Mobile SSVEPs of the real world using LCD glasses

The ability to record human brain activity during movement and in real world environments will significantly advance our understanding of the neural mechanisms behind cognition and behaviour. Mobile EEG is the most promising method but suffers from artifacts caused by eye, head and body movement. Current solutions require large numbers of electrodes and setups which would be impractical in real world environments. A solution that can provide clean data from single channels, in small discrete devices, would be an important research tool which would complement more complex lab setups with larger numbers of electrodes.

In a previous study we demonstrated a proof of concept of a new method for mobile EEG using LCD glasses (Dowsett, Dieterich and Taylor, 2020). Custom built LCD glasses can be set to flicker at any frequency to create steady state visually evoked potentially (SSVEPs) of real world visual scenes.

This method has a number of advantages. Firstly, the SSVEP has an excellent signal to noise ratio, and if enough trials are averaged, any motion artifacts, eye-movement artefacts, or environmental noise can be reduced to near zero. Using simulated EEG data, with a signal generator, we have demonstrated that a clean response can be obtained for 10 Hz SSVEPs after approximately 2.5 minutes of walking.

Secondly, SSVEPs can be created from any visual scene, from whatever the subject is looking at in the real world. This allows real world EEG data, as subjects do not need to be looking at a screen. We demonstrated that distinct SSVEPs can be generated from the same visual scene with different lighting, i.e. whether the right or left side of the room was illuminated with a spotlight.

Thirdly, the LCD glasses can generate SSVEPs at any frequency, unlike SSVEPs on a regular monitor which are limited to multiples of the refresh rate of the screen. In our first study we looked at SSVEPs in the alpha-band. In a more recent study we demonstrate mobile SSVEPs in the gamma band (using the same methods as in Dowsett, Dieterich and Taylor, 2020). Mobile EEG in the gamma band is particularly difficult as muscle artifacts and eye movements give a strong signal in the gamma range, and are difficult to distinguish from neural activity. Here we have demonstrated, again with a signal generator, that we can get clean data during walking in real world environments after a few minutes.

In our previous study we demonstrated that SSVEP responses to alpha-band flicker were reduced during walking in right parietal regions. In our current study the LCD glasses were set to flicker at a range of frequencies in the gamma band while 64 channel mobile EEG was recorded. For this experiment, data was collected in a more naturalistic setting: subjects were standing in, or walking down, a long corridor. Initial results show hemispheric lateralization in the gamma range from 40 Hz upwards, specifically a greater phase shift of the SSVEPs in walking vs. standing, in left parietal regions relative to right parietal regions. This effect was not present at 30-35 Hz, demonstrating frequency specificity in the gamma band. This indicates that the SSVEPs from parietal electrodes are the result of resonance with underlying functional neural circuits, and are not simply a stereotyped response to the visual flicker. The visual input was controlled across walking and standing conditions.

This method is particularly promising for real-world EEG because gamma range flicker is close to the threshold of perception (flicker fusion frequency) and is far less distracting than flicker at the lower frequencies typically used for SSVEPs. Furthermore, gamma oscillations are associated with working memory, attention, and perceptual grouping, and may be particularly important for multi-sensory integration involved in perceiving the environment during movement.

We plan to used gamma band SSVEPs to investigate neural activity in real world environments. But to achieve this goal, it is important to map out how different low level visual parameters such as colour and luminance can affect the signal. We also present results from a third study where we track the variation in SSVEP amplitude, phase and waveform (e.g. non-sinusoidal properties) across a variety of simple visual conditions such as different colours (red, green and blue) and brightness (low, medium and high luminance). The flicker was set to a range of frequencies; 30, 35, 40 , 45, 55, and 60 Hz, for one minute each, while recording 64 channel EEG in 10 standing participants (participants were excluded if they had any family history of epilepsy or color blindness). This data will provide an important baseline to track the variation in gamma band SSVEPs we see in real world environments.

Reference:

Dowsett, J., Dieterich, M., & Taylor, P. C. (2020). Mobile steady-state evoked potential recording: dissociable neural effects of real-world navigation and visual stimulation. Journal of neuroscience methods, 332, 108540.