WHAT'S NEXT? A (POSSIBLE) AGENDA FOR EVOLUTIONARY LINGUISTICS AFTER EVOLANG 9

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Every two years researchers at Evolang bring together an impressive amount of evidence to unravel the puzzling phenomenon of language evolution. However, an overarching framework of how to integrate all these bits of data into a coherent theory, into a full picture, is missing. This paper proposes that the complex adaptive system framework can serve this purpose. The central idea is that language structures adapt to the niche of learner populations and are therefore 'shaped' to fit the social and cognitive needs of human beings. That is, the structural features of today's languages should be viewed as the product of the co-evolution of domain-general preadaptations for language and language as a cultural tool, rather than growing 'naturally' based on genetic encoding.

1. Introduction

The EVOLANG series of conferences on the "Evolution of Language" is extraordinary at least in one sense: it brings together an incredibly wide range of scientific subfields. Researchers of various backgrounds such as biology, physics, engineering, psychology, neuroscience, archeology, computer science and linguistics come together to convince each other of their new insights into the possible pathways along which the complex system of human language might have evolved. Although some of them would normally not even acknowledge that the other guys are actually doing "science".

What we have seen on Evolang9 in Kyoto ranges from baby-robots learning to produce human like vowels (Asada, 2012) and chimpanzees with impressive short-term memories (Matsuzawa, 2012) to the genetics of the language impaired KE family (Fisher, 2012) and language structures emerging from random strings (Kirby, 2012). Obviously, there is no lack of interesting input to tackle the long-lasting quest of how a communicative tool using sounds and signs to encode abstract concepts could evolve in the first place. However, what is lacking is an overarching theory which integrates all these scattered bits of evidence into a coherent picture.

Attending the plenary talks as well as the oral presentations and poster sessions, one sometimes realized that researchers might not only disagree with a certain perspective but just speak in an entirely different scientific “language”. For example, when Asada (2012) baffled the audience by showing videos of how neural networks learn to produce vowel-like sounds, someone in the audience asked how that could explain the syntactic phenomenon of wh-movement. Clearly, researchers attending Evolang9 were not always on the same page.

Again, this shows that a unifying framework to integrate the multitude of evidence for language evolution is missing. In the following, it will be proposed that the *complex adaptive system* theory (Hawkins & Gell-Mann, 1992; Gell-Mann, 1994; Ritt, 2005; Beckner et al., 2009) applied to language could integrate all the different sources of evidence into a wider framework of historical language change and language evolution. To this end, the relevant sources of data will be shortly outlined by referring to research projects presented on Evolang9 (section 2). In section 3, it will then be sketched how the various bits of data could make sense from the perspective of language as a complex system, which in turn hinges upon another complex system: human cognition and its *preadaptations* to language.

2. The six data sources

First, it needs to be examined what are the potential sources of data that can help us understand what makes us humans so radically different from other species, so that our information encoding abilities could gradually evolve far beyond that of any other basic communicative system found in other living and extinct species. The potentially relevant subfields in this context are: **genetics**, **archeology**, **primate research**, **psychological experiments**, **computational modeling** and **corpora**. In how far have these been represented on Evolang9?

Simon Fisher discussed the “Molecular windows into speech and language” in his plenary talk about the **genetic** underpinnings of language (Fisher, 2012). The basic message that he wanted the audience to take away was that there is a huge gap in between genetic encoding of information by strings of amino acids and the phenotypic and behavioral outcome we are facing in linguistic studies. To unravel the myriads of interconnecting effects occurring between a concrete mutation in a DNA string like the prominent FOXP2 gene and its expression in brain circuits is a fascinating but daunting puzzle that is far from being solved. However, Simon Fisher reported that FOXP2 (and other genes regulated by it) seem to have an effect on the outgrowth of neurites from neurons as well as the plasticity of synapses (i.e. the connections between neurons) in their target neural networks (Fisher, 2012: 438). Since these networks or expression sites are scattered all over the brain from the neo-cortex to basic circuits in the cerebellum, the evidence points towards domain general effects of FOXP2 upon the basic building blocks of human cognition, rather than domain specific effects on language processing alone.

