition will hold over the entire cycle of statistical analysis, and one possible reason to stop the analysis is that there are no longer any patterns in the data that are simpler than the distribution of the data itself.

#### HUMAN LANGUAGE AND EMERGENCE

Human language provides an excellent source of naturalistic data from an emergent system. We hope our brief sketch of language acquisition and allomorphy in Tuvan suffixes has been helpful in demonstrating this point. For readers not familiar with analytical methods in linguistics, there are three main points that must be understood about the nature of this example.

The first is that the analytic method that we used breaks down the surface complexity of the suffixes (having 8 and 16 allomorphic forms, respectively) into the memorization of just two distinct morphemes, that is, one used to make the plural and one used to make adjectives. These memorized forms are deployed by using three generalizations (what linguists call “generative rules”) which dictate the exact consonant and vowel that must

appear appears in the suffix. Such generative rules have been used as a basic tool of linguistic analysis for the last 6000 years. The work of Panini, the great Sanskrit grammarian of the 4th century BC, is held in such high regard because of his thoroughness and especially due to his elegant and simple summaries of generative patterns in Sanskrit grammar. If we fully understand the importance of this observation, we can see that linguists have been practicing emergentism since at least Panini. A corollary of this is that none of the contemporary trappings of emergence such as computer modeling or connectionism are necessary components of emergent analyses. This latter point explains why so many different fields of study can benefit from adopting emergent analyses, as evidenced by this special issue of *Soundings*.

The second point emphasized in this article is that natural human language provides an exemplary source of emergent phenomena to be investigated. Because the study of human language as a system (not individual languages) has been conducted since the beginning of recorded history, we have amassed a large but still incomplete amount of knowledge about language. We should not be overconfident with this knowledge, but it does allow us to ask better and more focused questions about language. When we take a step back and consider all of the different questions that we can generate about language itself, it is very clear how an emergentist methodology has improved our questions. It has led us to query how language exists in our brains and what language tells us about culture and identity. We must be careful with language though because it is also the source of the expert illusion (see Minsky), the illusion that since we use language everyday in an effortless manner, we have a good understanding of it. The rote plodding of the analysis of the Tuvan morphology example demonstrates only the most minimal amounts of the complexity in the simple act of pronouncing a word. The complexity of language immediately appears once we ask the question of how some part of it works or why a particular language, or word or construction is the way that it is. Linguistics as a field of study has spent thousands of years falling down the rabbit holes of language and mapping the paths of questions and answers that have been investigated. We believe that this store of knowledge has not been fully taken advantage of by language investigators of all types, including linguists. The lack of familiarity with

the actual achievements of linguistics as a unique field of study stunts any inquiry into the nature of language. We also believe that a similar state of affairs holds for studies of emergence, because in the worst case linguistics will provide a “null hypothesis” to disprove about the nature of language and in the best case linguistics will shape better informed and more well focused questions about language.

Finally, as our third and final point we would like to call attention to the most radical emergentist proposal about the nature of language that we are aware of. Chomsky, Hauser, and Fitch argue that the defining characteristic of human language is the computational process of recursion. The core of this proposal is that “narrow language faculty” which is unique to the species *homo sapiens* is recursive in that it can freely combine smaller elements into larger ones in an infinite manner only limited by non-linguistic environmental constraints on human beings such as time, attention span, memory, fatigue, and so forth. This idea shows the full potential and spirit of emergent approaches to phenomena. The potential of emergentism in this proposal is apparent in that, if it is correct (which is by no means a settled matter), then the understanding of emergent systems will be key to our understanding of human language and vice versa. The spirit of emergentism is also indicated by this work because of its interdisciplinary nature. The authors combine the fields of linguistics, psychology, organismic and evolutionary biology, and biological anthropology to produce a very broad view of language from an emergentist perspective. True emergent studies are inherently cross-disciplinary.

It must be understood that we are assuming that the required statistical analysis mechanisms and decisions that underlie the discovery of the relevant decision trees are present in the brain, without yet knowing the full details of these mechanisms. Upon which cognitive representations statistical analysis is performed, and what decision processes exist for positing generalizations, remain some of the most important questions to be addressed, not only for linguistics but for the cognitive sciences as a whole. Our contribution to the application of emergence thought to language is to show that this is a promising avenue of inquiry.

