ISSN 1648-2824 KALBŲ STUDIJOS. 2014. 25 NR. * STUDIES ABOUT LANGUAGES. 2014. NO. 25

KALBOTYRA / LINGUISTICS

A Co-evolved Continuum of Language, Culture and Cognition: Prospects of Interdisciplinary Research

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crossref http://dx.doi.org/10.5755/j01.sal.0.25.8504

Abstract. This paper deals with questions of language evolution and discusses the emergence of linguistic communication systems in the framework of a co-evolving continuum of language, culture and cognition. Different approaches have tried to unravel the mechanisms underlying language evolution and put emphasis on different aspects, for instance, biological vs. cultural mechanisms. While both are important, I will argue that at least a strong nativism should be refuted. After comparing both approaches, evidence from various lines of research (but especially agent-based models) will be reviewed to argue for the existence of cultural evolutionary processes. In these experiments linguistic structure emerges from scratch via self-organization and selection merely due to interaction and cultural transmission. At the same time, the diversity we can observe in growing cross-linguistic data suggests that many grammatical and conceptual categories that had been considered 'universal' do in fact vary. These findings, especially in the semantic domain of space have led to claims about the relation of language and general cognition and a revival of the linguistic relativity hypothesis, but it remains unclear in which directions language, culture and cognition interact. Here I argue that these problems can be approached in the presented framework from an evolutionary perspective. I propose how to address them empirically by combining agent-based models, experimental semiotics and insights from comparative linguistics. I further aim to stress the importance of the ecological environment in evolutionary models and give examples of how it can be taken into account in future empirical work.

Key Words: *language evolution, linguistic relativity, cultural evolution, experimental semiotics, agent-based models, impact of ecology on language evolution.*

Introduction

How our uniquely human capability to communicate with symbolic language has emerged can be considered one of the grand questions in science (Christiansen & Kirby, 2003). The fact that language is completely unique to our species and has played a significant role in our cultural development throughout history and our social lives in general, make it an important topic to investigate.

After a brief review, in which the two main approaches toward language evolution are contrasted, the aim of this paper is to combine several fields of research to open up new territories in language evolution research. The present paper will focus on so-called agent-based models, where real robotic agents engage in linguistic interactions to model possible mechanisms of cultural language evolution – a strong argument against mere biological evolution. The implications of these experiments, namely that cultural mechanisms are actually sufficient for linguistic structure to arise, are then discussed alongside data from comparative cognitive linguistics. This data mainly concerns findings regarding spatial grammar across cultures and strongly opposes nativist and universalist accounts of language. In addition, it suggests interrelations between language and general cognition (most importantly, spatial cognition).

These two lines of research will then be discussed together to argue for a co-evolved continuum of language, culture and cognition, extending a three-way cycle proposed by Steels (2012) with ecological factors and an even closer integration of language and general cognition. Subsequently, I present a number of fruitful prospects this yields for future research into the nature of our species.

Cultural evolution, as will be shown, is a factor for language which cannot be neglected, especially not in the framework of the co-evolved continuum proposed. Agent-based models provide a very useful research paradigm, because they allow modeling hypotheses on the mechanisms of this factor in language evolution and further support its existence.

Theoretical Background

As a theoretical foundation, this section will present the two predominant approaches into which contemporary research on language evolution can be divided (cf. Steels, 2012). They have been dubbed 'biolinguistics' and 'evolutionary linguistics', each of them putting a distinct focus on the subject of investigation. Both try to uncover language's biggest and oldest secret, how this uniquely human phenomenon came to be and what mechanisms drive its ongoing development. However, the former puts emphasis on the biological side of things, investigating, e.g., genetic foundations and comparing interspecific phenomena, while the latter is highlighting the role of cultural factors as the main driving force in language evolution. Both can also be related to generative linguistics and its diverged descendant cognitive linguistics advancing different views on the

organization of the human mind, the question of modularity or interrelation of cognitive capacities and universals in human languages.