It would be interesting to see how these genetic effects on the basic architecture of neural networks could be modeled by using computational networks. These have been applied to understand language processing ever since McClelland and Rumelhart (1986) and modified to deal with even complex linguistic tasks like learning case marking and word order (Lupyan & Christiansen, 2002). Perhaps *neural networks* could model what effects we should expect to occur if neurons are less interconnected. However, modeling of neural networks has not been strongly represented on this year's Evolang, although other **computational models** have been presented which were invoked to test the effect of population size and population structure on communicative systems (Thompson et al., 2012; Quillinan, 2012), to explain the emergence of bilingualism (Roberts, 2012) and to generally promote cultural transmission accounts to language evolution (Kirby, 2012).

These insights from computational models in turn seem to dovetail nicely with the effects found in **psychological experiments** with artificial languages, where the output of one generation of participants is handed down to the next generation in iterated learning tasks (Smith & Thompson, 2012; Smith, Wonnacott & Perfors, 2012). Both the models and the actual data from testing participants can tell us what the predispositions are under which predictability, regularity and hence structure can arise in languages over several generations of learners. This can give rise to a new perspective on language universals, which might no longer be viewed as the reflections of hard-wired language acquisition devices but rather the outcome of general learning constraints shaping language structures over historical and evolutionary timescales (Christiansen & Chater, 2008).

Intriguingly, if languages adapt to the "niche" of human cognition throughout time (Lupyan & Dale, 2010), then it should be possible to find the traces of this shaping process in diachronic corpora. This opens up a whole new research area of diachronic **corpus linguistics,** which has barely been represented on previous Evolang conferences (but see for example Delz et al., 2012, for a corpus based study of diachronic changes in German verb inflection). However, the accessibility of annotated texts and corpora of different languages and language stages is rapidly improving, and so do the computational tools to deal with large databases, which might make corpus studies another interesting source of data for researchers at Evolang. Obviously, the time depth of corpora is very shallow compared to the round about 2 million since the first appearance of the genus *Homo*. But on the other hand, if we get at least a rudimentary understanding of what happened in between the first written records in cuneiform and today's languages, then the processes accounting for these historical changes observed might possibly be extrapolated further back into the past.

Where the data of corpora is not reliable or just not available, i.e. before ~3000 BC, the **archaeological** record of other human activities such as tool use and cave paintings may give additional hints when and how complex cognitive preadaptations for language emerged. Arbib (2012) for instance scrutinizes the cognitive underpinnings of problem solving strategies that might have linked tool use and language use in the evolutionary past of humans.

In this context, **primate research** can likewise give us a first impression of the cognitive 'stages' that our ancestors might have gone through on their way to the usage of complex visual and auditory symbols. Indeed, this strand of research has impressively been represented by Matsuzawa (2012), who showed that the "outgroup" of chimpanzees can teach us a lot about more sophisticated human cognitive abilities, and even more interestingly – about their limits. Namely, Matsuzawa (2012) argued with reference to a series of visual short-term memory tasks that chimpanzees can actually outperform humans recalling numbers that are spread on a computer screen and visible for less than a second.

On the other hand, humans have developed complex language, which does not rely on a unidimensional enhancement in only one specific cognitive skill. Rather, it seems that short and long-term memory as well as other cognitive abilities are involved in processing language. This might be interpreted as evidence that the evolution of language is not necessarily the outcome of a single evolutionary pressure for a complex system of communication, but that it is grounded in a multitude of different pressures shaping a set of *preadaptations* for language.

To unravel these evolutionary pressures and their adaptive outcome on biological/genetic as well as cultural/historical timescales we need a framework for evolutionary linguistics that allows us to combine the evidence of the *six sources of data* – genetics, primate research, archeology, psychological experiments, computational modeling and corpora – without major contradictions. The next section will argue that the *complex adaptive system* (CAS) theory is the most promising framework for this purpose.

3. Language as a Complex Adaptive System

In a first attempt to apply the complex system theory to genuinely social phenomena like human language, Gell-Mann (1994: 51 pp.) proposed that the process of language learning should be seen in the light of complex adaptive system theory as well. Infants are faced with a multitude of speech strings they need to 'break into' in order to get a first grasp of their communicative purpose. In this early phase neural circuits already tackle the problem of finding the regularities and irregularities of syllable patterns and word boundaries (Saffran, 2001, 2002, 2003), which will later help to further categorize the building blocks of sentences and unravel their interdependence, i.e. learn grammar. This is in line with Gell-Mann's (1994: 25) general working of a CAS. That is, a CAS uses *previous data* to form *schemata* (be it syllable structure, word boundaries, grammatical rules or constructions) by identifying regularities in the data and compressing them. These schemata then 'unfold' (e.g. in linguistic behavior) and face negative or positive feedback depending on the consequences of the interaction with the environment (e.g. whether communicative purposes are met or not). Based on the feedback the schemata can then be modified.

