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Review of the 9th International Conference on the Evolution of Language (Evolang9)

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1. Overview

The 1990's have witnessed a resurrection of an interest in the origins of language (in fact, such an interest had never actually faded). Although pin-pointing the exact triggers behind the initial sparkles is difficult, one may advocate for the integration of a number of scientific advances, including the first computer simulations of the self-organized emergence and convergence of linguistic conventions (Hurford 1989, Steel 1996), the significant progress in the systematic analysis of mtDNA or Y chromosome genetic distributions across the world (Cann *et al*. 1987, Underhill *et al*. 2000), the synthesis of the data from genetics, archaeology, and linguistics (Cavalli-Sforza *et al*. 1988, 1992), and many others.

In 1996, the first Conference on the Evolution of Language (Evolang) was held in Edinburgh for the purpose of fostering a dialog between scholars of diverse backgrounds. At the center of discussions — and in opposition to a generativist framework minimizing the value of such an attempt (Chomsky 1972, Berwick 1998) — laid an effort to account for the properties of the faculty of language in light of modern evolutionary theory (Hurford *et al*. 1998). The 9th Evolang conference (Evolang9), which took place in Kyoto 13–16 March 2012, was once again an opportunity for scholars from a wide range of disciplines to gather and bridge their lines of arguments (McCrohon *et al*. 2012, Scott-Phillips *et al*. 2012).

Since the origins and evolution of language have long been the research foci in both evolutionary linguistics and biolinguistics, we provide here a review of the variety of reports that was brought forward during Evolang9. Without being able to pay justice to the wide scope of all contributions that were made, we mainly summarize and frame the primary arguments that echoed during the conference, highlight significant evolutions of the field both in terms of methods and content, and present our opinions on future research in this line.

2. Approaches and Methods

The Evolang series has consistently been characterized by a high diversity of

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approaches and fields. Without being exhaustive, contributions usually cover linguistics (sociolinguistics, language acquisition, physiology of speech, syntax, etc.), logic, game theory, mathematical modeling and computer simulations, genetics, ethology, human and comparative psychology, neuroscience, paleo-anthropology, archaeology, philosophy, evolutionary psychology, and developmental biology. Trends however channel the relative weights of these fields from one conference to another. We give below five long-term tendencies we deem of special significance.

The first trend is the decrease in modeling approaches which has taken place between the mid-2000's and recent years. Models and simulations (most often self-organizing multi-agents models), for example, made the bulk of the contributions to Evolang5 and Evolang6 respectively held in Leipzig and Roma (Cangelosi *et al*. 2006). The investigations then revolved around (i) the emergence of compositional structures, and most often how a stable order for subjects, verbs and objects could be achieved without central coordination (e.g., Kirby 2000, Smith *et al*. 2003a, Gong *et al*. 2005, 2009), (ii) the impact of embodiment in robots, with noticed endeavors of Luc Steels' teams in Paris and Brussels in building on more sophisticated linguistic theories, such as the fluid construction grammar (e.g., Steels *et al*. 2005, Steels & de Beule 2006, Steels 2011, van Trijp *et al.* 2012), (iii) the impact of socially structured populations (with popular structures, such as scale-free or small-world networks) on the self-organization of linguistic systems or the diffusion of innovations (e.g., Dall'Asta *et al*. 2006, Barrat *et al*. 2007, Gong *et al*. 2008, Ke *et al*. 2008), and (iv) the impact of repeated episodes of learning on the design of linguistic structures (e.g., Kirby 2007, Kirby & Hurford 2002, Smith *et al*. 2003b, Steels 2012). Regarding the last effort, Simon Kirby's *Language Evolution and Computation* team and their *Iterated Learning Model* (ILM) were particularly instrumental in partly shifting models from horizontal lingu-istic transmission (among a usually 'immortal' population of agents) to vertical transmission (with generations of successively learning and teaching agents shaping a communication system).