1. Biolinguistics and the Nativist Account

While 'biolinguistics' could technically refer to any scientific inquiry across disciplines concerning the biology of human language and its evolution respectively, the term has mostly been used to refer to generatively-oriented programs that emphasize the biological evolution of language (Jenkins, 2001; Di Sciullo & Boeckx, 2011). Studies that can be subsumed under this term ground themselves in Chomsky's generative linguistics (Chomsky, 1980, 1993b) and are built on concepts such as Universal Grammar (UG) or the minimalist program (Chomsky, 1993a; Boeckx, 2006). The concepts of Universal Grammar, "the language instinct" (Pinker, 1994) and the "faculty of language" (Hauser, Chomsky & Fitch, 2002), all refer to language as hard-wired in a specialized module in the human brain. This notion thus presupposes a nativist bias toward human ability to acquire language, an emphasis of biological evolution and a modular view of the mind and brain – the latter implying that language is processed in a module separate from other cognitive abilities (cf. Fodor, 1983). This would mean that in all languages governed by universal concepts/ categories in the UG the very same structures should be observable (cf. Levinson, 2009, p.28). Linguistic minimalism is based on the Principles and Parameters approach, which provides "the language learner with a fixed set of principles", i.e. rules of grammar (Boeckx, 2006, p.14) and conceptualizes UG as perfectly designed and optimized to respond to all conceptual and physical needs regarding language (p.15).

One problem with UG though is that there is no unitary consensus in the scientific community on its exact contents, which has made it harder to argue for or against it (cf. Tomasello, 2005; Levinson & Evans, 2010, pp.8–9, for a summary of different UG definitions see Tomasello, 2004). If, for example, UG just refers to a set of learning principles (in an almost behaviorist manner, as already theorized by Skinner, 1957; or in the sense of usage-based models of language acquisition and change, cf. Tomasello, 2003; Langacker, 1987; Croft, 2000, 2010b), or if it just contains trivial aspects ("all languages have vowels", cf. Greenberg, 1986, p.14 cited in Levinson, 2009), then the idea of a UG would be broadly compatible with cognitive linguistic accounts that departed from strong nativism and generativism.

One line of research within the biolinguistic framework recently included investigation of the FOXP2-gene that has been associated with language impairments (Lai et al., 2001). The investigations were promising at first and the isolated gene has been referred to as "the language gene" since its accelerated evolution roughly coincided with the estimated emergence of language in humans (Zhang, Webb & Podlaha, 2002). However, FOXP2 is not regarded as a mere language gene anymore, as it could be shown to regulate a wider range of cognitive capacities for different body parts (cf. Steels, 2011b, p.341). FOXP2 is, if a part of the signaling pathway controlling language, probably just one link in the chain, and direct effects of the gene on human neurons have not yet been tested (Konopka et al., 2009).

Apart from this avenue of research, there is also a comparative approach within biolinguistics. The faculty of language has been theoretically divided into the faculty of language in the broad sense (FLB), which is shared with other species, and in the narrow sense (FLN), which is uniquely human (Hauser, Chomsky & Fitch, 2002). The FLB can then be investigated across species, for example in avian or whale singing or great ape communication (Fitch, 2010; Tomasello, 2008[1]). Traits in humans and distant species can be used to discern the principles for the evolution of systems like syntax, semantics and speech. These systems are all important for language and could have different evolutionary histories (Fitch, 2005, p.2).

In summary, biolinguistics favors biological evolution, presupposes innate language capabilities and thus views language as a discontinuously evolved capacity (the emergence of the FLN in humans can be viewed as the turning event providing all of the biological prerequisites, cf. Berwick & Chomsky, 2011). One problem remains, namely that there is no consensus on the UG/ FLN, and the concept remains hard to falsify.

2. Evolutionary Linguistics

Generative linguistics and accompanying concepts such as UG have been a mainstream approach in language research at least since the second half of the past century. Opposing positions have entered discourse, mainly coming from younger cognitive linguistic theories (e.g., Langacker, 1987) and typology (Croft, 2002; Levinson & Wilkins, 2006), challenging the idea of innate language universals and a modular view of cognitive language organization.

One argument by evolutionary linguists against simple nativism is the co-evolutionary argument, stressing the interference of culture and biology (see Levinson, 2009; Levinson & Evans, 2010). Language in this context would be just one example among many adaptations that *homo sapiens* have experienced over their (cultural) evolution. Culture would pass down form and content, while the biological organism, inherent learning mechanisms especially, provides constraints. Infants are pre-adapted to anticipate cultural variation and can easily learn local systems, while it is harder for adults to adopt new categorizations from their surroundings (cf. Levinson, 2009, p.27). The biological ability for language would then rather be a learning mechanism, specialized to acquire systems (e.g., language) that vary culturally and flexibly handle them, instead of a UG.

