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Hooked on Language*

William S-Y. Wang
Academia Sinica
Chinese University of Hong Kong

This is an informal, quasi-biographical essay, tracing aspects of my experience as a linguist, from exposure to foreign languages in childhood to current research on evolutionary linguistics. My intellectual journey has been from the narrow 'autonomy' of generative grammar, with its focus on formalisms, to a broad evolutionary perspective, merging with other disciplines concerned with language, both ontogenetic and phylogenetic.

Key words: evolutionary linguistics, lexical diffusion, tones, modelling

I came across an interesting collection of essays the other day, called *Curious Minds: How a Child Becomes a Scientist*.[1] It contains self-reports by a variety of distinguished scientists on the formative influences in their lives, to become an anthropologist, a physicist, a psychologist, a journalist, etc. Reading these personal histories started me reflecting on how I became hooked on language, and devoted my professional life to it.

As we must all recognize, memories are infinitely fallible. For this reason, Steven Pinker begins his essay with the charming request: 'Don't believe a word of what you read in this essay on the childhood influences which led me to become a scientist. Don't believe a word of what you read in the other essays, either.' [p.81] Nonetheless, he went on to give a fascinating account of the events that led to his prolific scholarship in psycholinguistics.

Several authors recounted the early and decisive formative influence of family life, particularly Alison Gopnik, the other psycholinguist in the collection. The environment of my own early years in Anhui could not be more different from the highly intellectual home she described for her childhood. Huaiyuan in the 1930s was a small town in interior China, and I have essentially no memory of it, even though my early childhood

* I offer these personal musings to join in celebrating the 70th birthday of Professor Ting Pang-hsin, who has my respect as a devoted scholar, and my affection as an old friend.

1 Brockman, J. (ed.) 2004. *Curious Minds: How a Child Becomes a Scientist*.

was spent there. Since I was by far the closest to my grandmother throughout my early years, my first language must have been some local variety of the Anhui dialect.

By the time I was eight or so, Anhui had fallen under Japanese occupation. My parents were in Shanghai then. Since life in an international city was presumably safer than a village under Japanese rule, they sent for us. The journey from Huaiyuan to Shanghai was a dangerous one. One of my earliest distinct memories is one of my grandmother gathering me under her, using her body as a shield, when the sky was covered with war planes and with mushrooms of anti-aircraft fire.

We lived in the so-called French Concession in Shanghai, so I must have heard some French. Half a block from us was a complex that used to be the International School, but the Japanese had taken it over for military use. Like many kids my age, we spoke varieties of Putonghua in school and at home, and Shanghainese among peers and on the street. The Anhui dialect was kept alive for many years only by my bond with my grandmother.

Shortly after the Japanese surrendered in 1945, my father, who had studied at Berkeley in the 1930s, went to New York City in search of a new life for us. In 1948, we went to join him there, sailing across the Pacific in some twenty days. The last few months in Shanghai, my family found a kindly old Yugoslavian lady to tutor me in English. Nobody knew, of course, that her English was far from typical, or whether she had ever heard much English spoken herself.

So essentially I had to learn English from scratch after we arrived in New York. At age 15, I had already passed the so-called 'critical period', though I am not sure this hypothesis for language acquisition is either as simple or as strong as some psycholinguists advocate.[2] While I can sound 'native' in English when I try, it takes some effort, even after speaking it for several decades. It is especially effortful when I am tired. On the other hand, my growth in the Chinese language was stunted with the transplantation, since I had left its environment. I don't really know if there are people who are truly completely proficient in two or more languages.[3] In my own case, I always deal best with numbers in Chinese, particularly in remembering them or in multiplying them. In matters academic, however, it is much more natural to use English since that is the language I work in.

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[2] Language is clearly not the only thing that can be best learned at an early age; age dependence is true of learning mathematics, music, and sports as well. Furthermore, language has many components: motor, sensory, memorial, computational, etc. It appears that the motor component, as is most age dependent, as in many athletic skills. Failing to master good pronunciation inhibits practice, which in turn hinders the learning of grammar, vocabulary, and pragmatics.

[3] Rather than 'bi-lingual', implying complete proficiency in both languages, perhaps 'semi-lingual' is more accurate since neither language has complete coverage.

My entire family returned to China in 1951. Uncertain of the situation there, particularly since it was during the Korean War, my father wanted me to stay behind to take advantage of a generous four-year scholarship I had just won in order to attend Columbia College. The plan sounded rational enough, but it had not taken into account the emotional turmoil in a 17 year old boy having to survive New York City completely alone. My first report card had mostly F's; one notable exception was an A-, but that hardly counted since it just showed that I had made the junior varsity team in fencing. I remember well being called in by the dean, who had no hesitation taking away my scholarship and throwing me out.