Although modeling and robotic approaches were reported during the Kyoto conference (e.g., Gong & Shuai 2012, Smith 2012, Spranger & Steels 2012) — noticeably by plenary speaker Minoru Asada, who emphasized the potential of cognitive development robotics to study language acquisition and more generally simulate child development —, several attendees observed a decline with respect to their former prominence. During a preliminary satellite workshop of the conference, Bart de Boer addressed this issue by stressing three common pitfalls of modeling: (i) fact-free science not referring to outside phenomena, (ii) cargo-cult science, an activity mimicking the procedures of science without delivering results (according to Feynman 1974), and (iii) circularity when a model only explains the data that were used to build it. To avoid these traps and keep modeling successful, de Boer advocated for various strategies. Better validating the models was one of them — with mathematical proofs, sensitivity studies, and model parallelism for internal validation and the prediction of real and non-circular data for external validation. Another direction worth taking was better complementing and re-using existing models, rather than always starting again from scratch — a tendency shared by many modelers. Finally, focusing on ques-

tions raised by non-modelers and attempting at bridging empirical gaps were deemed precious to increase the reliability of modeling (de Boer 2012).

A second trend is the more central position of experimental approaches in the study of language evolution. As noted by Normile (2012), this experimental stance covers a number of fields, from analyzing the online brain activity of stone tool-makers (Stout *et al*. 2008, Stout & Chaminade 2012) to studying how subjects learn an alien language composed of whistles (Verhoef *et al*. 2012). However, one of the most meaningful shifts lies, to us, in the displacement of the iterated learning model from 'silicon-made' subjects to human ones. This step was pioneered among others by Galantucci, with experiments of human subjects learning an artificial language to cooperate in front of a simple task (Galantucci 2005). Interestingly, several talks illustrated how the ILM, which started as a theoretical and modeling framework, had found its way to the experiment room (e.g., Scott-Phillips *et al.* 2010, Kirby 2012, Verhoef *et al.* 2012), perhaps reflecting, in a somehow radical way, de Boer's thinking on models and simulations.

A third evolution of the field relates to the broadening of the spectrum of comparative approaches between human language and animals' communicative systems. For obvious reasons, apes and monkeys have been the center of interest, with many experiments consisting in teaching a human or human-like form of communication (e.g., Patterson 1981, Savage-Rumbaugh 2001) to non-human apes or focusing on their comprehension of others' intentions (e.g., Call & Tomasello 1998, 2008; Heyes 1998; Schmelz *et al*. 2011). Other animal models have however gradually made their way and enjoyed high popularity at the Kyoto venue. Rather distant from humans on the phylogeny of species, birds became center of discussion (Fujita 2012, Katahira *et al*. 2012, Matsunaga *et al*. 2012, Okanoya *et al*. 2012, Sasahara *et al*. 2012, Stobbe & Fitch 2012), with special attention paid on the one side to parrots and keas for their remarkable cognitive abilities (Pepperberg 2010, 2012), and on the other side to a couple of species relevant for their close genetic relationship yet divergent environment (see below): white-rumped munias and Bengalese finches (Takahasi *et al*. 2012). Meanwhile, monkeys and apes were still present, and at a methodological level, keynote speaker Tetsuro Matsuzawa stressed the combination of field experiment — building specific device in the wild to study wild populations of apes manipulating tools (Biro *et al*. 2003) — with participant observation relying primarily on the bound between the ape mother and her child (Matsuzawa *et al.* 2006). All in all, the conference highlighted the strong expertise of various Japanese research centers in animal studies.