Language here is not discontinuous, but experiencing long-term changes shaping its evolution via processes of selection and self-organization over time (Steels, 2012), which also leads to diachronic variation and constant language change (Croft, 2010b). Thus, corpus studies from historical linguistics can be used to investigate the qualities and pat-

[1] It should be noted that while Tomasello's primate studies compare language capacities in humans and apes, he himself argues against the idea of an UG and stresses the need for cooperation and joint action as a basis for language.

terns of these changes and grammaticalizations to learn about their origin.

At the same time, comparative synchronous studies of the world's languages show that many linguistic concepts or categories (e.g., case, color categories or basically any morphosyntactic feature) that were deemed 'universal' in the past, do vary across languages and are missing in some (cf. Croft, 2010a; Steels, 2011b, p.345). Thus, universals do not hold. Section *Linguistic diversity is out there: the case for space* will cover this point in detail.

It is important to note that these findings of variation have also been used to argue against a modularized view. Language did not evolve separately from culture, but is highly influenced by it. In linguistic relativism it is further claimed that language and general cognition influence each other, driven by cultural factors (see *Linguistic diversity is out there: the case for space*). The common biology enabling language would then include basic capacities shared with other cognitive subsystems, e.g., recognition or production of hierarchical structure (cf. Steels, 2011b, p.341). It is conceivable that such cognitive functions would simply have been recruited over time by language (if not a sudden genetic mutation would have given rise to an autonomous language organ), which is supported by the facts that language areas can be distributed widely (Pulvermüller, 2005, 2010, consistent with the embodied view, e.g., Barsalou, 1999), that brain tissue is not adequately functionally specific and that different languages prefer different pathways or lateralize differently (cf. Levinson & Evans, 2010, p.13).

In sum, the evolutionary linguistics view stresses cultural evolution and employs research traditions from cognitive linguistics, historical and comparative typology and anthropology to explore the underlying mechanisms and consequences of this evolution in a synchronic and diachronic manner. Language is viewed as having emerged through a series of interactions between individuals negotiating conventions that propagate and continue to change.

Arguments for Cultural Language Evolution

Several arguments can be put forward to support a cultural evolution of language and refute an exclusive involvement of biology in the evolution of both language as a general phenomenon and individual languages. Here, I will first present experimental evidence, focusing on results of experimental computer science and robotics. In the following section, comparative language data is presented using the case of spatial language which suggests that universals are unlikely. Then we return to the experimental domain to show how both fields interrelate, which will lead to the final discussion.

1. Agent Based Models of Cultural Language Evolution

There have been various experiments suggesting possible evolutionary mechanisms for language. Instead of looking at "point zero" – a first instance of what could be considered language – these experiments rather address the mechanisms governing the observable structure of language: How do languages as structural semiotic systems emerge, and how do they change over time?

One kind of experiment in this domain is, for instance, iterated learning experiments. Iterated learning means that the output of the first individual's learning is passed on to a second individual as input, who is again passing on their output, etc., a process in which structure can be observed to emerge as a part of cultural learning. This has been claimed to be a reaction to the poverty of stimulus argument[2] (cf. Chomsky, 1980) via compositionality (Smith, Kirby & Brighton, 2003). Iterated learning does not only take place vertically but also results from horizontal negotiation of conventions, i.e. it can happen back and forth between individuals as well (cf. Scott-Phillips & Kirby, 2010, p.414). These models have been simulated virtually (Kirby, 2001; Smith, Kirby & Brighton, 2003), but also tested with human subjects (see Scott-Phillips & Kirby, 2010 for a review of experiments).

A more elaborate approach is the agent-based experimental studies by Steels and colleagues. While the agents in computational approaches adopting the iterated learning paradigm tend to be mathematically formalized, in agent-based models, they can be physical robots. This entails the advantage of their situatedness in an environment and personal 'perceptual' representation (individual in every agent, see Spranger, Loetzsch & Steels, 2012). Agents build up their own 'worldview' based on their hardware and actual bodies in the environment within which they interact (e.g., determining, different vantage points from which a scene is viewed and continuous features such as color, position, width, length and height). The perceived values are then transferred into categorizations in language (as proposed in Talmy's (2000) cognitive semantics) with a formalism of open-ended and procedural semantics called Incremental Recruitment Language (IRL) that "configure[s] a network of cognitive operations to achieve a particular communicative goal" (Spranger, Loetzsch & Steels, 2012).