Against the backdrop of this very general sketch, the position paper by Beckner et al. (2009: 2) fleshed out the idea of language being an adaptive system by stating that: a) whenever language is used, there are multiple agents involved; b) language is adaptive in the sense that the agent's linguistic output is based on past input, which is, however, not just repeated, but modified according to c) selective factors ranging from perceptual and processing constraints to social pressures. Hence, d) the features we find in today's languages are a historical and evolutionary outcome of the interaction between social and cognitive effects.

Addressing the latter ones in particular, Christiansen & Chater (2008) showed how domain-general *sequential learning abilities* might have shaped language structures throughout time. This finding has important implications for research on the evolution of language in general. If it is true that language is 'shaped by the brain', i.e. that the features of today's languages are shaped to fit the learning constraints of humans, then scrutinizing the evolution of language in the human lineage means finding the cognitive *preadaptations* which set the frame for the structures of a complex communication system. As a consequence, language structures would no longer be viewed as the 'outgrowth' of a set of specific language genes encoding a Universal Grammar, but rather as the gradual product of the co-evolution of two intertwined complex systems: human cognition and the corpora of produced linguistic structures (for related views see Deacon, 1997, Haspelmath, 1999 and Ritt, 2005).

Figure 1 depicts the principal idea of a 'diachronic language helix', i.e. the interaction between the complex adaptive system of human neural circuits and a hypothetical 'whole corpus' of a language, i.e. all structures uttered at one point in time.

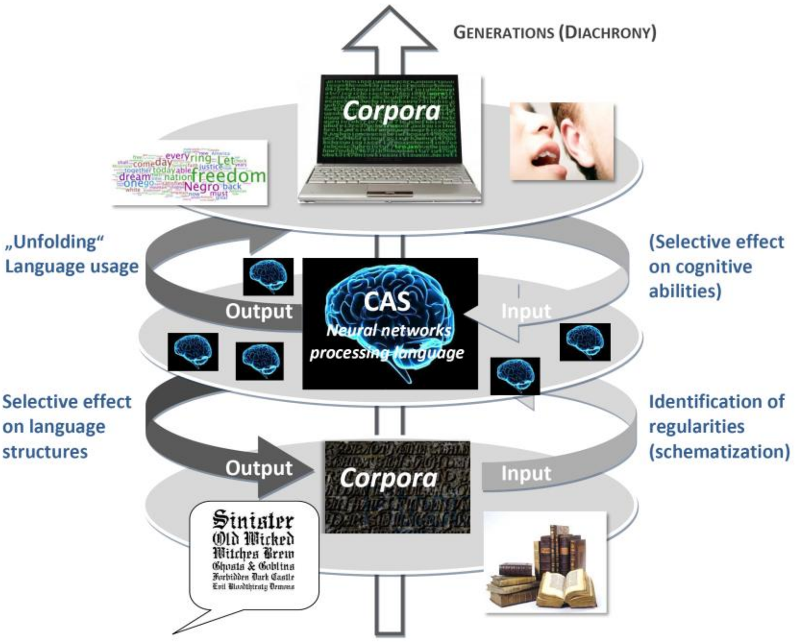

Figure 1. The 'diachronic language helix' of historical language change and language evolution.

Crucially, the diachronic pathway from one generation of corpora to another, as well as from one generation of language learners to another (represented by the neural networks involved in language acquisition) is shaped like a helix. This 'language helix' reflects the fact that the levels inserted here at three different stages are pure idealizations. Neither can a corpus of a language ever be complete and fully described at any point in time, nor are the language learners (i.e. agents) ever grouped into clear-cut generations. Hence, the shape of a helix is a) appropriate for representing the gradual and statistical nature of historical language change and language evolution, and b) it still captures the somewhat paradoxical fact that there are similar and repetitive processes at play throughout time although they do never give rise to the exactly same outcome (which would be represented by a circle). For example, it might be that languages lose some grammatical markers in an earlier stage and later re-gain similar markers. The grammaticalization processes involved in the building of these markers might have similar cognitive and social underpinnings but they do not give rise to exactly the same markers.

