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Neurofeedback training of frontoparietal alpha rhythm enhances episodic memory

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Neurofeedback Training (NFT) of brain rhythm is an operant conditioning paradigm through a video or audio interface and has been widely used in clinic. Episodic memory is a prerequisite for successful life functioning. This study aims to explore trainability of alpha NFT with a sham-controlled experimental design and effect of alpha NFT on episodic memory. Participants were randomly assigned into a control group receiving feedback of 4-Hz amplitude randomly selected from 7-20 Hz or an alpha group receiving feedback of 8-12 Hz amplitude. The NFT contained 12 sessions and each session consisted of 6 min blocks. Picture recognition task with identifying exact shape and size of objects was used to assess episodic memory. Topographic distribution of trained alpha rhythm was categorized through the whole-head EEG recording. The Alpha group exhibited a linear increase in amplitude and duration of alpha rhythm throughout the NFT exclusively. The Alpha group exhibited significantly higher amplitude and longer total duration of alpha rhythm compared with those of the control group. Accuracy of the picture recognition task in the Alpha group was significantly improved after NFT compared with that of the control group. In particular, participants with increased alpha rhythm which primarily distributed in bilateral frontoparietal region exhibited significantly linear trend between alpha duration and accuracy of the picture recognition task. The evoked alpha rhythm in the occipital region seemed to be no effect on accuracy of the picture recognition task. The present study provides additional evidence on the trainability of alpha rhythm through NFT and also identifies functional localization of alpha rhythm in the frontoparietal region on enhancement of episodic memory. Our results suggest a non-pharmacological intervention on memory enhancement throughout a NFT of alpha rhythm.

To further understand the effect of alpha NFT on memory, the present study evaluated the performance of two working memory tasks (a backward digit span task and an operational span task) and a word pair task of episodic memory before and after NFT. Moreover, we enrolled a sham group with the same exposure time to the training apparatus and protocol of the experimental group. The current study proposed a trainability of alpha NFT in terms of changes in both alpha amplitude and alpha duration. We further hypothesized that the alpha NFT, particular for well-trained “Responder,” had significant increase on the accuracies of all memory tasks. In the present study, successful training of the frontoparietal alpha rhythm was demonstrated in terms of progressive changes in the mean relative alpha amplitude, the total alpha duration, and the probability density function of continuous alpha episodes throughout 12 sessions in the Alpha group exclusively.

The Alpha group (particularly for “Responder”) showed a higher proportion of participants with significant enhancement in both working memory and episodic memory compared with that of the Ctrl group. Three questionnaires dealing with anxiety, depression, and insomnia revealed normal scores before and after NFT. Our findings suggest that alpha NFT has a great benefit on memory enhancement with little effect on anxious, depressive, or insomnia symptom. In the training course of alpha NFT, there was no obvious change in the mean relative alpha amplitude and total alpha duration at the beginning. This may indicate a potential focus of the participants' attention on trying to produce a right bar movement. This may lead participants to initially drive their attention on the feedback information. Such an issue of attention could lead to an interference in the genesis of alpha rhythm, which is indicated in previous studies. This attention process may be partially supported by the early stage with theta activation, which is related to the attention process. Afterward, a slight increase in the mean relative alpha amplitude was seen in the 5th–7th sessions followed by a dramatic increase in the mean relative alpha amplitude after the 8th–12th sessions. This pattern of increased alpha amplitude may reflect the latent learning of a trial-and-error process. The trial-and-error operation is a crucial process for biofeedback/neurofeedback.

In addition to changes in alpha amplitude and total alpha duration, the length of each individual alpha episode was progressively increased when the session number increased. From participants' reports, they can devise a strategy to produce a stable alpha rhythm in the frontoparietal region. In regards to the reliability issue of an NFT, the phenomenon of a long and stable successful event episode may be an important index to assess successful training [Dempster and Vernon, 2009]. Thus, the present study provided valuable information about the trainability of alpha rhythm in terms of probability density function of durations of successful alpha episodes. Our findings on the progress in the amplitude of upper alpha frequency bandwidth differ from a previous report that showed a linear increase of upper-alpha amplitude. The discrepancies between these two studies may arise from differences in training design vs. 3 days per week for 4 weeks) or in feedback context vs. two-step feedback.Our study provided promising results using an NFT of 8–12-Hz amplitude to demonstrate the trainability of frontoparietal alpha rhythm and their functional correlations with working memory and episodic memory. Design of a sham control group and “Responder” analysis provided valuable information to strengthen effect of the alpha NFT on memory. These findings may trigger further validation on the relationship between the frontoparietal alpha rhythm of NFT and cognitive performance.

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