The interactions can be referred to as "language games" (Steels, 2012), meaning pragmatic communicative situations in Wittgenstein's (1953) sense. It should be noted that, without any change in hardware, the agent's software is updated only as a result of every successive interaction over the entire 'lifetime' of the agent (cf. Spranger, Loetzsch & Steels, 2012). There is no artificial UG providing language skills, and no 'genetic mutation' changing the hardware to handle language. The second employed formalism uses a cognitive linguistic approach as well: Fluid Construction Grammar (FCG, Steels, 2011a) was developed to cope with both production (mapping meaning to form on the speaker's side) and parsing (reconstructing meaning from form on the hearer's side) acknowledging the continuum of meaning and form (and semantic and syntactic poles, respectively)[3] proposed by authors such as

[2] The argument states that primary linguistic data is intrinsically not good enough to infer rules.

[3] *Meaning* should not be taken literally, because it is not as such in the FCG formalism that basically consists of labels. Nevertheless, it can be considered a form of meaning 'subjectively' grounded in the real world through the artificial sensori-motor systems the robots are equipped with (cf. Steels, 2012, p.12), which is the big advantage of this young experimental approach over mere mathematical models. Furthermore the Construction Grammar approach from cognitive linguistics was applied,

Goldberg (1995), Kay and Fillmore (1999) and Croft (2001) and equipped with a double-layered architecture incorporating diagnostics and repair (meta-language processing, i.e. 'knowing what one talks about', cf. Beuls, van Trijp & Wellens, 2012).

Over many interactions the phenomena of self-organization and selection can be observed together with more general principles of structure emerging in a population. The fact that many interactions can be carried out virtually in a very short period of time makes it possible to look at temporal long-term changes, which would not be possible, e.g., in iteration experiments with human subjects.

As a result of the experiments, several linguistic phenomena have been described to emerge from scratch (agents start with sufficient and necessary functions, but without concrete choices, cf. Steels, 2011b): Agreement (Beuls & Steels, 2013) and specifically case (van Trijp, 2012) arose, minimizing combinatorial search and semantic ambiguity. A population adopts a strategy for markers (inventing new ones if they don't exist, then spreading them) that develops in a self-organized manner into an agreement/ case system which is passed on culturally. The same could be shown for color categories arising (Steels & Belpaeme, 2005). The key factor in these experiments is structural coupling: both emergent linguistic conventions and the concepts they express are organized "*based on the outcome of their [the agent's] communicative interactions*" (Steels, 2011b, p.351, emphasis in original). This is achieved by lateral inhibition[4] and alignment: concepts that are more successful in the present situation will be preferred (cf. Pickering & Garrod, 2006).

The origin of language in the games can be viewed as a cultural ratchet effect (cf. Tomasello, 1999, p.5), where one generation comes up with a new concept or strategy and subsequent generations not only pick up the established conventions, but further enhance them (cf. Tomasello, 1999). Thus, the system gets more and more stable through interaction not only between two agents, but also over generations, similar to technological artifacts, that are usually build based on what is already there, while completely new innovations are rare (but even these can immediately enter the cultural ratchet when they occur).

The aim of agent-based simulations is not to imitate language as it is out there, but to find a working model first, which can be implemented in computing or, as soon as it is elaborate and plausible enough, be checked for its natural validity (cf. Steels, 2011a, p.2).

An approach that tries to allow for more validity by using human subjects is experimental semiotics (Galantucci & Garrod, 2010). The idea is that instead of looking at language, participants have to come up with novel semiotic communication systems in experimental situations. It could, e.g., be shown how such systems arise in interaction to solve abstract coordinative games (Galantucci, 2005) or how they evolve from initially being very iconic to efficient symbolic systems, intransparent to outsiders (Garrod et al., 2007).

because generative (context free) grammar is not well suited to implement both, production and parsing.

[4] Scores of concepts that led to successful games increase, while scores of surrounding concepts that had been previously adopted decrease (cf. Steels & Belpaeme, 2005).

2. Linguistic Diversity is Out There: The Case for Space

In linguistics, many features of languages have long been taken for granted simply because there was not enough comparative data across languages. English (along other Indo-European languages) has long been the primary object of study.

