Offline EEG Signal Analysis to Enhance Visual Attention Training Platforms

Introduction: Sustained attention refers to a cognitive capability to maintain focus during a task [1]. Since face-like visual stimuli undergo specialized processing in human brain compared to other non-face objects [2], face images were employed in numerous brain studies particularly studies on attention. Using fMRI, deBettencourt et al. [1] designed a closed-loop attention training paradigm in which the transparency of an image category (face or scene) inside a sequence of blended images was adjusted based on the participant's decoded attentional level to the primed image category. Our study aims to develop a user-friendly neurofeedback system for attention training using EEG headsets and brain-computer interfaces. We'll interpret attentional states from healthy participants' brainwaves via a machine learning or deep learning model.

Protocol Design: Our experimental protocol consisted of eight blocks of trials with a respite between blocks. Each block started with a five-second texture cue instructing the attended subcategory image, followed by 40 trials of image stimuli. The duration of each trial was set to one second. A trial includes a composite image with a 50% transparency for each subcategory: scene (indoor or outdoor) and face (male or female). Participants are asked to identify whether the shown image contained the task-relevant image (e.g., an indoor image) or the task irrelevant image (e.g., an outdoor image) by responding to each superimposed image. They are asked to push the trigger button for each recognized relevant image and withhold their responses for irrelevant image.

Platform Design: The BCI platform consists of a wireless EEG headset, a workstation computer with dual monitors (one monitor was viewed by the experimenter to control the experiment, the other monitor was positioned in front of the participants for presentation of stimuli), data acquisition, and analysis software. Figure 1 shows a simple schematic of the platform's components. A Graphic User Interface (GUI) was also developed to allow a practitioner to conveniently administer the experimental protocol. The participants are asked to sit comfortably in a fixed chair with one hand resting on the lap and the index finger of the other hand positioned on the space button of the keyboard. The participants are instructed to pay attention to the monitor during the experiment and limit their excessive body movement. The participants are also asked to fixate their gaze to the middle of the screen.

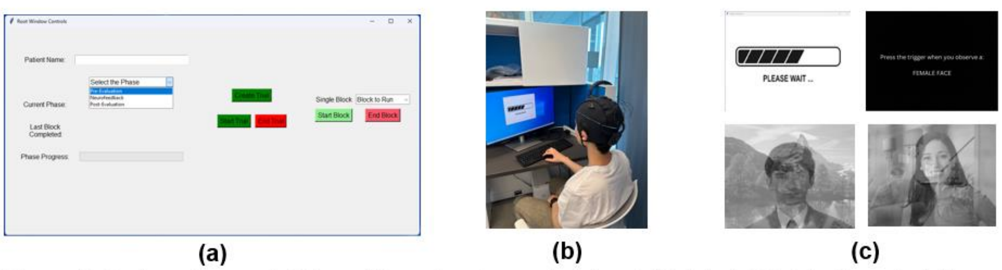

Figure 2. Dual-monitor workstation a) Experimenter workstation. b) Subject c) Subject's workstation.

Data acquisition: EEG signals are acquired using a wireless headset called Unicorn Hybrid Black (g.tec), that has 8 channels located based on 10-20 international systems. The exact locations are labeled sequentially as 'Fz', 'FC1', 'FC2', 'C3', 'Cz', 'C4', 'CPz', and 'Pz'. Quality testing of EEG signals are performed prior to each task through the Unicorn Suite software environment (g.tec). The sampling frequency is set to 250 Hz. We developed a Python-based software for the visual attention training platform. We perform our data acquisition in Python, which also controls the visual stimulation and the designed protocol. Within this platform, the EEG recording for each trial commences with the "device.GetData" command in a loop. To ensure the synchronous capture of EEG data in correspondence to the visual stimuli, the image display function is tactically embedded within that loop. Each trial consists of 40 images, and each image is presented for the duration equivalent to 250 EEG data sample points (1000 milliseconds). Hence, for every trial, each 250 sample points directly align with the display duration of each image.

Signal Preprocessing: The preprocessing steps include band-pass filtering, extracting 5 frequency bands, standardization, removing the linear trend from each channel, removing random and systematic noises, decomposing, segmentation, etc.

References

[1] M. T. DeBettencourt, J. D. Cohen, R. F. Lee, K. A. Norman, and N. B. Turk-Browne, "Closed-loop training of attention with real-time brain imaging," Nature Neuroscience, vol. 18, no. 3, pp. 470–478, 2015.

[2] K. M. O'Craven and N. Kanwisher, "Mental imagery of faces and places activates corresponding stimulus-specifc brain regions," Cognitive Neuroscience, vol. 12, no. 6, pp. 1013–1023, 2000.