Preventing Cognitive Decline Using Attention Training Based on Brain-Computer Interface

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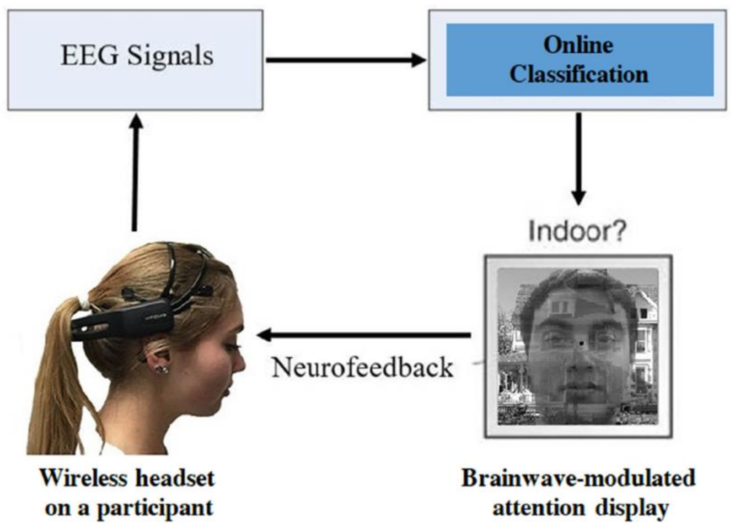

Figure 1. A schematic demonstration for attention training via neurofeedback based on brain computer interface.

Attention is a crucial element in cognition and perception. Sustained attention, also known as vigilance, refers to the capability of maintaining focus to a task over a prolonged period of time. In activities like driving a car, vigilance over the task is of pivotal importance. Lapse of attention may lead to severe consequences including loss of lives. Attentional deficit may be caused by a number of neurological diseases such as (ADHD), Alzheimer's disease (AD), Mild Cognitive Impairment (MCI), Traumatic Brain Injuries (TBI), Post-Traumatic Stress Disorder (PTSD), etc. Previous research has established that attentional capability can assessed and improved through neurofeedback based on functional magnetic resonance imaging (fMRI). The objective of this project is to develop an EEG-based Brain Computer Interface (BCI) to improve the usability of attentional evaluation and training and test it on cognitively-impaired participants. Compared to traditional fMRI-based BCI, the proposed EEG platform not only is more convenient and cost effective but also greatly reduces the risk of biohazards. Preliminary results show that the evaluation on attentional state using EEG yields accuracies similar to those in the literature using fMRI. Real-time BCI technology provides an amazing new method to simultaneously record and utilize brain activity to control external devices such as artificial limbs and other devices. While much progress has been made in neuro-rehabilitation using assistive devices, few studies have examined the use of BCI technology in cognitive rehabilitation to improve attention and memory. The current proposal aims to develop a neurofeedback device for attention training with high-temporal resolution, state-of-the-art real time measurement of neural activity of the brain that does not require stringent stillness of the human subject, has low cost, and is easy to use. This platform has potential for large scale and wide-spread application in cognitive rehabilitation for patients with dementia.

Besides attention, neural mechanisms underlying short-term memory (e.g., working memory, (WM)) undergo a significant early change in aging and in AD dementia patients. The memory decline also includes neural mechanisms underlying repetition learning, a form of implicit memory. Early AD/MCI manifests itself in loss of short-term memory but retention of intact long-term memory. Since WM and attention share common neural mechanisms, enhancement of attention improves encoding, maintenance and retrieval of items held in WM for online usage.

Figure 1 shows a schematic illustration of the proposed BCI platform. A wireless headset (Emotiv EPOC device) with 14 channels will be utilized for EEG monitoring. A program will be developed in MATLAB Simulink as the control console and for data acquisition and analysis. A graphic user interface (GUI) will be designed and developed so that the experimentalist can easily collect data and conduct analysis by clicking a few buttons. The experimental protocol consists of 8 blocks of data collection. Each block starts with a one second cue texture displaying the targeted picture and then follows with 50 trials of composite images. Each image is a superimposed transparent image of face and scene. Of all images, 50% of them contain a male face and the other 50% contain a female face. Likewise, 50% of the images contain an indoor scene and the other 50% contain an outdoor scene. The participant will be instructed to maintain sustained attention for the task relevant target stimulus (e.g. female face) and ignore the other stimulus (e.g. male face) while having overt behavioral responses to all images. A classification model will be developed utilizing support vector machine (SVM) analysis of complex EEG and event-related potential (ERP) features (including ERP N170, P300). Given the individual differences in human cognition, each participant will have personalized training sessions. To avoid overfitting, classification results will be calculated based on “leave-one-out” cross validation. EEG classification will be performed on the categories of images (face vs. scene) regardless of their subcategories. The attentional states and levels of the participant for the targeted picture will be determined from the EEG classification. The classification results will be applied for the next stage of work as closed-loop attention training. Neurofeedback will be provided based on EEG responses underlying sustained attention. When a participant loses focus of attention, the framework decreases the clarity of the task-relevant stimulus. When the attention is improved, the participant is rewarded via neurofeedback by increased clarity of target image in the superimposed picture.

The developed platform provides neurofeedback based on the participant’s recorded brainwaves and real-time analysis. The platform has potential applications in attention enhancement of patients with cognitive disorders. Attention is a central component of cognition and is vulnerable to a variety of injuries and disorders. Brainwave pattern measurements have become a strong predictor of cognitive impairment in persons afflicted with cognitive deficits. Attention training for patients after brain injury improves cognition but the conventional intervention is intensive and costly. This project will develop a new and engaging method to remedy attention and cognitive functions.