Another advantage of the helix is that it captures the mutual influence of both systems onto each other. On the one hand, learning constraints will shape the features found in the corpora of the next generation, on the other hand, the available input might also shape the linguistic abilities of learners – at least in ontogeny[1].

A subset of the utterances available at any point in time will be the input for any one language learner. However, as noted earlier, a language learner will not just mechanically repeat the input utterances, but rather ‘filter’ these through individual learning constraints and social dependence. In this way, the next generation of corpora will be modified according to the needs or the ‘niche’ (Lupyan & Dale, 2010) of the population of learners. It is likely that these needs are not fixed, but might change more or less rapidly. For example, social linguists like Trudgill (2011) and McWhorter (2007) have argued that populations with a lot of adult second language (L2) learners have different linguistic needs (e.g. less grammatical marking) than populations of native speakers. The account by Lupyan and Dale (2010) was a first attempt to proof this hypothesis by showing that there are negative correlations between population size and the occurrence of difficult grammatical features. Bentz and Christiansen (2010) argued that a linguistic adaptation of the L2 type might have taken place for Latin and the Romance languages as well as the Germanic languages (Bentz & Christiansen, submitted), and at this year’s Evolang Bentz and Winter (2012) have presented data which suggests that the relative number of L2 speakers can predict the numbers of case-marking paradigms in languages throughout the world.

All this evidence was brought forward to corroborate the framework of language as a complex adaptive system. In conclusion, this means that the features of today’s languages are the outcome of historical developments that

[1] Christiansen & Chater (2008) have argued against phylogenetic biological adaptation for language structures, because these pose a ‘moving target’ for the relatively slow process of genetic encoding. However, both ontogenetic and phylogenetic adaptations would be in line with this model of a diachronic linguistic helix. For further discussions see Winter (2010).

have socially and cognitively shaped the symbolic systems that have evolved throughout the world for a communicative purpose.

Now, in how far can the six data sources of section 2 be integrated into this model? On principal, there are at least two research areas that could be interesting for evolutionary linguists in this context: 1) trying to narrow down the cognitive *preadaptations* for language such as sequential learning abilities, which could tell us whether there is a universal core of all languages (albeit a domain-general one) and what it structurally looks like. This area will be most interesting for geneticists, psychologists and primatologists. 2) In a next step, we would need to find out how language structures are then actually shaped by learning constraints and social factors in historical language change. This can be approached by corpus studies and iterated learning tasks that might feed into more realistic computational models of the relevant developments.

It goes without saying that these two potential strands of research are not strictly independent of each other but will always need mutual feedback and input. This way, both the evidence from empirical research as well as historical linguistics and corpus studies could nicely dovetail to establish a framework of language evolution that could win researchers from various disciplines.

4. Conclusion

This paper argued that it is about time to find an overarching theory that would bring together the various strands of evidence which have been carefully collected and presented at the past Evolang conferences. At this point it seems that the *complex adaptive system* theory applied to language is the most promising candidate in this regard. It could integrate the data from genetics, primatology, psychology, computational modeling, archeology and corpus linguistics. This will help unravel the complex diachronic relationship between human cognition, social life and the usage of symbolic communication patterns.

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References

Arbib, M. A. (2012). Evolutionary parallels between language and tool use. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 3–11. World Scientific.

Asada, M. (2012). Towards language acquisition by cognitive developmental robotics. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 19–26. World Scientific.

Beckner, C., Ellis, N.C., Blythe, R., Holland, J., Bybee, J., Ke, J., Christiansen, M.H., Larsen-Freeman, D., Croft, W., & Schoenemann, T. (2009). Language Is a Complex Adaptive System: Position Paper. *Language Learning*, 59, 1-26.

Bentz, C. & Christiansen, M. H. (2010) Linguistic adaptation at work? The change of word order and case system from Latin to the Romance languages. In Andrew D. M. Smith, M. Schouwstra, B. de Boer & K. Smith (Eds.). *Proceedings of the 8th International Conference on the Evolution of Language*, pages 26-33. World Scientific.

Bentz, C. & Christiansen, M.H. (submitted). Linguistic Adaptation: The trade-off between case marking and fixed word orders in Germanic and Romance languages.