All the more relevant is the growing body of cross-linguistic studies, especially those taking into account language families that have been ignored in the past. In recent years, empirical cross-linguistic data has been collected and compared, wherein dramatic differences to the previously best described language families surfaced, challenging the assumption of universals (cf. Haspelmath, 2007; Croft, 2010b). The investigated languages differ not only morphosyntactically from Indo-European ones, but are also characterized by different semantic categories and concepts. Diversity in the domain of space has often been cited as an argument for cultural evolution (cf. Evans & Levinson, 2009), and spatial cognition is a favorable topic for cognitive science in general, as moving in space and locating oneself and other objects within it have been quoted as necessary components of higher "intelligence" and cognition (cf. Polani et al., 2007; Pfeifer et al., 2008). 'Intelligent' in this sense refers to cognitively higher animals that are interacting with and moving in an environment (in contrast to, for instance, plants). These demands would have led to the emergence of spatial thinking and explain why, e.g., mammals are so good at spatial processing.[5]

In field studies, Levinson and Wilkins (2006) have compared twelve languages in respect to spatial grammar. Their results show significant variations in how topological relations, movements or distant relations between objects are expressed. Levinson used this data to support his theory of three spatial *Frames of Reference* (FoR) that he supposed to actually vary in use and profiling among languages (Levinson, 1996, 2003). To give an example for the three FoRs consider the following:

(1) He is in front of the university.
(intrinsic FoR)
(2) He is to the left of the university.
(relative FoR)
(3) He is west of the university.
(absolute FoR)

All three sentences describe the same person standing at the exact same spot, but apply different coordinate systems. In (1) intrinsic coordinates of the *Ground* (G, one side of the building we would designate as *front*) determine the coordinates to locate the *Figure* (F, a male person; for the Figure-Ground distinction, derived from Gestalt-theory see Talmy, 2000). In (2) F and G are complemented by a third coordinate V, the *Viewpoint*, from which the scene is

[5] Time in comparison is processed not as easily and therefore appears to be more abstract, probably motivating conceptual metaphors for time (cf. Boroditsky, 2000).

observed; the strategy becomes relative[6]. In (3) G consists of fixed allocentric coordinates (the cardinal directions in this case) that are consulted to locate F in respect to G, an absolute solution, indifferent to where the speaker is located.

It could be shown that some of the twelve languages did indeed only employ one of the three FoRs. Aboriginal speakers of Guugu Yimithirr, for instance, solely use an absolute coordinate system to locate themselves and objects in space, as in (3). Interestingly, not only did languages, like this one, differ in concepts, but effects for non-linguistic cognition were observed as well. Speakers that exclusively use an absolute frame of reference showed extraordinary accuracy in pointing to objects out of sight and the cardinal directions outperforming a Dutch control group, a phenomenon which has been dubbed a "mental compass" (cf. Levinson, 2003). Additionally, different neural pathways have been shown to underlie the FoRs in the fMRI (Janzen et al., 2012). The fact that there are cultures solely relying on a single FoR and completely unfamiliar with concepts we take for granted[7] shows that our own Indo-European and anthropocentric biases strongly affected our image of cognition. At the same time, the results strongly support culture as a driving factor for language evolution and speak against universals. Partly as a result of the growing amount of data from newly described languages, 'linguistic relativity' experienced a recent revival. In the case described above, it could be inferred that non-linguistic cognition is influenced by language, as special cognitive abilities and disabilities (a 'mental compass', or inability to apply the concepts of left and right) reflect the FoR employed in a specific language. If a language does not use a FoR, the speakers do not either. Therefore a Neo-Whorfian claim can be found in the contemporary literature: language does not determine thinking, but might influence it (which is a more moderate claim than the original Sapir-Whorf-Hypothesis, which had been dubbed too deterministic by generativists). Furthermore in the spatial domain there is evidence that the FoR can affect how time is conceptualized spatially (Fedden & Boroditsky, 2012). In sign-language, homesigners (deaf children that did not learn a fully-fledged sign language) without spatial gestures perform worse in non-linguistic spatial tasks than Turkish speakers of the same age who had spatial grammar readily available (Gentner et al., 2013). There have been numerous findings in other modalities as well (see Everett, 2013 for a review).

Summing up, the domain of space can be used as a prime example for linguistic diversity based on cultural effects: different cultures categorize and conceptualize space differently in their languages. The next section will return to agent-based experiments, but stay in the domain of spatial language to show links between the comparative research presented above and studies in cultural language evolution. These will later be elaborated on in the discussion.

