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Symposium on "A multi-methodological approach to language evolution"

Introductory article: Studying the evolution of language: a multi-methodological enterprise

Angelo Cangelosi

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Abstract This symposium includes a selection of articles on the origins and evolution of language. These are extended version of selected papers presented at "EVOLANG6: The Sixth International Conference on the Evolution of Language" that was held in Rome in April 2006. This selection of papers provides a multi-methodological view of different approaches to, and theoretical explanations of, the evolution of language.

The field of language evolution is an interdisciplinary effort with an intrinsic limitation, i.e. the lack of "direct" data and evidence. We only have access to the final result of language evolution, i.e. human languages and language speaking individuals. However, there is a great deal of "indirect" evidence (e.g. comparative psychology experiments, archaeological records and fossils, anthropology studies, primatology, neurolinguistics, historical linguistics, etc.) that can be used to investigate possible language evolutionary scenarios, this has in the past hindered research.

A number of elements have significantly contributed to the progress in studying language origins over the last 20 years:

1. the reconciliation of language evolution theories with modern Darwinian theories (e.g. Pinker and Bloom 1990)
2. a strong interdisciplinary effort to the study of language and cognition
3. an improved understanding of scientific method generally that provides more forms of evidence for studying evolutionary issues, like distributions of genetic traits, distributions of probabilities of outcomes

A. Cangelosi (✉)
Adaptive Behaviour and Cognition Research Group, School of Computing, Communications and Electronics, University of Plymouth, Portland Square Building, (A316), Plymouth PL4 8AA, UK
e-mail: acangelosi@plymouth.ac.uk
URL: http://www.tech.plym.ac.uk/soc/staff/angelo

4. the contribution of computational modelling approaches, such as computer simulations of language evolution (Cangelosi and Parisi 2002).

Traditionally, scientific theories are expressed verbally or with the help of formal and mathematical symbols. Simulations are a novel way to express theories in science in a concise and operational way. Simulations are scientific theories expressed as computer programs. The program incorporates a set of hypotheses on the causes, mechanisms, and processes underlying the simulated phenomena and, when the program runs in the computer, the results of the simulations are the empirical predictions derived from the theory incorporated in the simulation. All this contributes to the development of new approaches to the study of the origins and evolution of language and leading to significant advances on language evolution theories (Christiansen and Kirby 2003).

This symposium provides evidence of the strong interdisciplinary approach to language evolution studies and of the contribution of computer modelling methodologies. The articles include contributions from the field of comparative psychology (Seyfarth and Cheney, Arbib and Bonaiuto), anthropology (Knight), experimental psychology (Jeffreys), social cognition (Seyfarth and Cheney, Bryson) and mathematical and computer modelling (Arbib and Bonaiuto, Briscoe, Bryson). Below I provide a brief summary of the six articles. I then conclude by highlighting some of the common themes, theories and results in these various multi-disciplinary contributions.

Arbib and Bonaiuto's contribution is based on computational and experimental neuroscientific studies of action learning. They extend the Mirror System Hypothesis of language origins (Rizzolatti and Arbib 1998) based on new computational neuroscience studies on imitation and action learning. This hypothesis charts a progression from a monkey-like mirror neuron system to a chimpanzee-like mirror system that supports simple imitation and thence to a human-like mirror system that supports complex imitation and language.

They present two new computational models of action learning and control: MNS2 and ACQ. MNS2 (Mirror Neuron System 2) is a new model of action recognition learning by mirror neurons of the macaque brain. This extends the previous MNS model (Oztop et al. 2004) by addressing data on "audiovisual" mirror neurons that associate sounds with manual actions. MNS2 associates each sound with a distinct pattern of activity that is applied to audio input units, corresponding to a direct connection from auditory cortex to cortex region F5 (precursor of Broca's area). This type of audio information is inherently actor-invariant and this allows the monkey to recognize that another individual is performing that action when the associated sound is heard. ACQ (augmented competitive queuing) is a model of opportunistic scheduling of action sequences. This constitutes the background for analysis of modelling strategies for "simple imitation" as seen in the great apes, and "complex/goal-directed imitation" as seen in humans. The authors use these models to examine a progression of modelling ideas that address the evolutionary progression from the (very) limited imitation abilities of monkeys to the "simple imitation" of the great apes and the "complex imitation" of humans. Complex imitation involves many processes that are building