Bentz, C., & Winter, B. (2012). The impact of L2 speakers on the evolution of case-marking. In Thomas C. Scott-Phillips, M. Tamariz, E. A. Cartmill & J. R. Hurford (Eds.). *The Evolution of Language*. *Proceedings of the 9th International Conference (EVOLANG9)*, pages 58-64. World Scientific.

Christiansen, M. H., & Chater, N. (2008). Language as shaped by the brain. *Behavioral and Brain Sciences*, 31, 489–509.

Deacon, T. W. (1997). *The Symbolic Species: The Co-evolution of Language and the Brain*. New York & London: W.W. Norton & Company.

Delz, M., Layer, B., Schulz, S. & Wahle, J. (2012). Overgeneralization of verbs - The change of the German verb system. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 96–104. World Scientific.

Fisher, S. E. (2012). Molecular windows into speech and language. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 438–440. World Scientific.

Gell-Mann, M. (1994)). The quark and the jaguar. *Adventures in the simple and the complex.* New York. W.H. Freeman.

Haspelmath, M. (1999). Optimality and diachronic adaptation. *Zeitschrift für Sprachwissenschaft,* 18, pages 180–205.

Hawkins, J. A. & Gell-Mann, M. (1992). *The evolution of human languages*. *Proceedings of the Workshop on the Evolution of Human Languages, held August, 1989, in Santa Fe, New Mexico.* Redwood City, California etc. Addison-Wesley.

Kirby, S. (2012). Why language has structure: New evidence from studying cultural evolution in the lab and what it means for biological evolution. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 480–482. World Scientific.

Lupyan, G. & Christiansen, M. H. (2002). Case, word order, and language learnability: Insights from connectionist modeling. *Proceedings of the 24th Annual Conference of the Cognitive Science Society*, pages 596–601.

Lupyan, G., & Dale, R. (2010). Language Structure Is Partly Determined by Social Structure. *PLoS ONE 5*:1, e8559-e8559.

Matsuzawa, T. (2012). Outgroup: The study of chimpanzees to know the human mind. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9), pages 227–234. World Scientific.

McClelland, J. L. & Rumelhart, D. E. (1986). *Parallel distributed processing. Explorations in the microstructure of cognition*. Cambridge (Massachusetts). MIT Press.

McWhorter, J. (2007). *Language interrupted: Signs of non-native acquisition in standard language grammars*. Oxford. Oxford University Press.

Quillinan, J. (2012). A model of communication of frequent social communication. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 518–520. World Scientific.

Ritt, N. (2005). *Selfish sounds and linguistic evolution*. *A Darwinian approach to language change.* Cambridge. Cambridge Univ. Press.

Roberts, S. G. (2012). A bottom-up approach to language evolution. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 523–525. World Scientific.

Saffran, J. R. (2001). Words in a sea of sounds: The output of infant statistical learning. *Cognition*, 81, pages 149–169.

Saffran, J. R. (2002). Constraints on statistical language learning. *Journal of Memory and Language*, 47, pages 172–196.

Saffran, J. R. (2003). Statistical language learning: Mechanisms and constraints. *Current Directions in Psychological Science*, 12, pages 110–114.

Scott-Phillips, T. C.,Tamariz, M.,Cartmill, E. A.& Hurford, J. R. (2012). The Evolution of Language. *Proceedings of the 9th International Conference (EVOLANG9).* World Scientific.

Smith, K. & Thompson, B. (2012). Iterated learning in populations: Learning and evolving expectations about linguistic homogeneity. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. The *Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 543–545. World Scientific.

Smith, K., Wonnacott, E. & Perfors, A. (2012). Regularization of linguistic variation in populations. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 545–547. World Scientific.

Thompson, B., Smith, K. & Kirby, S. (2012). Cultural evolution renders linguistic nativism implausible. In Scott-Phillips, Thomas C.; Tamariz, Mónica; Cartmill, Erica A.; Hurford, James R. *The Evolution of Language. Proceedings of the 9th International Conference (EVOLANG9)*, pages 557–559. World Scientific.

Trudgill, P. (2011). *Sociolinguistic typology: Social determinants of linguistic complexity*. Oxford. Oxford University Press.

Winter, B. (2010). The moving target argument and the speed of evolution. In Smith, A.D., Schouwstra, M., de Boer, B., & Smith, K. (Eds.). *Proceedings of the 8th International Conference on the Evolution of Language*, pages 352-359. World Scientific.