A fourth methodological trend was a latent reflection on the scientific paradigms relied on to study the evolution of language. In addition to de Boer's suggestions on successful modeling, Roberts & Winters addressed the development of nomothetic approaches in contrast with idiographic ones. While the latter deal with singular cases, the former draw on large sets of data — spanning over large linguistic, cultural, physical, and other domains — and seek law-like patterns behind 'surface' correlations (Roberts & Winters 2012). Nomothetic approaches have been the subject of recent publicized studies and hot debates among scholars working on the origins and current diversity of modern languages (e.g., Lupyan & Dale 2010, Atkinson 2011, Bybee 2011, Dunn *et al.*

2011). Since the Evolang conferences rather focus on the emergence and development of the faculty of language, contributions relying on this methodology remained limited. However, as large datasets in various fields have ever been more and more available and manipulable, there are reasons to believe that such contributions could become influential in future venues. Nonetheless, Roberts & Winters warned against the pitfalls of this line of work, where poor quality of data (e.g., in terms of sampling), spurious correlations and lack of alternative hypotheses may all lead to wrong conclusions (for further details, see www.replicatedtypo.com). Statistical problems linked to the non-independence of the statistical units of a study — whether due to the historical relatedness of languages or their spatial distribution with possible geographic diffusions — prove to be especially difficult (Jaeger *et al*. 2011), as also noted by Russell Gray during his keynote lecture regarding his work on linguistic Bayesian phylogenies (Gray *et al*. 2009). Integrating different approaches — nomothetic, idiographic, constructive — is seen as the best way forward to compensate the weak explanatory power of the first approach — correlation does not imply causation —, the limited range of the second and the potential circularity of the last.

The final point we want to make regards brain imagery techniques applied to activities related to communication and language evolution. EEG (encephalography) or fMRI (functional magnetic resonance imaging) are of course ubiquitous in today's neuroscience, but original studies are gradually appearing which focus on the evolution of language. Takashi Hashimoto thus mentioned studies where simultaneous EEG recording took place in two subjects playing a coordination game (Hashimoto 2012), allowing to observe the neural activity at various stages of the formation of a symbolic communication system. Russell Gray also referred to Stouts and collaborators' experiments where the brain activities of the tool-makers were recorded through PET (positron emission tomography) during sessions of tool-making. This allows detecting significant changes in activated areas for different prehistoric lithic industries (e.g., Oldowan and Acheulean), and possible overlap with language circuits (Stout *et al*. 2008, Stout & Chaminade 2012). Finally, whole-brain fMRI recordings in Zebra finches of neuronal correlates of song learning were presented, showing evolving activations during the course of the sensitive period in primary and secondary auditory areas (van der Kant & van der Linden 2012, Moorman *et al*. 2012).

Given these methodological remarks, we can now turn to the contents of the contributions reported at Evolang9, trying to frame various lines of evidence and disciplines.

3. Designing Language Structures: Disentangling Biology, Culture, Cognition and Learning

During Evolang9, Hajime Yamauchi usefully reframed the famous ban against publications on the origins of language by the Société Linguistique de Paris in its cultural and political context (Yamauchi *et al*. 2012). As in the 1860's, the evolution of the contributions to the Evolang series reflects the dominant forces and structures of the scientific domain.

David Premack's famous quote, "Human language is an embarrassment for

evolutionary theory" (Premack 1985: 281–282), has been used as a subtitle for some of the past Evolang conferences. Generally speaking, these meetings have attempted at providing an answer by disentangling the influences of various frames to which language may belong, including (i) biology (with the genetic substrate of language), (ii) culture (with language existing in a socially constructed community of interacting speakers), (iii) cognition (with language building on and coexisting in the human mind with other cognitive abilities), and (iv) learning (with language being repeatedly learnt and transmitted between generations of speakers).

Such frames are only partially separable from each other, and one may advocate for natural selection as the primary force that drove language evolution, stating that all further effects may ultimately be traced back to genes and their evolution.

Several periods of discussions during Evolang9 actually focused on the role played by natural selection in the emergence of language, with clear evidence that more than twenty years after Pinker & Bloom's (1990) seminal paper on the question, some scholars still opposed to its primacy. Keynote speaker Massimo Piattelli-Palmarini particularly challenged the standard evolutionary perspective, defending instead an evo-devo (evolutionary developmental biology) perspective with minor gene rearrangements and shifts in gene regulation leading to major morphological changes, hence understating the driving role of function for such changes as long as survival and reproduction are preserved. The specific analogy with the eye of the rhopalia jellyfish (Gerhart & Kirschner 1997, Coates 2003) was cited as a complex structure without function by Piattelli-Palmarini, although the question was raised by the discussants of how it could have spread to the entire population without functional advantage — see also Mackie (1999) for further arguments about the functionality of the cubozoan ocelli or 'eyes'.

