Modelling of syntactical processing in the cortex

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Abstract. Probably the hardest test for a theory of brain function is to explain the processing of language in the human brain, in particular the interplay of syntax and semantics. Clearly such an explanation has to be very speculative, because there are essentially no animal models and it is hard to study detailed neural processing in humans. Our approach to this problem is to use well-established basic neural mechanisms in a plausible global network architecture, that is formulated essentially in terms of cortical areas and their intracortical and corticocortical interconnections, in order to analyse and generate complex semantico-syntactical structures. The resulting model consists of 10 interacting 'cortical areas', modelled as associative memories with sparse representations (Palm, G.: Neural Assemblies, Springer, 1982). A short overview of the architecture of the model is given in Fig. 1.

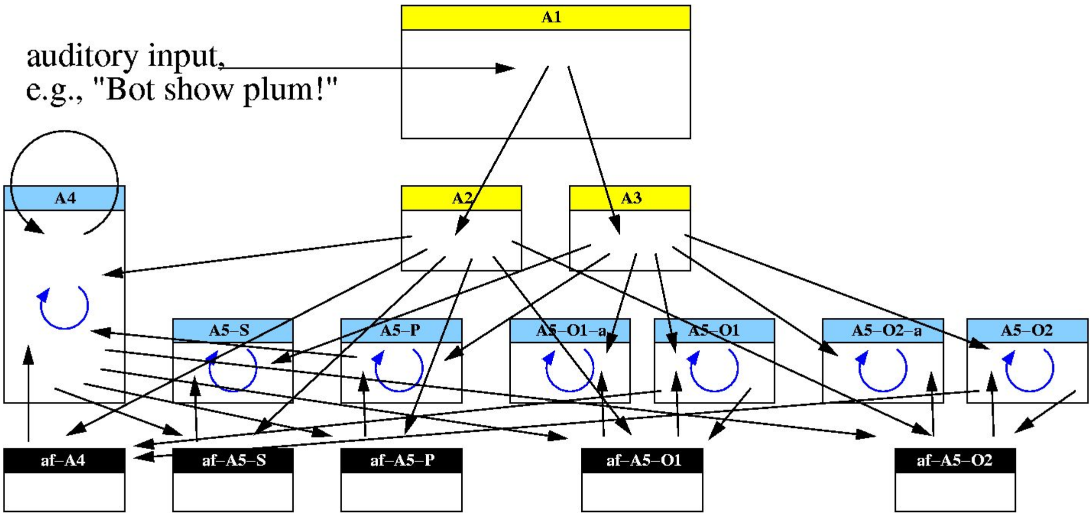

Figure 1: The language system consisting of 10 cortical areas (large boxes) and 5 thalamic activation fields (small black boxes). Arrows within an area correspond to short-term memory.

The system contains one area where sequences are stored and stored sequences can be recognised (or generated). This is realised by sequential hetero-associations, an idea which is closely related to Abeles's idea of synfire chains (Abeles, M.: Corticonics – Neural circuits of the cerebral cortex, Cambridge University Press, 1991) and more distantly to Pulvermüller's sequence detectors (Pulvermüller, F.: The Neuroscience of Language, Cambridge University Press, 2002).
The neural implementation of this system not only shows that the comparatively intricate logical task of understanding semantico-syntactical structures can be mastered by a neural network architecture in real time, it also gives some additional advantages in terms of robustness and context-awareness. In particular, the model is able to correct ambiguous input on the single word level due to the context of the whole sentence and even the complete sensory-motor situation. For example, the sentence “bot lift bwall” with an ambiguous input between “ball” and “wall” is correctly interpreted as “bot lift ball”, because a wall is not a liftable object. Similarly, the sentence “bot show/lift green wall” with an artificial ambiguity between “show” and “lift”, can be understood as “bot show green wall” even if the disambiguating word “wall” comes later and even across an intermittent word (“green”). Furthermore, the language input could be used to disambiguate ambiguous results of visual object recognition, and vice versa.