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A Biologically Inspired Computational Model of Language Cognition

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1. Introduction and Background

Significant progress had been made about how the brain works, from the molecular to the functional level, in the past few decades. But how can researchers, often get trained in a particular neuroscience discipline to understand and use all that data to develop the right kind of hypotheses to test? We have to develop novel computational models to tackle this challenge. It might be possible to develop software programs to mimic the behavior of the brain based on the results of proven scientific studies. Computational modeling is the only inherently dynamic way to help us to specify that function precisely. It not only provides some new explanations for the nerve physiology processes occurring in our brain, but also provides new ideas for the artificial cognitive systems [1,2]. What is needed is a formal way to systematically relate multiple data sets, thus bridging the function of brain and computational models. Functional Magnetic Resonance Imaging (fMRI) provides a high resolution volumetric mapping of the haemodynamic response of the brain, which can be correlated with neural activity, thereby allowing the spatially localized characteristics of brain activity to be observed. It is a new trend to use fMRI studies to confirm and improve cognitive computational models.

Hickok and Poeppel [4] provided a dual-stream model of speech processing. The approximate anatomical locations of the dual-stream model components are illustrated in Figure 1. Regions shaded green depicted areas on the dorsal surface of the superior temporal gyrus that are proposed to be involved in spectrotemporal analysis. Regions shaded yellow in the posterior half of the STS are implicated in phonological-level processes. Regions shaded pink represent the ventral stream, which is bilaterally organized with a weak left-hemisphere bias. The more posterior regions of the ventral stream, posterior middle and inferior portions of the temporal lobes correspond to the lexical interface, which links phonological and semantic information, whereas the more anterior locations correspond to the proposed combinatorial network. Regions shaded blue represent the dorsal stream, which is strongly left dominant. The posterior region of the dorsal stream corresponds to an area in the Sylvian fissure at the parietotemporal boundary, which is proposed to be a sensorimotor interface, whereas the more anterior locations in the frontal lobe, probably involving Broca's region and a more dorsal premotor site, correspond to portions of the articulatory network.

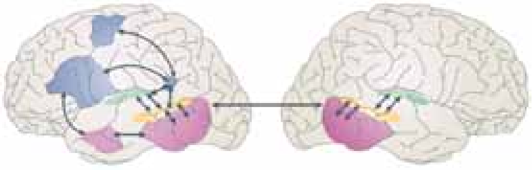

Fig. 1 : Approximate anatomical locations of the dual-stream model components (adapted from[4])

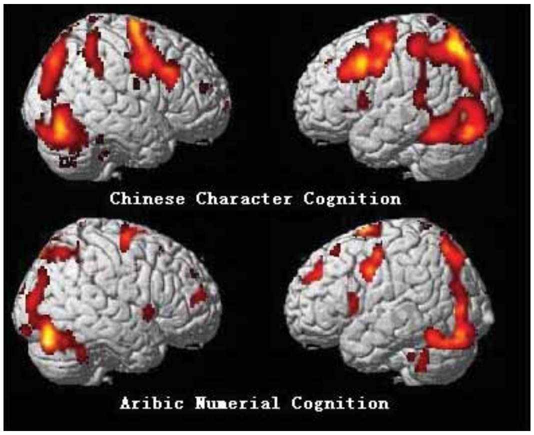

Fig. 2 : the brain activations during two tasks

Our research deals with the comparison between Chinese character and Arabic numerals cognition. During the brain activations during two tasks, we observed activations in the premotor area (PMA), the prefrontal cortex (PFC), the left Inferior frontal cortex (Broca area, Br), the left angular gyrus (AG) and the area of left intraparietal sulcus (IPS) during the two tasks. More over, the activation volumes of brain areas