It was out of the question for me to return to China in such disgrace, even if the political situation had allowed me to, which it did not. But I persisted in my education by taking evening classes in the School of General Studies of Columbia University. Day time I had a job with the Brass Rail restaurants, basically as an apprentice book-keeper.

By then, I had developed a strong curiosity about language. One day shortly after we started school at Columbia, I went to lunch with some fellow freshmen. It was a working class Chinese restaurant with a gruff waiter in a dirty, oily apron. Remarkably, the menu was a matrix printed on a sheet of paper, where the rows are labeled by the meats and the columns are labeled by the vegetable to be stir-fried with the meat. After several unsuccessful bids in Putonghua, with the waiter barking at me in some sort of Cantonese, I had to order for everyone in English. This prompted one of the fellows to ask why Chinese people do not speak Chinese with each other. I was both embarrassed and offended by this innocent question, but I was not able to give a coherent response. I certainly wished that I could.

Both of the evening classes I took were in linguistics, and their instructors could not have been more different. Mario Pei was a giant of a man, impeccably suited, with a *phi beta kappa* key dangling from a gold chain. When he announced to the overflowing classroom, in a voice that boomed with authority, exactly how many languages were spoken in the world then, we were all awed by his erudition. Far be it for anyone to wonder how he arrived at such precise knowledge for something as fuzzy bordered as language, and in a world where many regions were still largely unexplored. He took a special liking to me and invited me to co-author a small piece with him in the Sunday magazine of the New York Times; it was on Chinese place names—my first publication.

The other class was taught by a young disheveled instructor who spoke with a very thick New York accent. There were perhaps seven of us in a room that holds at least forty. He rushed in late, distributed a very hefty hand-out of data from a bunch of African languages, and directly launched into a discussion of the comparative method. Even then, in the 1950s, Joseph Greenberg already had some stellar achievements in the classification of the languages of Africa. The fundamental contributions he was going to make in the areas of typology, markedness, language universals, and deep comparisons were yet to come. It was many years later, after Joe had moved to Stanford and I had gone to Berkeley, that I was able to resume learning from him.

Columbia College decided that my repentance was genuine and took me back a semester later. This allowed me to graduate in time, with a hodge-podge of courses in engineering and social sciences. For the foreign language requirement, I took some courses in Japanese—and wished I had not avoided the language so deliberately when I was in occupied Shanghai. My memory of these courses is much sweeter for the instructor, Shirato-sensei, who had that special combination of warmth and strictness. I was able to also squeeze in a summer at the Russian School of Middlebury College in Vermont, and derived great joy memorizing the sonorous poems of Lermontov and Pushkin.

Other languages I studied to varying extents at different times are: French [several weeks at the Alliance Francaise in Paris], Swedish [I was based in Stockholm for a year], and Swahili [in a course I co-taught at Ohio State University]. I also learned enough German to pass a reading exam at the University of Michigan, but somehow that experience left very few traces in my long-term memory. From the opposite perspective, I taught English to foreign students at the English Language Institute at the University of Michigan, and introductory Chinese at the Ohio State University. Language learners are a heterogeneous lot, and it would be foolhardy to say that some one method of language teaching works best for all. Clearly, all the high-tech language teaching aids are dazzling, and can be very useful on the side. But I am old fashioned enough to believe that there can be no substitute for the kindness and devotion of a teacher; nor can anything replace the sheer labor of memorizing some beautiful poem or catchy songs, and the immense satisfaction that comes with its recall many years later.

By the time I was accepted into the Linguistics Program at the University of Michigan, I felt essentially committed to the field in a kind of natural progression. I have always assumed that I would work in a university, and linguistics is a field that allows the coming together of a variety of activities, from tinkering in a laboratory, to visiting aphasics in hospitals, to trekking off among speakers of strange languages in exotic worlds, etc. More than anything, I was simply hooked on how various languages sound, and how they enable/require you to see and represent the world in diverse and interesting ways.

At Ann Arbor, I had the good fortune to work in the laboratory of Gordon Peterson, a leading scholar of acoustic phonetics. The striking mismatch between hearing people speak in clean discrete words and seeing these words in continuous shaded smudges on the sound spectrogram made a deep impression on me. It is evident from this mismatch that the brain requires a tremendous amount of knowledge and computation to be able to convert the smudges to words—to recognize speech. My awareness of the cognitive prerequisites for language probably traces back to these spectrograms.

In the 1960s, it did not take long to realize that programming a computer to recognize speech without making good use of this fund of knowledge was a foolhardy enterprise. Now, half a century later, the awesome power of computation, coupled with newly developed methods of statistics, especially the Hidden Markov Models, have made that goal of automatic speech recognition somewhat more plausible. Nonetheless, the computer is still quite a chasm away from what the humblest human can do in recognizing speech, particularly in conditions of noise, notably the so-called 'cocktail party' environment.