Irrespective of the actual weight of standard selection, several contributions reminded of the complexity of the phenomena at hand. Yasuhiro Suzuki and colleagues introduced the intricacies of the evolution of herbivore-induced plant volatiles, and how interwoven evolutions of species led to complex dynamics with possible increase or decrease in biodiversity (Shiojiri *et al*. 2010, Suzuki *et al*. 2012). Keynote speaker Simon Fisher furthermore detailed the complexity behind the role of the FOXP2 gene, arguing against the reductionist view of the 'gene for oral language' and stressing the complex set of genetic interactions in which FOXP2 fulfills its functions (Fisher & Scharff 2009, Fisher 2012). Fisher also highlighted some recent advances in neurogenetics, and how this discipline might help in future to decipher the convoluted relationship between the cognitive function of language and its genetic basis.

The subtlety of natural selection beyond the key ideas of genetic variability and selection was particularly addressed during Evolang9 through the notions of masking and unmasking of selective pressure in relation to the process of niche construction. Interestingly, these phenomena were referred to by scientists from various fields, covering modeling and animal studies.

During his concluding lecture, Terrence Deacon gave a clear example outside the linguistic sphere: While many animals synthesize ascorbic acid (vitamin C), anthropoid primates lack this capacity and only possess a non-functional

version of the crucial gene involved in the chemical mechanism. According to Deacon, the primates' fruit diet, rich in vitamin C, explains this evolution: Because this vitamin was readily available 'exogenously' for these animals, the selective pressure on the gene involved in endogenous synthesis relaxed — it was masked — until it lost its function. This in turn bounded primates to their diet, playing a role in the construction of their specific ecological niche. Functions related to living in this niche — especially being efficient in acquiring food rich in vitamin C — hence became under stronger selective pressure. In other words, the selective pressure on such functions was unmasked in the process (Deacon 2003, Wiles *et al.* 2005). Deacon insisted that the whole process was cyclical, with adaptations for niche-maintaining leading to novel functional synergies. He also applied this evolutionary pattern to language, stating that the construction of a symbolic linguistic niche resulted in unmasking specific selective pressures on the human brain while at the same time masking previous ones, hence allowing brain structures to evolve in functionality (Deacon 2012).

Other speakers presented test cases for this framework. The evolution of Bengalese finches (BFs) in Japan with respect to white-rumped munias (WRMs) was especially enlightening. WRMs are wild birds found in tropical Asia and in some parts of Japan; a strain was isolated 250 years ago and domesticated, resulting in today's BFs. Studies devoted to the features of the vocal cultures of both strains, with two colonies recorded over several generations in sound-proof boxes, showed that WRMs kept the colony founders' song through generation while BFs displayed rapid divergence (Takahasi & Okanoya 2010, Takahasi *et al*. 2012). These observations could be explained by a stronger innate bias in WRMs toward specific songs, which in turn is related to the previous notions of masking and relaxed selective pressure: WRMs in the wild are under strong selective pressures to produce songs that will attract conspecifics, while this pressure was relaxed/masked in the domesticated strain. In such studies, evaluating the similarities between birdsongs, or their overall complexity and diversity, can be done with simple or more refined techniques. Katahira *et al*. (2012) relied on hidden Markov models to study the high-order context dependencies in Bengalese finch songs, showing that a first-order model was enough to predict the songs. We can also report here on Sasahara *et al*.'s (2012) approach, which consisted in applying network construction and analysis techniques to the transitions observed between different phrases along song sequences of the species California Thrasher. It appeared that the structural properties of the bird's 'syntax' allowed both familiarity at the local level of the song sequences and novelty at the global level; both aspects were judged useful by the authors, with the first one to establish a singer's identity and the second one to let birds develop virtuosity in their singing.

