

Display Optimization in SSVEP BCIs

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INTRODUCTION

Brain – computer interface (BCI) systems allow people to send information without moving [1]. Some BCIs rely on the Steady State Visual Evoked Potential (SSVEP), a type of EEG activity that occurs when subjects focus attention on a stimulus that oscillates between about 5-40 Hz. Thus, the efficacy of an SSVEP BCI depends on how quickly and effectively it can distinguish SSVEP activity that reflects user attention from background noise. This depends on many factors, including EEG signal quality, task and display parameters, signal processing approaches, and user factors.

SSVEP BCIs often utilize stimuli containing oscillating checkerboxes. Figure 1 below shows four examples of such displays [2][3][4][5]. In these BCIs, subjects direct attention to one of the oscillating checkerboxes to convey interest in a corresponding region. Thus, directing attention to the left checkerbox would move a game character, map, car, or cursor. It is also possible for subjects to focus attention on two targets, which could improve information throughput by increasing the number of commands available to a user [6].

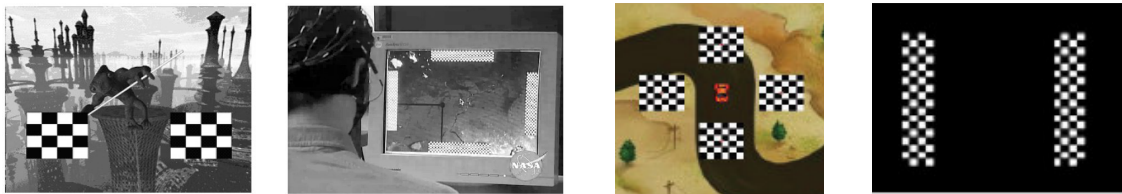


Figure 1: Four displays used in SSVEP BCI systems that contain oscillating checkerboxes. From left to right, these images are from: Lalor et al., 2005; Trejo et al., 2006; Martinez et al., 2007; and Allison et al., in press.

Although work has shown that optimized checkerbox configurations can affect SSVEP parameters (e. g., [7]), the checkerbox approach has not been compared to a comparable plain display in the context of a BCI. In this study, subjects focused attention on a display containing five oscillating stimuli. In different conditions, these stimuli were filled with either a plain or checkerbox texture. This allowed direct comparison of these two display approaches.

METHODS

Four subjects participated in this study. Stimuli were presented on a flatscreen computer monitor about one meter in front of the subject. Data were recorded from six parietal and occipital sites (P3, Pz, P4, O1, Oz, O2, relative to site Fz (see figure 2) in an Electro-Cap cap. All impedances were kept below 5 kOhms. Data were sampled at 128 Hz on a Guger Technologies amplifier and processed using Matlab. The amplifier used an analog bandpass filter with a 0.5 Hz and 50 Hz cutoff frequencies.

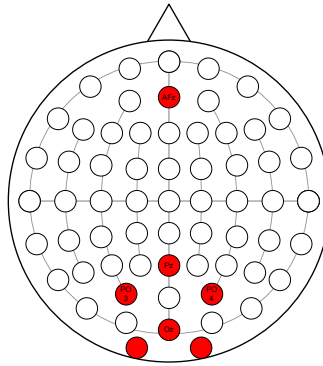


Figure 2: The electrode sites used are shown in red.

Data were processed using the minimum energy approach described in [8]. This method seeks to minimize noise by linearly combining the EEG signals over an arbitrary number of electrodes. The resulting SNR was used to evaluate different conditions.

Figure 3 shows the two displays used. This study compared solid white stimuli (shown in the left panel of figure 3) to similar stimuli containing checkboxes that oscillated at the stimulation frequency (shown in the right panel of figure 3). In both display types, the five stimuli oscillated at constant frequencies: top arrow = 13 Hz; right arrow = 14 Hz; bottom arrow = 15 Hz; left arrow = 16 Hz; and the center box = 17 Hz. The displays were developed in DirectX implemented in Visual C++.