Similar lessons apply to the area of automatic language translation. Again, saying something in English and saying the corresponding something in Chinese involves much more than finding dictionary equivalents and giving a different sentence parsing. The cognitive prerequisites for language translation are, if anything, much more extensive than they are for speech recognition. There is a colorful phrase in Italian: 'traduttore, traditore!'—to translate is to betray—which captures the nature of the difficulty quite well.

When I was nearing the end of writing my dissertation, I wanted to get a deeper grounding in general linguistics, as well as to brave the world outside of Peterson's warm laboratory. I was impressed by the work of Zellig Harris of the University of Pennsylvania, and wrote him about opportunities to study with him. *Syntactic Structures*, written by his student Noam Chomsky, had just been published, and it struck me as an exciting area to explore; so I wrote to M.I.T. as well. Perhaps by some quirk of fate the letter never reached Harris; in any case I never heard from him. In contrast, a very friendly letter came back promptly from Morris Halle, offering me a post-doctoral fellowship at the Research Laboratory of Electronics, working in a group directed by Ken Stevens of the Department of Electrical Engineering.

Morris was working with Chomsky on *Sound Pattern of English* at that time, and with Stevens on distinctive features associated with glottal behavior. My curiosity about tones came into focus around then. I also read some syntax. A question that was always with me was how much of this theoretical apparatus being developed so aggressively at M.I.T. was useful for understanding languages other than English, and for understanding human language in general. But back then, I had little feeling of the total complexity of language, in time and in space, and I was all too ready to be dazzled by slick rules and clever arguments. I had all the zeal of a new convert, and was eager to spread the word of generative grammar, at least the 1960s version of it.

An early antidote to this zealous attitude came from Greenberg. I had just published[4] a fancy rule of tone sandhi in the Min dialect of Chinese, which had won the seal of approval from the M.I.T. establishment.[5] The tones in this dialect chase each other in a circle when in sandhi position, and I was able to describe this circular movement by proposing a set of phonological features of tone and attaching variables on a pair of these features. Some months later, I exploited the same formal device in describing the Great Vowel Shift in the history of English.[6]

I was bursting with pride when I showed this tone sandhi rule to Greenberg when we met at a conference. He listened to me attentively, and muttered something soothing like 'very nice'; then he asked me 'and then what?' I was crestfallen at this response from my first teacher; but I was not able to understand what he must have had in mind for many years to come.

To put it in terms I now use, the rule I proposed was a solution to a *local* problem —one of tone sandhi. To achieve significance, my work should have been couched within a series of *global* considerations, beyond the rule formalism that I was playing with. Does the rule, or any part of it, tell us anything about the history of Min dialects in general? Or, more globally, does the rule reflect anything about the underlying cognitive process, any more than a simple verbal account of what the tones are doing? The 'success' in rule formalism, in this case the paired variables, gave me a false sense that the job has been done, side-tracking me from pursuing the deeper empirical questions of history, cognition, etc.

A related way of looking at the question of how to do research is via the interplay between state and process. Descriptive linguistics, structural linguistics and generative linguistics all tend to concentrate on the state, paying scant attention to the various processes that led to the state. Yet often studying the process is the best way toward understanding the state, as clearly shown in the work of Greenberg. I became dimly aware of this relation when I was looking at the development of MC tone IV. In many Min dialects, IVv[7] has a ***higher*** pitch than IVu, contrary to what is found in other Chinese dialects. Phonetic considerations would lead to the opposite expectation, since voiced initials typically lower the pitch of the voice.

A reasonable assumption for such a flip-flop in tonal development is that the pitch of IVu was originally high and that of IVv was low. If so, IVu must have gone down in pitch while IVv went up. According to the prevailing conception of sound change,

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4 *International Journal of American Linguistics*, 1967.

5 The tone paper was cited in the *Sound Pattern of English.*

6 *Language*, 1968.

7 I use Roman numerals in correspondence with the traditional Chinese names of ping, shang, qu and ru, followed by u and v in correspondence with the traditional Chinese names of qing, zhuo, or yin, yang.

inherited from the Neogrammarians of the 19th century, the words of a particular sound class always changed ***en bloc***; this is, sound change is lexically abrupt. But then the question arises as to how the two blocks of syllables could have passed each other on the pitch scale without colliding into each other and merging, resulting in just one class, i.e., IV. The sound change, I hypothesized, may have been implemented several words at a time; that is, lexically gradual. Pursuing this line of thought, I came up with various other considerations that led me to conclude that the scenario of lexical gradualness must be correct, for at least a large class of sound changes, if not all of them.