Another test case came from the modeling efforts attempting at assessing the weights of biology, culture, and learning in the emergence of linguistic structures. A Bayesian iterated learning model of cultural transmission coupled with a mechanism of biological evolution showed that weak genetic biases could be quickly unmasked and stabilized by cultural transmission in a population of speakers, yet never turn into strong biases because of a masking by iterated learning (Kirby *et al*. 2007, Thompson *et al*. 2012). These simulations stand against the postulate that linguistic universals are due to strong innate biases — a 'uni-

versal grammar' (UG) (Chomsky 1965). Instead, they suggest that such universals can rather be explained by weak biases and a coordination of biology and culture regardless of their different evolutionary rates.

Another key concept that was repetitively addressed during Evolang9 was the double articulation of language, with meaningful units (morphemes) built from meaningless units (phonemes) and then articulated in larger structures (sentences and discourses). In his keynote talk, Simon Kirby denoted the first articulation of the duality of patterning, combinatoriality, and the second, compositionality.

The emergence of compositionality was investigated by Kirby and colleagues with a lab experiment involving learning an artificial language — strings of syllables paired with structured graphic meanings. Subjects could get tested on their learning, with their answers then used to teach naive learners, much in the fashion of iterated learning in computer models (e.g., Kirby *et al.* 2008). Different conditions led to different results. Isolated subjects learning a system and transmitting it to the next generation — i.e. vertical transmission but no horizontal transmission —, with an additional and external mechanism to avoid ambiguity, led to the emergence of a compositional communication system. While not preventing ambiguity restricted compositionality to develop, replacing ambiguity avoidance by horizontal transmission — having two subjects for each generation, communicating with one another on the various meanings — restored the previous result. Finally, when vertical transmission was removed and only horizontal transmission took place, compositionality was only limited. These various results showed that a combination of both naïve learners and communication was needed to achieve compositionality. In addition, a fourth study, where structures were learned and exchanged without corresponding meanings, further showed that semantics was not needed for the emergence of repeated subsequences in the strings of syllables.

In order to address the emergence of combinatoriality, getting away from existing languages was needed. Tessa Verhoef and colleagues have addressed this issue by relying on slide whistles used by subjects to produce sounds, the properties of which could be analyzed in terms of combinations, repetitions, etc. Their results suggested that phonemic coding not rely on pressure from large number of signals — an argument behind the hypothesis that an initial holistic proto-language could have evolved as the number of exchanged meanings increased with time. Rather, starting from random sequences of whistles, iterated learning gradually led to whistled elements being reused according to combinatorial constraints (Verhoef *et al*. 2011, 2012).

Combinatoriality, as described by Kirby, was also addressed in a contribution regarding the alarm calls of Campbell's monkeys (Barceló-Coblijn & Gomila 2012). Contrary to popular vervet monkeys' holistic alarm calls (Seyfarth *et al*. 1980), Campbell's monkeys' six calls displayed an internal structure, with the adding of a final –oo resulting in a different meaning ('krak' relates to leopards, while 'krakoo' can be used for almost any disturbance) (Ouattara *et al.* 2009). What looks a priori here as affixation points to the morphology found in human language. However, Barceló-Coblijn & Gomila insisted that the components of the alarm calls not share all the features of human morphemes. On the one hand,

the final –oo does not possess a meaning of its own and the call resulting from the concatenation of, say 'krak' and 'oo', does not have a meaning transparently related to the meanings of its parts. On the other hand, the authors stressed that morphemes are more than minimal units of meanings, and are at the crossing of two processes. The first process is lexicalization, by which concepts are turned into lexical units respecting the 'edge features' of morphemes. These features describe the semantic and syntactic compositional properties of morphemes, and lead to a hierarchical structure of lower and higher meaningful units. The second process is externalization, by which lexical units get a phonological structure. Campbell's monkeys' alarm calls were then defined as pleremes — meaningful signals made of meaningless particles —, relating only to the second process of encoding and compressing information into an external signal.