blocks of the capability for language such as the ability to parse a continuous stream of perceived actions into meaningful hierarchies of chunks, make inferences, and use these mechanisms to modulate the production of one's own actions. The understanding of what different brain mechanisms may underlie behavioural differences between monkeys, apes, and humans helps us better understand the evolution of brain mechanisms for action which paved the way for the evolution of the human language-ready brain. Arbib and Bonaiuto strongly support that this combination of computational modelling methodologies and neuroscientific investigations will provide new insights into the brain mechanisms that support protosign, protospeech and, in their full elaboration, language.

Briscoe's contribution is based on mathematical modelling of linguistic phenomena and its relation to language origins. He discusses the ubiquity of power law distributions in language organisation, as well as in other domains. In language, the distribution of languages within language families approximates a power law (Wichmann 2005). In terms of inherent properties of language, Zipf showed that the relationship between word frequency and work ranking position yields similar distributions. Power law distributions are good approximations of many other non-linguistic phenomena, such as the distribution of people within cities, citations amongst scientists, accesses of web pages, activation of genes, size of earthquakes, number of sexual partners, and many more (e.g. Albert and Barabasi 2002).

Briscoe argues against Miller's (2000) argument, based on Zipf's law observations, that large vocabulary size is a consequence of sexual selection. Instead he claims that power law distributions are evidence that languages are best modelled as dynamical systems that serve adaptive needs. For example, modern hunter-gatherers are known to have large vocabularies specialised in this way. This may not have been the sole driver for increasing vocabulary size, but it has the advantage that it predicts that vocabulary will be to a large extent organised by specificity of reference (e.g. plant species and their subspecies) in order to enhance foraging. Once we accept such a pressure to name in an increasingly complex and multifaceted environment, then the tendency for there to be smaller numbers of high frequency words of generic reference and a larger number of rarer words with highly specific denotations is just a case of the structure of vocabulary mirroring our perception of this environment. Finally the article raises some challenges concerning the implications of power law distributions for models of iterated language learning. For example, verbs of certain semantic classes semi-predictably occur in alternant constructions often with systematic meaning changes. Children reliably learn such alternation rules, but current accounts of (iterated) language learning predict that rare, irregular linguistic traits should be unstable and not be successively relearnt by each new generation.

Bryson's article focuses on two important new linguistic theories: memetics and embodiment. Each of these theories directly concerns the study of language in both natural (humans) and artificial (robots) cognitive systems. Both theories have profound implications for its potential use by machines, its acquisition by children and of particular relevance to this symposium, its evolution. The term *embodiment* identifies a theory that meaning and semantics cannot be captured by abstract, logical systems, but are dependent on an agent's experience derived from being

situated in an environment. This theory has recently received a great deal of support in the cognitive science literature (e.g. Glenberg and Kaschak 2002; Barsalou 1999) and is having significant impact in artificial intelligence (Pfeifer and Bongard 2006). On the other hand, *Memetics* refers to the theory that knowledge and ideas can evolve more or less independently of their human-agent substrates. While humans provide the medium for this evolution, ideas can be developed without human comprehension or deliberate interference.