I chatted about these musings with Yakov Malkiel in the hallway of Dwinelle Hall, some time around 1967. He gave me an encouraging smile, and suggested the term 'lexical diffusion' for the hypothesis. It was somewhat later that I read a little into the literature of Romance Linguistics, an area much more hospitable to this way of thinking than classical Indo-European Linguistics. In fact, Yakov himself has just published a short essay on a very similar theme.[8]

Given such a view of the process of change, there will be words which lead the change, words which lag behind, as well as words which have both the changed and unchanged pronunciations. So a change is characterized by a three stage process of UVC, U for unchanged, V for variation, and C for changed, whether the innovation is in the system of sounds, meanings, word formation, or syntactic patterning. This view of change predicts that all living languages will always exhibit a considerable amount of 'orderly heterogeneity', a very useful term introduced by Weinreich, Labov and Herzog.[9]

The view is also consistent with what evolutionists say about changes in the biological world, how variations result from innovations, and how only a few innovations are selected in the transmission across generations. In fact, Darwinian thinking was frequently in the back of my mind when I mused about language evolution. No one is foolish enough to believe that language evolution and biological evolution are exactly alike, but clearly there are many significant parallels between them, as Darwin himself repeatedly noted in his writings. In fact, it may very well be that there are useful parallels with the evolution of physical and social systems as well, as recent thinking on complex adaptive systems seems to suggest.

With the exception of a handful of scholars who were willing to consider it constructively and objectively,[10] the hypothesis of lexical diffusion first met with

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8 Malkiel, Yakov. 1967. Each word has a history of its own. *Glossa* 1:137-149.

9 Weinriech, Uriel, W. Labov and M. Herzog. 1968. Empirical foundations for a theory of language change. *Directions for Historical Linguistics*, ed. by W. P. Lehmann and Y. Malkiel, 97-195. University of Texas Press.

10 A balanced discussion of lexical diffusion in its early days of development was given by W. Labov in his presidential address to the Linguistic Society of America, published in *Language*.

skepticism, and sometimes, derision.[11] Part of the difficulty had to do with the fact that many of the early examples of lexical diffusion came from Chinese, and these did not resonate in a field that was still quite Euro-centric. Also, some of these early Chinese case studies were not analyzed in enough depth to be totally conclusive.[12]

We had the objective of making a large amount of systematic phonological data available to fellow researchers on Chinese dialects so that scholars working far away from each other can collaborate. For this purpose, we compiled in the late 1960s what may have been the first computer data-base for linguistic research; we simply called it Dictionary on Computer, or DOC.[13] Nowadays, of course, the technology has advanced so dramatically that what took several of us many years to do can be done within a few weeks. Collaboration across great distances via the internet has also become common-place.

But a linguistic theory must be relevant to all languages of course, not just Chinese, and indeed many languages from diverse families have been studied from the viewpoint of lexical diffusion. Lien Chinfa has put together a list of such studies in his contribution to the Encyclopedia of Language and Linguistics.[14] There can be no longer any doubt that the UVC scenario of lexical diffusion is real, not only for sound change, where the theory was first argued, but even more so for morphological and syntactic change.[15]

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11 At a conference held at UCLA in the early 1970s, the audience was amused by Tom Bever, when, in satirizing lexical diffusion, he stressed the rimed words in "Professor **Wang** is obviously **wrong**." I joined the mirth by answering "Professor **Beaver** is much too **eager**", continuing his play on surnames.

12 As an example, a paper of 1972 by C. C. Cheng and myself on tone change in Chaozhou did not consider the relevant complexities of dialect contact, simply because we had no access to the relevant data at the time. Professor Ting Pang-hsin, among several other scholars, was kind enough to discuss this issue in his 1978 paper, *BIHP* 50:257-71.

13 C. C. Cheng was the prime mover for the original version of DOC; see his introduction to DOC (1994). In recent years he has harnessed the new technologies of speech compression and Geographic Information Systems to build such data-bases with powerful refinements that we could only dream of.

14 *Encyclopedia of Language and Linguistics*, pp.2141-2144. More recent studies include: G. Sambasiva Rao. (ed.) 1994. *Language Change: Lexical Diffusion and Literacy*. Delhi: Academia Foundation. Lee, Sang-Oak, et al. (eds.) 2003. *The Lexical Diffusion of Sound Change in Korean and Sino-Korean*. Journal of Chinese Linguistics Monograph 20. The 2005 doctoral dissertation by Au Ching-Pong, City University of Hong Kong, explored the question of lexical diffusion by means of computer simulation of multi-agent interactions, with interesting results on a variety of sound change.

