NEUROFEEDBACK TRAINING AS A METHOD FOR EVALUATION OF BRAIN SYSTEMS FOR LANGUAGE

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1. Introduction

Since language is a complex faculty concerning multiple domains, it is thought that the brain system for language has evolved in an integrative manner such that numbers of componential systems make their own contributions to the whole system. Recently, on the other hand, neuroscience studies have begun to show that a neurofeedback training of repeated self-induction of a specific brain activity pattern could alter behavioral ability corresponding to the trained brain activity (Shibata *et al.*, 2011). Given this causal effect, we wondered that the neurofeedback training might serve as a new method to test causal relevance of hypothetical neuro-linguistic models. That is, if behavioral performance on a certain linguistic ability changed according to the self-induction training of activity of a specific brain system, we could argue that such brain system might have effective contribution to that ability in an adaptive manner.

Based on this idea, we specifically tried to examine organization and possible adaptive capacity of brain systems contributing to an ability to express intentions by hierarchical structures of written symbol strings. Although both the hierarchical structure (Everaert *et al.*, 2015) and the intention-sharing (Tomasello, 2003) are believed to be essential for human language, relation between the two remains unknown. Therefore, we first proposed a neural model concerning intention-sharing by the hierarchical structures of symbol strings through an electroencephalography (EEG) experiment, and then tested the effect of the EEG neurofeedback training with respect to the model.

2. EEG experiment and neurofeedback training

We adopted experimental semiotics approach (Galantucci, 2009) that could simulate emergence and evolution of a novel language system through trial and error across participants. In each trial of our experiment, we assigned a pair of participants either a sender or a receiver of a string of three symbols involving the hierarchical structures. The sender composed a symbol string to indicate a target object in the experimental screen, and was additionally required to imply an instruction whether the receiver should choose the target or not. As a result, most participants expressed the meaning of the choose/not-choose instruction within specific hierarchical structures of the string. EEG analyses showed significant suppression of 11 Hz EEG power at the left frontal, bilateral parietal, and occipital electrodes during a composition period of the symbol string. Thus we proposed a neuro-linguistic model that desynchronization of alpha-band neural activity in multiple brain systems (Murphy, 2020) would contribute to realization of the intention expression through the hierarchical structures.

We conducted 4-days neurofeedback training (1.5h per day) to independent participants. We visually presented feedback signals that represented magnitude of 11 Hz power suppression at the frontal, parietal, and occipital electrodes, and asked the participants to try to increase the feedback signals as high as possible. Although effects of the neurofeedback training on performance change between pre- and post-training behavioral tests varied across participants, we observed the representative case in which richness of intention-reading in a picture description task (Cummings, 2019) dramatically improved after successful training of the EEG suppression at the parietal and occipital electrodes. This case also showed less improvement of utilization of the hierarchical structures to express intentions in the string composition task, in parallel with less achievement of the left frontal power suppression during the EEG training.

3. Discussion

Differential training effects across pragmatic understanding of intentions and utilization of the hierarchical structures may suggest partially independent evolutionary organization of brain systems for these aspects of language. We speculate that incorporating connectivity information into the neurofeedback method might help to further elucidate integrative organization of these systems.

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References

Cummings, L. (2019). Describing the Cookie Theft picture: Sources of breakdown in Alzheimer's dementia. *Pragmatics and Society, 10(2)*, 153-176.

Everaert, M. B. H., Huybregts, M. A. C., Chomsky, N., Berwick, R. C., & Bolhuis, J. J. (2015). Structures, not strings: Linguistics as part of the cognitive sciences. *Trends in Cognitive Sciences*, *19(12)*, 729-743.

Galantucci, B (2009). Experimental semiotics: A new approach for studying communication as a form of joint action. *Topics in Cognitive Science*, *1(2)*, 393-410.

Murphy, E. (2020). *The oscillatory nature of language.* Cambridge: Cambridge University Press.

Shibata, K., Watanabe, T., Sasaki, Y., & Kawato, M. (2011). Perceptual learning incepted by decoded fMRI neurofeedback without stimulus presentation. *Science*, *334(6061)*, 1413–1415.

Tomasello, M. (2003). *Constructing a language: A usage-based theory of language acquisition.* Cambridge, MA: Harvard University Press.