3. Models for a Cultural Evolution of Spatial Grammar

The aforementioned theories of spatial grammar are also applied experimentally in a line of ongoing research. For instance, Spranger and Steels (2012) let robots play language games that focused on the identification of objects in space via relations. The robots had to apply perspectival reversal (take the point of view of another object or agent into account) and use *fixed landmarks* (LMs). In the IRL (see *Agent Based Models of Cultural Language Evolution*), cognitive operations and the objects over which they operated were put into a network. In a set of experiments the agents where equipped with a spatial lexicon without grammar (a pidgin language based on German) and it could be shown that the more complex the scenes to communicate about became, the more spatial grammar was needed to disambiguate. In a next step, they observed grammatical constructions arising by constraining the agents to one FoR-strategy using an allocentric LM. After a certain number of interactions, 'cognitive' processing efforts dropped dramatically compared to the 'pidgin-speakers' and the robots succeeded in more complex communication games. A self-organizing emergent grammar was observed (cf. Spranger & Steels, 2012, p.13).

While this study focused on grammar, Spranger (2013) looked at spatial LM systems. It could be demonstrated that the use of marked LMs in spatial language positively affected communicative success (compared to populations that used other strategies). It could further be shown that unmarked LM systems might be an intermediary evolutionary stage, since something has to be a potential LM in the interactions before actually becoming one.

It is remarkable that, just as can be observed in field studies, robots that are given different constraints ahead of the experiments develop diverse, but splendidly adapted strategies – a finding which shall serve as a final argument for cultural evolution here. Just as real-world populations, the robots can profile different reference systems in their spatial grammar. Majid et al. (2004) therefore suggest that the choice of an FoR could have an ecological bias (which they call "ecological determinism", p.112). In their study, they present data from 21 languages, showing that there are interesting (albeit not yet verified) correlations between certain ecological features like dwelling or subsistence mode and predominant FoR.[8]

Discussion: A Holistic Continuum

Of course, neither the theory of cultural language evolution nor the theory of a biological foundation for language can be refuted completely. They have to be weighed up against each other, without taking a too extreme position. Most researchers would certainly acknowledge that some biological structure is required in the first place to actually be able to start a cultural evolution process (Steels, 2011b). But biology is not everything.[9] The reviewed evidence for

[6] The viewpoint could be either that of the speaker or of the hearer.

[7] For instance, Kant (1768/1991) believed the egocentric concepts of left and right would be universal.

[8] This can further be underlined with findings from cognitive anthropology: Hutchins (1983), for instance, describes a navigational system employed in Micronesia, which integrates the environment to an extend that it would work nowhere else, but enables the locals to travel miles on the sea without instruments – an example of exceptional cultural adaption, driven by ecological conditions.

[9] In fact, there is even explicit counter-evidence from biology, arguing that it would be highly unlikely for specific language genes to have de-

cultural diversity in language and cognition and successful agent-based experiments show that linguistic universals might only comprise a very small fraction, and that structure can emerge without any changes in biological "hardware" simply by means of negotiating cultural conventions through interaction. In this sense, while rejecting extreme nativism, a weaker biolinguistics approach can still be employed. *Bio-* here would mean, e.g., how language is actually processed at the neurobiological level (cf. Pulvermüller, 2010), how pathways are distributed and shared with other cognitive subsystems and which genes organize them.

I agree with the three component spiral Steels (2012) proposes: language evolution would be driven by a biological, a cultural and a social force. The last one is particularly important, because it has been neglected so far. Language can be regarded as a social phenomenon as well, depending on its use in social contexts and cooperative action, "mutualism" and "indirect reciprocity" (Tomasello, 2008). I would further extend the cultural force to "eco-cultural", as comparative studies in linguistic relativity research and anthropology suggest that the ecological environment can constrain or gear cultural evolution into certain directions (cf. Majid et al., 2004, p.112; Everett, 2013).

In a non-modular view, "language is embedded in a larger cognitive system that it can make full use of", as Steels (2012) holds to explain how in language processing monitoring[10] is implemented in the cognitive architecture. If, though, general cognition is already driven by external factors and to a certain extend relative, language is likely to recruit slightly differently shaped cognitive strategies in different populations.