15 The suggestion on syntactic change was made early by Mei Tsulin in the context of lexical diffusion. Detailed studies on lexical diffusion in syntactic change have been reported by

Indeed we are beginning to have some quantitative ideas on the time course of these diffusion processes.[16] The point simply is that the word is the basic unit whereby language evolves, since it is the smallest free unit used in language, and is the unit for which the speaker has the greatest freedom of choice. The quantitative observations on word usage Zipf made almost a century ago are again attracting attention, now across languages, with large data-bases, and powerful modeling methods.[17]

As any active discipline, linguistics often moves forward by differences of conception and of opinion. The word 'controversy' has been used to refer to some of the larger issues, such as Labov did when he discussed the 'Neogrammarian controversy' vis-à-vis lexical diffusion. An even larger issue currently looming over language research has to do with the degree of innateness in our language ability and language behavior.[18] Nature and nurture are clearly not mutually exclusive factors, despite much misunderstanding to the contrary, and the inter-weaving of the two is captured nicely in the title of a recent book[19]—*Nature via Nurture*. This issue is discussed with great clarity in the anthology of Elman et al.[20]

On the one hand, particularly for advocates of the 'poverty of stimulus' argument, the tendency is to believe in some 'language organ' which makes it possible for the child to master a language in spite of the paucity and poor quality of the linguistic samples it is exposed to. This solution to the nature/nurture controversy seems to me to be overly facile, and lures one to bypass much necessary though difficult research of our evolutionary trajectories. I commented on this approach as an instance of 'organum ex machina',[21] recalling how the gods came out of machines to solve intractable human problems in Greek tragedies. In fact, nothing vaguely resembling a 'language organ' has been detected over the many decades since it was articulated.

Anne Yue-Hashimoto and Zhang Min for Chinese, by Ogura Mieko for English, as well as by many others.

16 For example, see some of the works by Cavalli-Sforza, Ogura, Shen, and Wang-Ke-Minett listed among the references. Recently, Partha Niyogi of the University of Chicago has been working on these problems as well with methods from computer sciences and mathematics.

17 See Peng-Minett-Wang for an effort in this area.

18 It is important to always remember that people differ along a wide spectrum in their language ability and behavior. Some of these differences are discussed in the anthology put together by Fillmore, Kempler and Wang.

19 Ridley, Matt. 2003. *Nature via Nurture: Genes, Experience, & What Makes Us Human*. Harper.

20 Elman, J. L., E. A. Bates, M. H. Johnson, A. Karmiloff-Smith, D. Parisi, and K. Plunkett. 1996. *Rethinking Innateness: a Connectionist Perspective on Development*. M.I.T. Press.

21 Wang (1984).

We are surely a long way from having a complete answer to the twin questions of how the child learns language, and how such learning led from no language perhaps 100,000 years ago to the kind of languages we have today. But evolutionary linguistics and cognitive linguistics are still in their infancy, and they stand ready to reap the advantages of some of the great breakthroughs and few frontiers opened in modern science made in recent decades. The detailed comparison of human and chimp genomes[22] as well as their ontogenetic behaviors,[23] has become possible only several years ago. New technology for imaging the brain during its normal functions, and perhaps even intervening via transcranial magnetic stimulation, has opened up new horizons for neurolinguistic research. In this connection, the discovery of mirror neurons is clearly another exciting frontier with important implications for our understanding of how language emerged via various forms of empathy and imitation.[24]

Computational resources for quantitative modeling and simulation is yet another advantage that has become available in modern science only in recent decades. Models come in a great variety of forms and flavors to help us sharpen our understanding of the universe around us. The cartographer's map, the artist's cartoon, the chemist's sketches of molecules are all tools which aim to extract from the complex raw data a few simple dimensions relevant to the problem at hand. Through the systematic elimination of irrelevant data [which can be regarded as noise in the channel] during the modeling, the investigator hopes to arrive at a more focused picture of the essential aspects of the problem. The tree diagrams that linguists draw, whether they represent the historical relations of a family of languages, or the syntactic relations among the words in a sentence, are models in this sense.

Moreover, instead of being a mere passive representation, like the tree diagrams, computational models allow the researcher to interactively vary the parameters in order to assess their effects. In dealing with a problem as difficult as the phylogenetic emergence of language at the dawn of human evolution, where direct observational data is impossible to obtain, computational modeling becomes all the more valuable because it is one of the very few windows available for looking at the problem.

There are some indirect observations, coming from paleo-anthropology, genetics, and archeology, which appear to bear upon our problem, in that they allow us to infer a time window. The earliest fossils that have been classified as anatomically modern humans date back some 150,000 years ago. This is also approximately the date when the *FOX-P2* gene took on the form it now has in modern humans, a gene that is

22 Clark et al. (2003).
23 Tomasello and Carpenter (2005).
24 Arbib et al. (2006).

believed to be relevant to our language abilities.[25] At the other end of the window, archeological evidence in the form of cave art, open water navigation, etc., suggests that beginning 50,000 years ago our ancestors were behaving in a way that most probably involved a linguistic ability not very different from what we have today.