We hope our brief sketch of the acquisition of complex sound patterns has been helpful in exhibiting how human language is

an emergent system. We understand human language and emergence to exist in a symbiotic relationship. Thus, the study of the structure of human language provides excellent naturalistic data from an emergent system. Further, the study of emergent systems, in language or any other domain, may lead to deeper understanding of the structure of human language. In this sketch, we have identified specific and general questions about both human language and emergence that should be pursued further. We hope this chapter brings some clarity as to why these are important questions and suggest useful ways to pursue them. Many of the questions posed by this chapter directly benefit from other work on emergence presented in this volume. By understanding the contributions of emergence to computer science, philosophy, neurobiology, economics, and many other disciplines, we can achieve a fuller understanding of human language as an emergent entity.

## NOTES

1. Here is a useful description of the difference between Classic Artificial Intelligence and Connectionism:  
Classic AI is viewed by many as represented by 'computationalism' which focuses on symbol manipulation based on the metaphor of a digital computer as the best way to understand mental processes while connectionism is viewed by many to focus on developing associationist models of mental processes but note these distinct views are not necessarily incommensurate. ("Connectionism")
2. Note that the Tuvan words are presented in phonetic transcription. Consonants are generally similar in pronunciation to English orthography except for "x" which is a sound not found in English, but represents a voiceless velar fricative, the sound at the end of "Johann Sebastian Bach" with a German pronunciation. The vowel symbols have the following pronunciations, [e] as in "bet", [a] as in "hot," [u] as in "boot," [ö] is similar to German *schöne*, and [ü] to German *Würde*. The symbol [y] represents a high back unrounded vowel as found in Russian or Turkish. Doubled vowel symbols represent long vowels.

## WORKS CITED

- Anderson, Gregory D. S. and K. David Harrison. *Tyvan*. München, Germany: Lincom Europa. 1999.
- Aslin, Richard N., Jenny R. Saffran and Elissa L. Newport. "Computation of conditional probability statistics by 8-month-old infants." *Psychological Science* 9.4: 321-324. [July].
- Blevins, Juliette. *Evolutionary Phonology: The Emergence of Sound Patterns*. Cambridge: Cambridge University Press. 2004.
- Chomsky, Noam. *The Logical Structure of Linguistic Theory*. [1955]. New York: Plenum Press. 1975.
- . *Morphophonemics of Modern Hebrew*. [1951]. New York: Garland Publishing. 1979.
- and Morris Halle. *The Sound Pattern of English*. Cambridge, MA.: MIT Press. 1968.
- , Marc Hauser and Tecumseh Fitch. "The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?" *Science* 298.5598. 1569-79.
- "Connectionism." *Wikipedia*. 2007. 11 December 2007 <<http://en.wikipedia.org/wiki/Connectionism>>
- Halle, Morris and Jean-Roger Vergnaud. *An Essay on Stress*. Cambridge, MA.: MIT Press. 1987.
- Harrison, K. David. *Topics in the Phonology and Morphology of Tyvan*. Doctoral Thesis. Yale University. 2000.
- Humboldt, Wilhelm von. *Über die Verschiedenheit des menschlichen Sprachbaus und seinen Einfluss auf die geistige Entwicklung des Menschengeschlechts*. [1836]. Translated as *On Language. On the Diversity of Human Language Construction and Its Influence on the Mental Development of the Human Species*. Cambridge: Cambridge UP, 2nd rev. edition. 1999.
- Jacobson, Roman and Morris Halle. *Fundamentals of Language*. New York: Mouton de Gruyter. 1956.
- Kenstowicz, Michael. *Phonology in Generative Grammar*. Cambridge, MA.: Blackwell Publishers. 1994.
- Minsky, Marvin. *The Society of Mind*. New York: Simon and Schuster. 1985.
- Trubetzkoy, Nikolai. *Grundzüge der Phonologie. Travaux du cercle linguistique de Prague* 7. [1939]. Translated as *Principles of Phonology*. Berkeley and Los Angeles: U of California P. 1969.
- Wedel, Andrew. "Feedback and Regularity in the Lexicon." *Phonology* 24.1: 147-185.