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Improving Memory Performance Using a Wearable BCI

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Introduction: Human ability to encode and memorize information fluctuates from moment to moment. Several studies have reported differences in electroencephalography (EEG) signals recorded during memorization of items that were forgotten at a later point of time compared to those that were remembered [1,2,3]. Given these observations the question then arises whether or not a wearable BCI system can be designed to identify poorly encoded items. Such a device could be used to provide feedback to the user so as to improve the memory encoding process. This paper reports on an experimental study designed to assess this possibility.

Material, Methods and Results: 14 healthy individuals participated in this study. The experiment paradigm consisted of an encoding phase followed by a recognition phase. In the encoding phase, 120 words were presented to the participants for memorizing in two blocks. The presentation of each word lasted for 2 s followed by a 0.5 s inter-trial stimulus. In the recognition phase, 240 words including the 120 words previously learned in the encoding phase were randomly displayed to the participants. The participants were asked to identify whether or not they had seen each word during the encoding phase, and how confident they were in their given answer.
EEG was recorded during the encoding phase using a wireless Emotiv EPOC headset with 14 electrodes (i.e. F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, O2) and 2 mastoid reference electrodes. The EEG signals were band-pass filtered (i.e 0.01-35 Hz), segmented and baseline corrected. Automatic artifact rejection was applied.
Our experimental results revealed that our participants successfully remembered on average 72% of the presented words in the recognition phase. Corroborating previous studies [1,2,3], averaging over multiple EEG trials of the encoding phase suggest that the power of the pre-stimulus theta and beta and the power of alpha after the onset of the words over the parietal/occipital electrodes could be potentially useful as features for identifying poorly versus well encoded words. Moreover, signal amplitudes from 1.5 to 2s after the onset of the words in the parietal/occipital electrodes were significantly different between the two conditions (see Fig. 1).

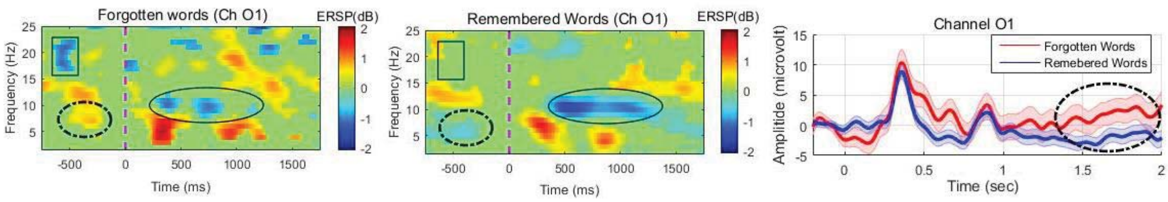

Figure 1. *Time-frquency and ERP plots of the encoding phase from 14 subjects at O1. The elipses and squares denote the significantly different regions across the forgotten and remebered words (p<0.05). The dashed purple lines denote the onset of the words.*

To evaluate the discriminability of these features on a single-trial basis, the trials of each subject were sorted based on the magnitude of each feature. Thereafter, the number of forgotten and remembered words were counted in the 6 and 12 trials (i.e. 5% and 10% of the set size) with the highest and lowest magnitudes. Among the different features evaluated, the power of pre-stimulus theta (i.e. -0.5 s to 0) over the occipital electrodes was the most successful in discriminating between the forgotten and remembered words. As an example, in the 6 and 12 words with the highest (lowest) pre-stimulus theta at O1, on average 44% and 36% (14% and 22%) were forgotten respectively. In contrast, if the same number of words were randomly selected, on average 28% of them were forgotten. Interestingly, paired t-tests showed that in the 6 words with either the highest or the lowest pre-stimulus theta power and the 12 words with the highest pre-stimulus theta power, the number of forgotten words was significantly different from chance level ($P<0.05$).

Discussion: Our preliminary results suggest that it is possible to design a wearable BCI system for improving memory. Currently, reliable prediction relies upon a number of trials (i.e. those with the highest or lowest pre-stimulus theta power). We aim to improve upon this through more sophisticated feature selection procedures and spatial filters. Moreover we will explore features discriminative of subject confidence in recalling items.

Significance: Our study can potentially lead to practical, wearable BCIs which can help users learn more effectively and efficiently through presenting items to be encoded during times of optimal cognitive capacity and by repeating stimuli that have been predicted most likely to be forgotten.

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