Barceló-Coblijn & Gomila were not the only participants to remind the audience of the very specific nature of linguistic symbols. Piattelli-Palmarini also mentioned properties of words that made them more than other symbols: aspectual reference, headedness, internal structure, and the previously mentioned edge features.

In the context of Evolang9, the previous considerations on lexicalization and combinatorial properties could be connected more generally to the cognitive context of language evolution. James Hurford commented on *Merge*, which can be said to extend the previous notion of lexicalization and lie at the center of the Minimalist Program inside generative grammar (Chomsky 1993, 1995). Whether this cognitive capacity came before or after externalization is at stake: Externalization enables communication with others, while merge may not only enhance it but also participate in the development of complex private thoughts. Which came first is hard to know, since, as demonstrated by Hurford, a double dissociation exists between having complex private thoughts and possessing a complex communication system. However, biolinguist Cedric Boeckx took side and advocated for communication not playing a role in the initial development of linguistic cognitive abilities (although it later became relevant with cultural transmission). The merging operation was listed along with the edge property and cyclic transfer, or phase, as the three minimally specified syntactic components needed for a plausible UG. Boeckx further introduced the notion of a global neuronal workspace (GNW) to provide a frame in which bridges could be built across previously disconnected cognitive modules; a language of thought, with lexicalization and then merging of concepts, allowed meanings of various natures to integrate (Boeckx 2012). This approach explicitly echoed Fodor's language of thought (Fodor 1975), but was also reminiscent of Fauconnier & Turner's (1998, 2002) scope blending, or Mithen's (1996) cognitive fluidity. The GNW was furthermore rooted in the brain structure and evolution. First, neurons with long-distance connections were seen as central in cross-modules exchange. Second, modern humans' brains evolved to be more globular than our ancestors' (Neubauer & Hublin 2011, Gunz *et al*. 2012), thus leading to easier communication between on average spatially closer areas. No matter whether it derived from constraints linked to locomotion, bite force, cognition, and so on, according to Boeckx, the evolution of the brain shape provided easier cross-modularity.

Other contributions detailed the evolution of language in the brain and

alongside other cognitive abilities. Some talks focused on non-linguistic capacities in animals, like Kazuo Fujita's search for meta-cognition (Fujita 2012), or Moore's (2012) and Froese *et al.*'s (2012) studies of primates' depth of analysis of others' actions, whether or not in the context of communication. As usual, co-evolution enjoyed popularity, with various proposals. Invited speaker Tao Gong attempted at simulating the co-evolution of language acquisition and joint attention (Gong & Shuai 2012), while Michael Arbib (2012) and Russell Gray put forward the now classical relationship between language, gesture, and tool use. The results of the previously mentioned PET recordings of tool-makers were particularly stressed by Gray: The manufacture of late Acheulean tools, but not of older Oldowan or even of early Acheulean tools, resulted in increased activation in areas of (i) the parietofrontal praxis circuits in both hemispheres and (ii) the right hemisphere homologue of Broca's area. The hierarchical complexity of the organization of actions in the later tools correlates with the syntactic features — among others recursion — of modern language.

Tetsuro Matsuzawa gave an example illustrating the idea that abilities may not always get reinforced in a co-evolutionary fashion: His trade-off theory of memory and representation indeed articulates the acquisition of language and the strong decrease in eidetic imagery in humans, with the backup of experiments demonstrating the highly efficient eidetic memory of chimpanzees (Inoue & Matsuzawa 2007).

Finally, the social and cultural frame of language was considered through the prism of psychology, as well as of linguistics, animal studies or models.