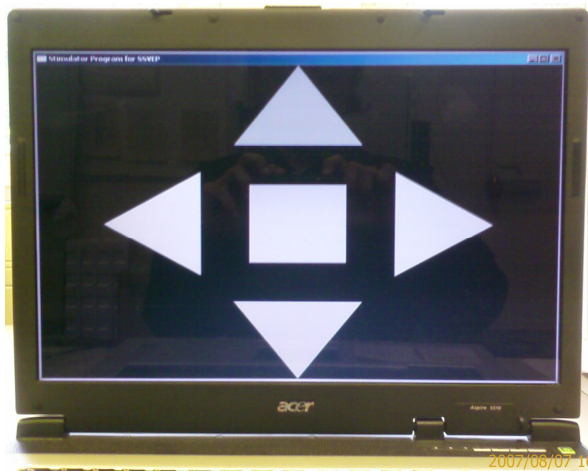


Figure 3: The left panel shows the display with the plain texture, and the right panel shows the checkbox version of this display.

RESULTS AND DISCUSSION

The widely used checkbox approach is not in fact superior to a comparable plain display for some subjects. Figure 4 below compares the SSVEP activity elicited by plain versus checkbox displays at each of the five frequencies studied for two of the four subjects. Although there is considerable variation between the two subjects and across frequencies, it is clear that the checkbox display would not be the best choice for either of these two subjects, especially subject 3. From the current data, it cannot be determined whether this variation across subjects is due to innate differences between subjects, different attentional strategies, subject background, or other factors.

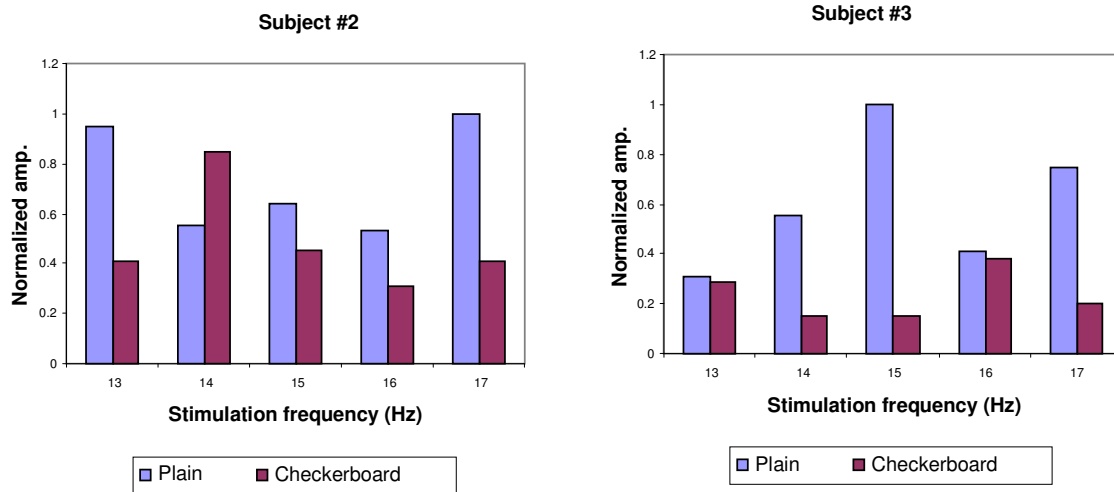


Figure 4: A comparison of the SSVEP activity elicited by plain vs. checkbox displays in two subjects. The y – axis presents the normalized amplitude of the frequency spectrum.

These results are consistent with other reports that show that other facets of SSVEP activity vary considerably across subjects. The best simulation frequency, recording sites, SSVEP frequencies where activity is strongest, threshold for selection, and type of display also differ across subjects [2][5][9]. Thus, to attain the best performance with each subject, an intelligent system (either a human expert or an automatic adaptive algorithm) should identify the best settings for each user. For example, one subject might function well with settings that include checkboxes that oscillate in the range of 13-15 Hz. Another subject might attain better performance with identical settings, except that the checkboxes are replaced with plain stimuli.

By identifying relevant display parameters that could affect SSVEP signal quality and thus BCI performance, this report provides additional information that might be used to further customize SSVEP BCIs for individual users. Further work should explore broader frequency ranges, more display types, effects of training, possible causes of inter – subject variability, and adaptive classifier mechanisms.

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