MODELING LANGUAGE EMERGENCE BY WAY OF WORKING MEMORY

ALESSIO PLEBE and VIVIAN DE LA CRUZ

Department of Cognitive Science, University of Messina, v. Concezione 8
98121 Messina, Italy
{aplebe,vdelacruz}@unime.it

MARCO MAZZONE

Laboratory of Cognitive Science, University of Catania, viale Andrea Doria n 6
95125 Catania, Italy
mazzonem@unict.it

1. The working memory hypothesis

One idea on the origin of language is that a key element, if not the most crucial, was the availability of neural circuits in the brain for working memory (Aboitiz, 1995; Aboitiz, Garcia, Bosman, & Brunetti, 2006), the kind of of short-term memory theorized by Baddeley (1992). The neural connections working memory relies upon are those that the language network relies upon as well, namely the extensive connections between temporoparietal and prefrontal areas. This perspective sees, in fact, the neural areas involved in language not as an independent system but as one embedded in and part of a greater cortico-cortical network. Prefrontal cortex has been suggested to be "subdivided into a mosaic of areas for specialized working memory tasks" (Goldman-Rakic, 1995). Francisco Aboitiz and his collaborators in keeping with Goldman-Rakic's view, consider phonological working memory as being one among these systems. They suggest that a phonological rehearsal loop originated as a working memory device involved in the imitation of different vocalizations. Though of paramount importance in the ability to discriminate vocalizations, the phonological loop is only a small part of the role working memory plays in human language. A brain ready for language may have evolved by virtue of an expanding working memory capacity, which allowed not only the processing of complex sequences of sounds, but the ability to keep under attention the semantic meanings of these sounds as they were being formulated as well as the posing of constraints for the emergence of syntactic processes. One theoretical advantage of this hypothesis is that in the attempt to understand how a uniquely human function such as language arose in our species the positing of a specific language device is not necessary.

2. The proposed model

A possible way of exploring hypotheses on the origins of language, without getting daunted by the gap of hundreds of thousand of years worth of events that we cannot arrive at knowing, is to analyze the ontogenetic transition from a non-linguistic phase to a linguistic one. It is of course not an investigation on the evolutionary path to full-blown language itself, but a way of inquiring about what kind of basic connection patterns in the brain might have rendered it better suited to eventually support language as we know it. We propose a model of the early acquisition of language elements, grounded in perception, composed by cortical maps, one of which implements higher-level working memory. This model is a system of artificial cortical maps, each built using LISSOM (Laterally Interconnected Synergetically Self-Organizing Map) architecture (Miikkulainen, Bednar, Choe, & Sirosh, 2005), a concept close enough to the biological reality of the cortex, but that possesses the simplicity necessary for building complex models. A similar but simpler system was first introduced in (Plebe & Domenella, 2006), in order to model the emergence of object recognition. It has been recently extended to simulate the acquisition of object names (Plebe, De la Cruz, & Mazzone, 2007). The model consists of two main paths, one for the visual process and another for the auditory channel, which convey to a higher map, with working memory connectivity. The system not only demonstrates the ability to develop semantic associations, but also the emergence of an embryonic syntax, in the combination of names and adjectives. In addition, the model also allows the analysis of the extent to which working memory connectivity is essential for language.

References

Aboitiz, F. (1995). Working memory networks and the origin of language areas in the human brain. *Medical Hypotheses*, *44*, 504–506.

Aboitiz, F., Garcia, R. R., Bosman, C., & Brunetti, E. (2006). Cortical memory mechanisms and language origins. *Brain and Language*, *98*, 40–56.

Baddeley, A. (1992). Working memory. *Science*, *255*, 556–559.

Goldman-Rakic, P. S. (1995). Architecture of the prefrontal cortex and the central executive. *Annals of New York Academy of Science*, *769*, 71–83.

Miikkulainen, R., Bednar, J., Choe, Y., & Sirosh, J. (2005). *Computational maps in the visual cortex*. New York: Springer-Science.

Plebe, A., De la Cruz, V., & Mazzone, M. (2007). Simulating the acquisition of object names. In P. Buttery, A. Villavicencio, & A. Korhonen (Eds.), *Proceedings of the workshop on cognitive aspects of computational language acquisition* (pp. 57–64). Stroudsburg (PA): Association for Computational Linguistics.

Plebe, A., & Domenella, R. G. (2006). Early development of visual recognition. *BioSystems*, *86*, 63–74.