At the core level of interactions, Matsuzawa insisted on the significant consequences of the differences in mother-child bonding between primates and humans. While baby primates are clinging to their mothers during the first months of their lives, early physical separations in humans allow face-to-face communication, vocal exchange, and early object manipulation. Cries in human babies are absent in primates, where the young by themselves move to reach their mothers' breasts.

At a larger scale, models tend to focus on the co-evolution of social and linguistic conventions. Models have evolved from homogeneous populations to structured yet static communities (e.g., Nettle 1999), before the introduction of more dynamical ties between agents (e.g., Gong & Wang 2005, Gong 2010). Bachwerk & Vogel (2012) presented a model with social ties continuously updated based on the success of previous interactions. Using a control parameter defining how cautious/impulsive the agents were to establish friendship (that is, reinforcing their tie with another agent) upon successive communication, the authors concluded that a high social update rate (making friends quickly and also forgetting older friends faster) paralleled sociological observations, and was very likely in early hominids, despite raising questions regarding the possibility to then build systems of conventions at a large scale.

In addition to building friendship and cooperation, the role of conflicts and competition between individuals was also considered in the emergence of language. The possibility of cooperative behavior under natural selection at the individual level has long been questioned (e.g., Axelrod & Hamilton 1981), and simulations like the previous one often leave this problem aside, although it

applies to the emergence of language as a specific form of cooperation based on exchanging information. Jacob Foster elaborated on recent works on the evolution of human cooperation, emphasizing intergroup competition as a factor favoring intra-group cooperation (Boyd & Richerson 2009). He considered language in this context as a catalyst for other intra-group cooperative behaviors and an accelerator of cultural differentiation (Foster 2012).

These different studies all show that carefully consideration of social structure is necessary, both to remind of the inter- and intra-group relationships that prevailed during hominid prehistory, and to account for the specific social distributions observed today, like scale-free or small-world networks, or quantitative observations like Dunbar's (2010) number of 'relationships'.

The socio-cultural environment of our hominid ancestors was finally addressed by a few contributors, although one may consider that as in previous Evolang conferences, this line of research did not prove as present as it perhaps should be: Indeed, theories and models about languages in animals and modern humans always run the risk of diverging from the actual course of prehistory. Archeological and paleo-anthropological data are safeguards against attractive but ultimately artificial evolutionary scenarios, but they also suffer from the complex chains of inferences needed to go from often scarce material remains to behaviors and collective thinking. This was apparent in Cuthbertson & McCrohon's (2012) re-reading of evidence on sea-crossings, leading them, contrary to others (Davidson & Noble 1992, Morwood & Cogill-Koez 2007), to deny the need of a sophisticated language to account for this behavior. In a similar fashion, Johansson (2012) reviewed the evidence for Neanderthal's language, building on data which lead to a variety of interpretations — likely depending on the intuitions of the scholars making use of them. A recurrent problem therefore lies in the integration of such data with other analyses of language evolution.

4. Future Research on the Evolution of Language

What conclusion may be drawn from the previous sections in terms of future research on the evolution of language, and can suggestions be made regarding potentially fruitful explorations?

First, the experimental trend on communication/coordination games is likely to develop in the coming years and strengthen itself as a fruitful paradigm. Just as computer simulations gradually shifted from the emergence of 'simple' linguistic conventions (holistic words, vowels, word orders) to more refined linguistic constructions (say, the expression of space; Spranger & Steels 2012), we may expect future games to focus on more specific linguistic domains (Steels 2012). They will then touch more closely on the grammatical devices used in modern languages and how such devices may have emerged in the past, thus connecting to similar attempts by 'traditional' linguists (e.g., Carstairs-McCarthy 1999, 2010; Heine & Kuteva 2007). However, one may wonder if they will not meet the same difficulties as some current models: as games grow in complexity, deciphering and presenting the emerging processes at hand become difficult. As one describes a formerly unknown language, providing a synchronic description of its linguistic processes can prove daunting; adding the additional layer of com-

plexity that creates diachrony and emergence often brings more issues than solves problems.