If we accept this 100,000 year window as a first approximation, then the question can be posed as: how did our ancestors begin with a system of signals such as found in other apes and end up with a language like ours? Studies by primatologists, particularly the recent field investigations, remind us that our closest extant relative, the chimpanzee, has many advanced aspects in its behavior, including social structure, tool use, and local cultural traditions. Such behaviors tell us that a whole ensemble of cognitive abilities were already in place for language to interface together and build upon.

The point to bear in mind is that both our prelinguistic ancestors and the prelinguistic modern infant do not start from a blank slate for language to emerge, either phylogenetically or ontogenetically.[26] In the spirit of the 'tinkerer', suggested by François Jacob, evolution must have made significant use of the abilities our ancestors already had for language to emerge, in terms of different types of memory, perceptual strategies, as well as various pattern extraction and computational abilities. Furthermore, evolution here is a dual stream process, with cultural evolution proceeding at a much faster rate than biological evolution, and each influencing the other in significant ways.

In a lecture delivered at Osmania University in 1978, I suggested that language must have "evolved in a mosaic[27] fashion, with the emergence of semantics, phonology, morphology and syntax all at different times and according to different schedules ...", and that language may be "regarded as a kind of 'interface' among a variety of more basic abilities. These abilities underlie nonlinguistic processes as well, and involve the perception of patterns in the frequency and temporal domains, the coding and storage of

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[25] To say the *FOX-P2* gene is relevant for language is a far cry from calling it a 'language gene', which is a dubious concept. See the discussion by Chow in Minett and Wang (2005). Something as intricate as our language surely is multi-genic, and no evidence as yet has been reported that there is anything that has evolved in our genome that is exclusive and specific to language.

[26] The recent study by Tomasello and Carpenter (2005) on the emergence of social cognition in three young chimpanzees is very informative, especially in comparison with stages of development in children. In their words, "early ontogeny of human social cognition comprises two distinct trajectories, each with its own evolutionary history: one for understanding the basics of goal-directed action and perception, common to all apes, and another for sharing psychological states with others in collaborative acts involving joint intentions and attention, unique to the human species." p.vii.

[27] This mosaic metaphor has been recently repeated and expanded effectively in Hurford (2003).

events and objects at different levels of memory, the manipulation of various hierarchical mental structures, etc."[28]

These thoughts uttered at Osmania stayed in my mind as I continued my usual duties of teaching and research at Berkeley. Occasionally I discussed them with friends with similar inclinations, but mostly they stayed dormant. Shortly after I retired from Berkeley in 1994, I moved to Hong Kong. The new setting gave me impetus to think the questions afresh, particularly since I have also moved from a linguistics department to a department of electronic engineering, a context that recalls my post-doc days at the Research Laboratory of Electronics at M.I.T. Together with a group of graduate students who come primarily from various engineering departments, I have been exploring the language mosaic from a new modeling perspective.

It was also around this time that I ran across a little book in a Berkeley bookstore called *EMERGENCE*, written by John Holland. John and I co-taught the first introductory course at the University of Michigan when its Communication Sciences Program was first installed in the 1960s, and I was glad to be in touch with him again, and through John, a closer interaction with the Santa Fe Institute, of which he an integral member. The perspective of that book is complexity theory, and it draws from a wide range of disciplines. But its focus is to explain how highly complex systems can arise from simple initial conditions by multiple interactions and adaptations. My intuition is that language is such a complex adaptive system, and that some of the concepts and methods being developed elsewhere to understand complex systems can perhaps be harnessed for linguistics. In any case, our group has adopted such an emergentist perspective, which forms the background of the research done by our group, which I will now discuss.

To go from no language to modern language must involve several important phase transitions, to use a concept from complexity theory. Like ice becoming water and water becoming steam at different critical temperatures, our ancestors must have taken several intellectual leaps in the journey to modern language. Numerous instances of interaction among our ancestors, under selection pressures from a strong curiosity about the environment and an equally strong desire to communicate, enabled our ancestors to take these leaps. Furthermore, these phase transitions for language were inevitably accompanied by the evolution of other human qualities, such as self-consciousness, private planning of action, joint attention with others, and various aspects of social cognition.