In this article, Bryson supports the theory of memetics by linking it to the established literature on semantic space. She proposes a model of language use based on a combination of memetically acquired semantics and grounded, embodied understanding. She uses this framework to suggest explanations for how abstract lexical terms are learned. She further suggests this provides a common representation for all kinds of lexical semantics, as well as a representational substrate for exploiting insight and analogy to link different representations and form broader understanding. She then examines the extent to which these memetic mechanisms might account for language independently of embodiment. As for its relationship to the origins of language, Bryson suggests that it is our memetic capacities that have allowed humanity to evolve our uniquely elaborate culture. This culture is capable of capturing and transmitting our embodied knowledge, but also of evolving useful concepts independently of embodiment. While our embodiment is unquestionably a part of our intelligence and therefore our language, it is memetics that accounts for the origins of that language. What makes us a uniquely memetic species is the conjunction of our capacity for precise temporal imitation and our capacity for second-order representations which may have its origins in our social representation capabilities.

Jeffreys extends computational-based models of cooperation and communication to new experimental investigations with human participants on the role of linguistic communication in supporting nonkin cooperation, and vice versa. He also focuses on the role "cheap talk", i.e. in its conventional game-theoretic definition as any form of communication within the game that costs no resources to produce, nor risks any if false (Camerer 2003). Jeffreys conducted new experiments with human participants using the ChickenHawk social-dilemma game, similar to a single-shot prisoner dilemma game. This game can distinguish between uncoordinated and coordinated cooperation. Three different groups were used to control the level of cultural homogeneity of the groups of participants: (i) classroom group within a campus population with maximum cultural homogeneity, (ii) cafeteria group within same campus for medium homogeneity and (iii) mall population with an expected much lower level of cultural uniformity. The main hypothesis was that high cultural homogeneity is correlated with higher proportion of "cheap talk" use.

In experiments with players belonging to a culturally homogeneous population (campus classroom population), natural-language "cheap talk" led to efficient coordination, while nonlinguistic signalling yielded uncoordinated altruism. In experiments with participants from a moderately more heterogeneous population nearby (campus cafeteria), the "cheap talk" condition still produced better coordination than other signalling conditions, but at a lower level and with fewer acts of altruism overall. Jeffreys's interpretation of such a study suggests that: (1)

without language, even willing cooperators coordinate poorly; (2) given a sufficiently homogeneous social group, language can coordinate cooperation in the face of opportunities for anonymous defection; (3) coordination therefore depends not on merely a general propensity to cooperate but on the overlap of social identities, which are always costly to acquire and maintain. He concludes claiming that as far as linguistic variation establishes how much social identities overlap, natural-language "cheap talk" is self-insuring, suggesting that linguistic variation is itself adaptive.

Knight proposes an anthropological analysis of the co-evolution of linguistic abilities with social morality and the rule of law. Although many scholars assume a connection between the evolution of language and that of distinctively human group-level morality, Knights notes that this is contrary to modern Darwinian theory. Darwinian evolution precludes the possibility of innate psychological mechanisms evolving to benefit the group at the expense of the individual. Group level moral regulation is indeed central to public life in all known human communities, and the production of speech acts would be impossible without this.

Knight discusses a major difference between humans and their nearest primate ancestors. Apes do not recognize group level social contracts and "contractual reality" does not exist for them. When they signal, consequently, they must intervene in physical and biological reality. By contrast, a human linguistic utterance is an intervention in a different kind of reality, known as 'institutional reality'. Underworlds, totemic spirits and promises exist insofar as it is collectively believed that they do (Searle 1996). When human life became subject to the rule of law, participation in this kind of reality became possible for the first time. Thanks to this remarkable development, abstract principles such as recursion—formerly restricted to internal cognition—could now for the first time find expression in public language. Language is dependent on civilized, rule-governed behaviour. However Knight notes that this cannot be assumed; it must be explained. Ancestral humans surely had good Darwinian reasons to band together in enforcing the rule of law. Therefore the challenge is to explain on a Darwinian basis how life could have become subject to the rule of law.

Finally, the article by **Seyfarth and Cheney** gives a contribution in the field of primate social cognition. They propose a "social cognition hypothesis" of language origins strongly based on experimental and observational data on non-human primates' social representation capabilities. For example, they demonstrate that societies of baboons are very complex and require advance cognitive capabilities to represent, and deal with, such a compositional ("syntactic"), social structure.