Imagine living in a vast area like a Guugu Yimithirr speaker (cf. Section *Linguistic diversity is out there: the case for space*): left and right are not very helpful, so you would rather want to save the cognitive effort of segmenting your body conceptually[11] and concentrate on your absolute position, which is much more convenient for orientation in your local environment. And since you are so good at knowing where north is, it makes sense to use it in language as well, which will yet again further train your 'mental compass', as it has to be accurate for successful 'language games'. This is not Whorfian determination; this is a mutual influence of language and cognition driven by the need to adapt to a specific cultural environment.

Other languages use salient LMs: Tzeltal speakers apply *uphill* and *downhill* to locate objects, which is highly efficient for them, since their territory (Tenejapa, Mexico) is located at a giant slope (cf. Levinson, 2003). In tropical rain forests, in contrast, relative FoR systems are more frequent (cf. Majid et al., 2004, p.112). Again, this seems fairly obvious, since in a dense jungle it can be hard to track fixed LMs. Mian, spoken in Papua New Guinea, even applies the spatial orientation system motivated by two nearby rivers to talk about temporal relations. It is only after years of formal education that this way of mapping slowly gets replaced with a left-and-right representation (cf. Fedden & Boroditsky, 2012). Probably, none of these strategies would have emerged if those communities didn't actually live in the environment they do.

In my opinion, this line of research bears good prospects to be integrated into studies concerning cultural language evolution. Not only should ecological and cultural relativity factors between language and cognition be included in the three way spiral mentioned above, but also in future practical experiments.

An agent-based approach is very promising as it enables one to test working models of cultural selection that can be refined until results that appear close to nature emerge. However, more factors should be included into agent-based generational simulations. Spranger (2013, p.1204) notes that the languages in the lab "develop in a vacuum", while "in the real world, different syntactic and semantic systems and strategies within a language interact and influence each other". An example for such different strategies is given by the spatial FoRs mentioned in section *Linguistic diversity is out there: the case for space*. I therefore propose comparative experiments with several populations of agents in different 'ecological' conditions to analyze whether environmental biases can influence cultural choices. Communicative success is, after all, the selective force in the simulations, while at the same time it might be responsible for the choices that real communities make. One could further try to merge the populations outside of their original environment (I would predict absolute systems to vanish in favor of flexible relative and intrinsic systems, as prevailing in mobile Western societies[12]). Also, more than one modal grammar (e.g., space and time) could be made available to the agents to see if different semantic systems can influence each other evolutionarily over many interactions or if cognitive effort can be reduced in non-linguistic tasks related to a previously acquired linguistic strategy. One could even propose far-reaching studies to answer big questions fought over in the literature, such as "does Pirahã have recursion?", which is disputed by opponents and proponents of UG. Everett (2005) claims that Pirahã has a lot of linguistic anomalies strongly tied to the culture and lifestyle of the native speakers of that language. It is imaginable to build on previous experiments in the future to simulate their cultural environment as well as communicative goals specific for their culture, and subsequently try to verify how likely recursion arises necessarily in this context or not. 'Specific goals' means cooperative goals (cf. Tomasello, 2008) and equals the social component in

veloped, except in a completely stable linguistic environment, where cultural change is not too fast for the biological arrangement to co-evolve with the language. Such a scenario is highly unlikely as culture usually changes significantly more rapidly than genes (see Chater, Reali & Christiansen, 2009).

[10] i.e. the routine diagnostics and repair during production and parsing (cf. section *Agent Based Models of Cultural Language Evolution*)

[11] Levinson (2003) shows that infants from absolute communities acquire their local system in fact faster than Western children do with our arbitrary left-and-right system.

[12] In large urban areas, we are in a similar situation as in a dense jungle, and usually we travel so far that a local system would not be handy. Additionally our culture abstracts so often from our natural vantage point (maps, television, etc.) that it makes sense to have an absolute FoR as well, cf. *the university is north from the city center*, but it is much less in use than the relative one (*left*, *right*, in *front,* etc.).

Steels' spiral. Language is something that emerges from interaction, as should have become clear at this point. It does not arise in discrete individuals (cf. the *private language* argument brought up by Wittgenstein, 1953). Various experiments show how interacting dyads can develop novel semiotic communication systems based on mutual goals and a shared common ground if they are exposed to completely novel tasks where cooperation becomes a necessity (cf. Gallantucci & Garrod, 2010). Hence, future semiotic experiments can be used to test the role of ecological influences on emerging communication systems. This avoids the problem that artificial agents hardly represent any psychological reality and corresponding findings could bridge the gap between both fields. I suggest employing virtual reality paradigms, wherein subjects play coordinative games that require them to come up with novel ways to communicate. If different populations play in different environments with different affordances, perhaps systematic differences between the arising systems can be observed.