Perhaps the first important phase transition was symbolization: the realization that an arbitrary signal could represent something quite distinct from the signal itself. Such a moment of sudden insight was vividly described for us by Helen Keller, when she

[28] Reprinted in my *Explorations in Language* (1991:116).

realized in a flash that the strokes that her teacher was drawing in her hand symbolized the water flowing over her hand. Her realization is of course importantly different from the closed sets of frozen signals reported in the world of animal communication; these are stereotyped instances of emotional responses [such as warning cries for predators], or of purposeful gestures [such as an extended open palm to beg for food]. The difference is that her realization is ***productive***, which led to an ever increasing open set of additional symbols, the use of which is not restricted to the immediate environment.

Another critical phase transition has to do with the nature of the signal itself. By building the syllable upon the rhythmic open and close movements of the jaw, which are of course already well developed for chewing food, our ancestors invented a method of communicating information that is amazingly rapid. Modern speech typically is spoken at 10 or more phonemes per second. Consonants and vowels are much faster to articulate than the call signals of many primates, which are primarily prosodic in nature, rather than segmental.

Psychologists speak of a short term memory, or working memory, which lasts several seconds to store individual chunks of information for more extensive analysis. We have no way of knowing for sure how much this short term memory found in modern man applies to our ancestors many millennia ago. Nonetheless, the ability to pack much more information into a chunk by means of syllabic phonology must have significantly helped bootstrap both the quantity and the quality of the communication process, beginning at those times.

Furthermore, syllabic phonology as it developed, building from features to segments to syllables to breath groups, and so on, where smaller units make up ever larger units, provided a good template for hierarchical structures. Such hierarchical structures are used again and again in morphological and syntactic systems as language became increasingly complex when our ancestors ventured into new worlds and accumulated more knowledge.

The modeling we have done so far in phonology is quite limited. It is based on the hypothesis that perceptual distance tends to be maximized, everything else being equal. This follows the earlier studies of B. Lindblom, B. De Boer, and others. Whereas their work studied vowels, we concentrated on lexical tones in languages such as Chinese. Since tones are like vowels in that they vary along continuous parameters, we expect their clustering tendencies to be the same. This expectation is verified in simulations; see Ke, Ogura and Wang (2003).

We have done some modeling work on the emergence of the lexicon as well; see Ke et al. (2002) for an early effort in which the initial conditions are extremely simple. To start this research, we assumed a population of agents, A, who are each able to manipulate a set of possible utterances, U, to encode a set of meanings, M. The language of each agent is represented by two matrices, one for his speaking, P, and one for his listening, Q.[29] The columns in each matrix are labeled by the individual utterances, and the rows are labeled by the individual meanings. At the beginning of the experiment, each cell is filled with a random number between 0 and 1, subject to certain probabilistic constraints, simulating the situation that the agents all map the utterances and meanings differently. That is to say, the agents do not initially share a lexicon, and each agent pairs the utterances and the meanings differently.

To run the experiment, an agent is randomly selected from the population to be the speaker, and another agent is randomly selected to be the listener for a communication event. The speaker will randomly select a meaning to convey, look across the row for the cell with the largest probability, and emit the utterance which corresponds to it. The listener, upon hearing the utterance, will look down the column for a cell with the largest probability, and select the meaning which corresponds to it.

If the listener selects the same meaning as the one the speaker conveyed, the communication event is a success. Then the values in the relevant cells are incremented with a constant, delta, and the values in the other cells are appropriately decremented in order to preserve the probabilistic constraints. On the other hand, if the listener selects a different meaning from the one the speaker conveyed, the communication event is a failure. Then the values in the relevant cells are decremented by delta, while the other cells are incremented.

The striking result from such experiments is that the matrices of the agents will become more and more similar until they all become identical, merely through the action of incrementing and decrementing the cells associated with numerous communication events. The population has converged on a common lexicon. In the terms of dynamic systems, the agents have achieved synchronization.

Such a process for the emergence of the lexicon may be seen as a simulation of conventionalization, perhaps what the ancient philosopher Xunzi had in mind when he suggested the famous phrase 約定俗成. The driving force is simply the agents' desire to communicate more effectively, reacting systematically to the successes and failures in the communication events. The process is clearly bottom-up; all agents and all communication events carry equal weight—the global structure is the product of numerous local interactions.

In addition to the convergence, another interesting result is the suddenness with which the convergence appears. There is a moment of clear phase transition, where the trajectory of convergence increases sharply until it reaches the entire population. The

[29] These matrices are also sometimes called active or productive (=speaking) and passive or receptive (=listening). The distinction between them may be justified by noting that typically one understands many more words and constructions than one produces.

exact moment of this transition depends on a host of factors, including the numbers of agents, utterances, meanings, and the value of the delta. Yet another factor has to do with the degree to which the two matrices of an agent can influence each other to achieve internal coherence. Presumably, all of these factors can eventually be given some empirical interpretation. For instance, there may have been an optimal size for early hominid tribes for language to emerge; the convergence times obtained by running the model for different population sizes are consistent with this hypothesis.