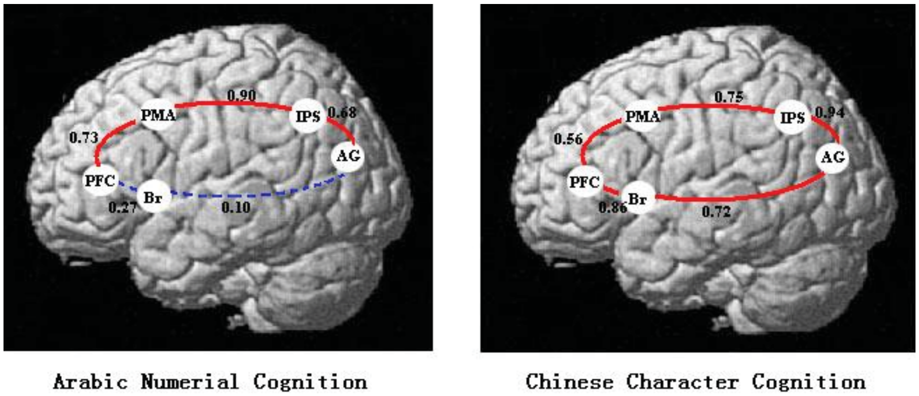

Fig. 3 : Brain Deactivations in Mathematic Stress

during Chinese character cognition were larger than during Arabic numeral cognition.

The within-condition interregional covariance analysis (WICA) is a novel method for ROI-based functional connectivity analyses [5]. We exposed human subjects to two cognition tasks in one functional magnetic resonance imaging (fMRI; *n*=30) experiment and applied WICA to analyze the connectivity between the brain activation areas during two tasks. We observed a profound activation area in PMA and the high functional connections between it and other activation areas during the two tasks. Further, the analysis of functional connectivity indicates the functional connection between Broca area (Br) and angular gyrus (AG) during Chinese character cognition task was enhanced in comparison to Arabic numeral cognition task.

2. Experimental Observations and Future Trends

Observed from the brain regions, there is an important pathway to process the language cognitive tasks. Auditory inputs of language information is transmitted by the auditory cortex angular gyrus, and then to Wernicke area, then spread to the Broca area. The visual inputs from visual association cortex information were directly transmitted to the Broca area. Visual perception and semantics of language are dealt separately by the different sensory pathways. These separate channels to reach the Broca area, and the meaning, and language related to the more high-level cortex regions. Based on the connectivity of the brain and the neural language processing in human brains, there are two dynamic hierarchies. In the top level, six coarse-grained modules construct a large-scale distributed network, which provides its ongoing organization and topological properties of the connection of brain networks. In the bottom level, each module is implemented in a smaller scale within the distributed multi-agent system, which achieve short-time working memory and remodeling features within each cognitive module. Figure 4 illustrates the two-hierarchical computational model. The two-level subsystems apply symbolic representation and distributed representation respectively to adapt to the explicit and implicit processing in the dynamic hierarchies. The implicit learning in the bottom level can obtain the explicit knowledge from the top-level network, while the explicit learning in the top level acquired in the underlying implicit knowledge from the bottom level subsystems. The system is implemented with the top-down guidance learning and the bottom-up selective learning. The computational model has emergent and self-learning features.

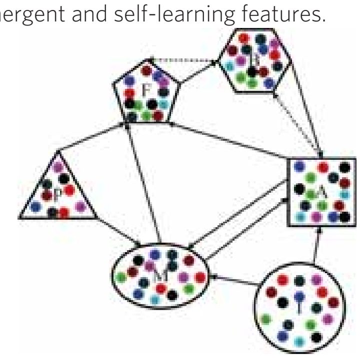

Fig. 4 : A Biologically-Based Computational Model

Our model model sheds light on how the cognitive processing is completed in human brain. It could enlighten us to achieve advanced artificial intelligence. fMRI cannot only provide principal approaches for computational models, but also the rigorous and unique tests of computational models. We hope that this article encourages researchers to expand their useful fMRI datasets into computational modeling.

3. Conclusion

In this article, we investigated language cognitive computational modeling from fMRI experiments. Considering the connectivity of the brain, a two-hierarchical model is designed by larger-scale network and smaller-scale multi-agent system. The computational model has emergent and self-learning features. Our ongoing research aims to provide new approaches to carry on human cognitive research and novel ideas to implement new generation intelligent systems to solve some of the complex real world problems.

Acknowledgements

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