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学位論文内容の要旨

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学位論文題名

The Mechanism of Audiovisual Cross-Modal Conflict: Establishment of Neuropsychological Evidence and Application for Non-Invasive Neuromodulation Techniques

（視聴覚クロスモーダル葛藤のメカニズムの解明
−神経心理学的エビデンスの確立と非侵襲的ニューロモジュレーション技術の応用−）

Background: Complex, uncertain, and rich stimuli exist everywhere in the real world. Visual and auditory stimuli are two primary sensory modalities in our lives. People would be distracted by irrelevant information and ignore the relevant information as a result of cognitive conflict caused by unimodal (visual or auditory) or cross-modal (visual and auditory) information, thereby lowering the quality of human life. Nowadays, cognitive conflict effects within unimodality are well characterized, but less is known about cross-modal conflicts and their neural basis. Recently, there has been a dramatic increase in the use of transcranial electrical stimulation (tES) techniques to improve cognitive performance by modulating cortical excitability. However, the effectiveness of these techniques on the interference effect of cross-modal conflict has not been thoroughly investigated.

Aims: In this thesis, Study 1 aimed to investigate the two types of cross-modal conflict that cause semantic competition (focusing on vision while ignoring auditory distractors and focusing on audition while ignoring visual distractors) through a single WM task and its brain activity. Study 2 examined the effectiveness of tES techniques during cross-modal inhibition on the right inferior frontal gyrus (rIFG), one of the key brain areas identified in Study 1.

Study 1

Methods: 31 healthy, young, right-handed males (mean age = 23.08 ± 1.91) were recruited. Two types of paced serial addition test (PSAT), paced auditory serial addition test (PASAT) and paced visual serial addition test (PVSAT), were performed under distractor and no-distractor conditions. In the distractor condition, one of the PASAT or PVSAT was utilized as a target task, while the other was used as a distractor stimulus. In addition, the concentration of oxygenated hemoglobin (Oxy-Hb) changes in the bilateral dorsolateral prefrontal cortex (DLPFC), bilateral ventrolateral prefrontal cortex activity (VLPFC), and bilateral inferior parietal cortex (IPC), based on previous studies, were measured during PSATs by functional

near-infrared spectroscopy (fNIRS). To investigate the interfering effect of cross-modal conflict, the repeated measures analysis of variance was used. Moreover, Pearson's product-moment correlation analyses were used to examine correlations between Δtask performance accuracy of PASAT and PVSAT (with distractor – with no-distractor) and ΔOxy-Hb changes (with distractor – with no-distractor) of them in each brain region.

Results and discussion: Behavioral results showed a significant cross-modal interference effect only in the PASAT, but not in the PVSAT. The results of Oxy-Hb changes showed a significant increase in the PASAT with the distractor conditions compared with the PASAT with the no-distractor condition in the bilateral VLPFC and IPC, but not in the PVSAT. Additionally, only in the bilateral IPC of the PASAT were there significant positive correlations between Δtask performance accuracy and ΔOxy-Hb changes. These results suggest that performance on the auditory task is considerably impaired by visual cross-modal conflict, and the bilateral VLPFC and IPC are important areas for inhibiting visual cross-modal distractors.

Study 2

Methods: In a randomized, double-blind, cross-over, placebo-controlled study design, 12 healthy, young, right-handed subjects were recruited. All participants experienced three types of stimulation in random order on three separate days, anodal transcranial direct current stimulation (tDCS), transcranial random noise stimulation (tRNS) and sham, over the right inferior frontal gyrus (rIFG). Before, during, and after stimulation, participants repeatedly performed PASAT tasks including three conditions: no-distractor, semantic distractor, and non-semantic distractor. While we measured behavioral performance (accuracy) and neurophysiological response (event-related potential, ERP) by using electroencephalography (EEG). The amplitudes of N200 and P300 were selected as task-related responses and analyzed. To investigate which stimulus type is more effective for the inhibition of cross-modal conflict, a three-way repeated-measurement analysis of variance (ANOVA) with stimulation type (sham, tDCS, and tRNS with DC-offset), time (baseline, online, and offline), and task type (PASAT, PASAT with semantic distractors, and PASAT with non-semantic distractors) as within-subject factors was applied to behavioral and neurophysiological outcomes.

Results and discussion:

The results showed the tDCS on the rIFG had a wider effect than the tRNS with DC-offset on the rIFG, regardless of the task type and time period, and specifically improved the performance of the PASAT with non-semantic distractors and decreased N200 amplitude related to the conflict monitoring mechanism, while the tRNS with DC-offset on the rIFG had a specific-effect on the PASAT with semantic distractors and increased P300 amplitude related to the inhibitory process involved in inhibitory processing. These results demonstrate the importance of proper use of tDCS and tRNS differently depending on the type of distractor stimulus. Future studies will be needed to examine the further validation and reproducibility of these results by increasing the sample size and also examine whether the effectiveness of these techniques varies depending on different age groups.