Recording 'online' brain activities as people engage in communicative activities seems another exciting avenue for research. With the simultaneous recording of several subjects, correlating synchronization at the psychological, linguistic, and neuronal levels becomes possible, which in a way opens the door to the idea of "neuro-pragmatics".

Integrating replicative archaeology and brain imagery, analyzing neural patterns of activities such as tool-making at the light of language-related brain areas also appear attractive. Tool-making and the related, precise control of motor actions are appealing in regard of the fine motor control needed for speech, but what other activities could be further studied? The Symbolic Revolution around 50,000 years before present, as observed by archaeologists in Europe and independently of its exact causes in the broader context of *Homo sapiens* emergence in Africa (Conard 2010, d'Errico & Stringer 2011), suggests looking at the making of more artistic and symbolic objects like anthropo-morphic or zoomorphic sculptures, for example, the ivory lion-man of Stadel-Höhle im Hohlenstein or the Venus of Hohle Fels (Conard 2009), or music instruments like flutes (Higham *et al*. 2012). What are the psychological and neurophysiological differences between making a tool and making a piece of art? Does an additional amount of imagination and creativity get reflected in the brain activations continuously or intermittently during the making process of the latter? Do we observe a clear distinction as between Oldowan and Acheulean, or a continuum going from purely 'functional' tools — that is, whose only goal is, say, to scrap meat, but not to carry symbolic meanings — to tools with symbolic markings to 'non-functional' objects like figurative sculptures?

Focusing on the neural aspects of the evolution of language also suggests addressing more closely the neurophysiology of language production and perception. Indeed, the neural bases of our communication system not only cover high-level cognitive functions, but also lower-level sensory and motor abilities that are essential and sometimes unique to our species. The neurophysiology of the emergence of *speech* has been addressed by some scholars (e.g., Kay *et al*. 1998, MacNeilage 1998, DeGusta *et al*. 1999, McLarnon 1999, Davis & MacNeilage 2004), though their focus has been mostly on the production. Although the issue was rather left aside during Evolang9, Shuai & Gong (2012) addressed the per-ceptual side by shedding some light on categorical perception, the functional lateralization of which was considered in the broader framework of language evolution (Wilkins & Wakefield 1995, Gannon *et al*. 1998, Cantalupo & Hopkins 2001, Botha 2003).

Departing from the preceding topics, another option for future research lies in semiotic approaches to early forms of symbolism (Coupé 2012). This line of thinking has been partially explored by palaeo-anthropologists (e.g., Henshilwood & Dubreuil 2009, Rossano 2010), but the investigations are often restricted to the surface of semiotic science — like Peirce's notions of icon, index, and symbol — and could make a better use of the typologies of signs established by semioticians (e.g., Peirce 1998, Farias & Queiroz 2003). Just as some speakers insisted on the special semiotic status of linguistic units with respect to others

symbols, one could question the specificities or archaeological artifacts as signs, or investigate whether the semiotic specificities of linguistic units also apply to them.

Finally, given the emphasis on the complexity of the relationship between the genotype and the phenotype, one may look for more realistic models of biological evolution in simulations integrating biology, culture, and learning. Many results on strong or weak innate biases behind today's linguistic universals are based on rather simple — if not sometimes simplistic — models of genetic regulation. One may therefore ask whether significantly different outputs could be obtained with designs involving gene networks rather than more independent genetic units.

As a conclusion, it appears that research on the evolution of language successfully follows an integrative path when it comes to the methods and fields involved. Concepts previously designed for the sole field of modeling — like iterated learning — have met the experimental field with success. Replicative archaeology, which previously helped understand our ancestors' past behaviors (including language) has now been benefiting from brain imagery techniques. Animal studies start to apply these techniques too, as well as network analysis. Theoretical notions of the Minimalist Program are now said to find their roots in the past evolution of brain shapes. To us, this is a strong sign of the vitality of the field, whose actors already plan to meet at Evolang10 in Vienna in 2014.

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