The more recent work of our group has been involved with developing more complex models, as discussed in greater detail in Gong and Wang (2005). One theme of our work has to do with the emergence of syntactic compositionality in language. Whereas earlier speculations on this question often assumed that syntax emerged quite late as a separate phase transition after the lexicon had been maximized, our modeling suggests that the use of word order could have emerged almost as early as the first conventionalized lexical items. This is to say that the considerable ability that humans have at extracting recurrent patterns in the holistic utterances was put to use from the beginning of language emergence. Our hypothesis is that the lexicon and syntax co-evolved.[30]

Another theme of our work is to explore the idea that more complex syntactic orders were built upon earlier simple orders.[31] For example, if the population had acquired a two word stage of agent-predicate and predicate-patient, then it is a simple step to telescope the two patterns to the more complex order of agent-predicate-patient. On the other hand, if the two word stage was of agent-predicate and patient-predicate, then the complex order may need to be determined by other factors, such as the frequency of occurrence of patterns to which individuals were exposed. The reader can easily see from this account that language modeling research is quite far from being able to explain some of the syntactic intricacies found in modern languages, such as various forms of long distance anaphora or cross-serial dependencies.

In certain respects, such as with the two word stage, our explorations reveal some parallels between the phylogeny of language emergence (= how the human species acquired language), and the ontogeny of language emergence (= how the child acquires language). In both cases, the process is one of acquisition. The critical difference of course is that in the latter case there are usually fully developed adult languages in the environment that the child samples, whereas in the former case, our ancestors had to invent the system ***de novo*** in a piece-meal fashion.

Yet another theme we are exploring has to do with the social structure within the population. Clearly no real speech community is made up of identical agents. A basic

[30] Gong, Minett and Wang (2006).
[31] Minett, Gong and Wang (2006).

feature is to consider age grading among the agents, perhaps simulating some parent-child vertical transmission. The older agents in the population may die off while new agents are born. We may also simulate some degree of horizontal transmission, where adults may imitate each other in some linguistic aspects. The social structure can be represented with different kinds of network topologies, with certain agents being connected with more agents than others, serving as hubs. There may well be some optimal placement as well as degrees of connection for a given number of hubs in facilitating convergence. Furthermore, the connections themselves may be directional or not, and may be weighted according to various criteria. Such experiments would give us indirect information on the size and social structure of the ancestral tribes, to complement the findings of anthropologists and population geneticists.

Finally, we are also concerned with the problems of language contact and competition, leading to phenomena such as multilingualism, hybridization, and sometimes, language death. A recent model on endangered languages, suggested by Abrams and Strogatz (2003), predicts how one endangered language may bring about the death of a competing language. However, their model completely ignores the role of the bilingual as well as the possibility of a stable multilingual society.

Our feeling is that except for extreme cases of conquest and sudden genocide, bilinguals and multilingual societies are indispensable aspects of the reality of language contact and competition. We are currently building a model in which bilinguals and possible multilingual societies are integral parts of the dynamic system. For a given social structure, our model predicts the probability that an endangered language can be maintained if an increase in the perception of its status can be brought about. We will shortly begin a course of fieldwork whose aim is to identify other factors that influence the probability of successful maintenance.

Modeling and multi-agent simulation are tools which have come upon the scene in linguistics only some two decades ago, in part due to the explosive growth of the computer. They have already attracted a lot of interest, and promise to yield important new insights in evolutionary linguistics. These methods can suggest ways of looking at things, which will in some cases lead to more rigorous proofs. Since language is treated as an evolving dynamic system, some of these proofs may take the form of sets of linked differential equations.

The availability of better tools in science is often the leading edge of a productive wave of new research. There is a famous line from the Confucian Analects that reminds us that doing a job well requires good tools: 工欲善其事, 必先利其器. A clear example from the history of science is the improvement of the lens, allowing the astronomer to view distant stars and the biologist to study tiny microbes. With the new tools of modeling and multi-agent simulation, new horizons have opened up for evolutionary linguistics in the study of language emergence, both phylogenetic and ontogenetic.

These are indeed fertile times for evolutionary linguistics; its questions are being shared by literally every conceivable community of scholars interested in communication, from artificial intelligence researchers who design interactive robots to zoologists studying how whales signal each other across huge spans of ocean water. The excitement has to do both with the convergence of interests from so many types of scholars, but also with the sense that breakthroughs in our understanding of what language is may be not far off. Looking back over the decades, I see that my fascination with language has always been rewarding—not necessarily with answers that immediately satisfy, but certainly always with questions that challenge and intrigue. Now that linguistics finds itself focally situated among many disciplines, I expect that I will be more hooked on language than ever.[32]

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