Seyfarth and Cheney first consider similarities and dissimilarities in cognitive and articulatory abilities of humans and other primates. Primate vocal communication is very different from human language. Although differences are most pronounced in call production, these have been overemphasized and distracted attention from the information that primates acquire when they hear vocalizations. On the other hand, continuities in humans are more apparent in perception and cognition. They suggest that natural selection has favoured nonhuman primates who, upon hearing vocalizations, are capable of forming mental representations of other individuals, their relationships, and their motives. They call it a "language of

thought" about social cognition. This social knowledge constitutes a discrete, combinatorial system that shares several features with language. This was probably a general primate characteristic whose appearance pre-dates the evolution of spoken language in our hominid ancestors. The prior evolution of social cognition created individuals who were preadapted to develop language. This challenges the view that some features commonly assumed to be uniquely linguistic (such as the combinatorics of discrete mental representations and the encoding of propositional information) were introduced by language. Instead, Seyfarth and Cheney propose that these features originally evolved as general cognitive skills for understanding social life and predicting others' behaviour.

These articles provide evidence of a multi-methodological investigation to the study of language origins. They also share a few common themes and hypotheses on the evolutionary origins of language and their relationship to other cognitive and behavioural capabilities. In particular, the four main themes common to more than one article are: (1) the link between language and complex imitation capabilities; (2) the important role of social cognition in favouring the evolution of language; (3) the emergence of compositional capabilities in language and other cognitive domains; and (4) the co-evolution of language with other behavioural capabilities.

1. The important *role of imitation* in language origins is discussed by Arbib and Bonaiuto and by Bryson. Arbib and Bonaiuto analyse the evolutionary progression from simple imitation in primates to goal-oriented imitation in humans. Complex imitation implies advanced cognitive capabilities (e.g. parsing actions into chunks, inferences) that are common to language processing capabilities. Bryson shows how the role of memetics in supporting language evolution might be based on complex imitation capabilities capable of storing and transmitting large information content.
2. The essential *role of advanced social cognition* structures and representations as pre-cursor of linguistic capabilities is central to Seyfarth and Cheney's paper. Bryson's memetics hypothesis also requires the pre-evolution of the capacity to represent the social structure of human ancestors' societies. Knight's analysis of the evolution of the rule of law and social morality reflects the centrality of the role of social constructs and representation in language evolution.
3. The third common theme regards the evolution of a general *capacity to combine discrete and hierarchical representations* as a precursor to the evolution of compositionality and syntax in human languages. Seyfarth and Cheney claim that social knowledge of complex, hierarchical social structures constitutes a discrete, combinatorial system that shares several features with language. Bryson follows the same argument when she discusses the capability to handle second-order representations. Knight discusses the evolution of the ability to handle recursion for the public communication of abstract constructs. Arbib and Bonaiuto discuss the pre-evolution of the capability to handle hierarchical and discrete action representations as a precursor to the origin of human language.
4. Finally, various articles share a focus on the *co-evolution of language, cognition and behaviour*, Jeffreys's paper centre on the co-evolution of language and

cooperation/altruism. Briscoe's paper shows how the dynamics of languages, such as those reflecting power law distributions, might actually reflect the co-evolution of perceptual capabilities. Arbib & Bonaiuto, Seyfarth & Cheney and Bryson all highlight the co-evolution of language with social cognition and action cognition.

Overall, this collection of papers on the evolution of language demonstrates the significant contribution of a multi-methodological approach based on anthropological analyses, primatology and animal psychology investigations, neurolinguistics, cognitive psychology and computational modelling. This combined effort from researchers from different disciplines, and with different methodological approaches, can shed light on the complex evolutionary dynamics and interactions involving language and other social, neural and cognitive capabilities.

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