While we are still far away from doing things as elaborate as the Pirahã-example, the experiments conducted already suggest we are on the right track to do so. I believe the emphasis of an integrated continuum of co-evolving language, cognition and culture (including social and ecological conditions) can be of high value for a foresightful agenda in experimental language evolution research.

Conclusions

At the beginning of this paper, two approaches toward language evolution have been presented. Generatively oriented biolinguistics emphasizes the role of biological evolution and a universal language module (UG), while cognitively oriented evolutionary linguistics stresses cultural evolution and linguistic diversity. At the end of the day both fields are important, since language is shaped by more than one evolutionary process, as Steels (2012) points out. However, in this paper I hold that at least a strong nativist claim within biolinguistics is not fruitful. I therefore reviewed robotic agent experiments rooted in historical and cognitive linguistic ideas, as well as comparative linguistic data to argue for the fact that cultural language evolution does indeed exist. Applying the uniformitarianism principle suggested by the geologist Lyell (cf. Steels, 2011b, p.446), slowly moving long-term processes of selection and self-organization could have shaped language, just like the continents of earth have been shaped over millions of years - a view that seems to reflect observable language better than the idea of a sudden discontinuous transcending from pre-linguistic humans to our first ancestors equipped with a "language instinct".

I furthermore suggested complementing the cycle of biological, cultural and social evolution with insights from linguistic relativity research that in my view can be integrated into the experimental approach to model language evolution. Taking the ecological environment into account in experiments might tell us why the world's languages differ in the way they do. Only with an interdisciplinary approach, I believe, it is possible to describe the full continuum of culture, language and cognition that has evolved throughout history. If we want to describe human language and its evolution, we can commence by describing certain phenomenal aspects, but to see the whole picture we have to look at how these aspects interdepend and comprise the situated, embodied, and highly cultural species we are. Experimental designs integrating these aspects are a first step, and this paper has set out to lay the theoretical foundations.

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Jonas Nolle

Išplėtota kalbos aplinka (kontinuumas), kultūra ir pažinimas: tarpdisciplininio tyrimo perspektyvos

Santrauka

Šiame straipsnyje nagrinėjama kalbos vystymosi ir ir lingvistinės komunikacijos sistemos, išplėtotos kalbinės aplinkos, kultūros ir pažinimo kontekste. Ankstesniais tyrimais jau buvo bandyta atskleisti kalbos evoliucionavimo mechanizmus, akcentuojant skirtingus aspektus, pavyzdžiui, lyginant biologinius ir kultūrinius mechanizmus. Jie abu yra svarbūs, tačiau, mūsų manymu, natyvizmo (įgimtų idėjų) teoriją reikėtų atmesti. Palyginę abu aspektus, nagrinėjame įvairius mokslinio tyrimo duomenis, ypač modelius su veiksniais (agentais), ir teigiame, kad egzistuoja kultūriniai evoliucionavimo procesai. Mūsų eksperimentuose lingvistinės struktūros atsiranda iš nedaugelio ženklų, dėl saviorganizacijos ir atrankos bei tarpusavio sąveikos ir skirtybės leidžia teigti, kad daugelis universaliomis laikytų gramatinių ir konceptualiųjų kategorijų iš tiesų skiriasi. Šie rezultatai, ypač semantiniame lauke, leidžia daryti išvadas apie kalbos ir bendrojo pažinimo santykį ir pateikti lingvistinio reliatyvizmo hipotezę, tačiau ir toliau lieka neaišku, kaip sąveikauja kalba, kultūra ir pažinimas. Straipsnyje teigiama, kad šias problemas galima spręsti pateiktame kontekste iš evoliucionavimo perspektyvos. Siūlome būdą, kaip spręsti jas empiriškai, derinant veiksniais (agentais) paremtus modelius, eksperimentinę semiotiką ir lyginamosios lingvistikos įžvalgas. Be to, pabrėžiame ekologiškos aplinkos reikšmę evoliucionavimo modeliams ir pateikiame pavyzdžių, kaip į tai atsižvelgti tolesniuose empiriniuose mokslo darbuose.

Straipsnis įteiktas 2014 10
Parengtas spaudai 2014 11

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