Poster: *Characters vs. Words* - Observations on Command Design for Brain-Computer Interfaces

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1. OVERVIEW

Brain-computer interfaces (BCIs) allow users to communicate to a nearby computing device (computer, smartphone, etc.) using thoughts or other covert actions that result in a detectable change in brain-waves. Consider a BCI command to be a *word* consisting of a sequence of *characters*. Each character is a thought or action that can be reliably detected through brain waves. For this work, we specifically consider *eye-blinks* as the user action of interest. Eye-blinks are an interesting modality for BCI commands because of their easy detectability and naturalness (and hence covertness). It turns out that there is an interesting trade-off between the complexity of characters and the length of words. In this work, we perform a user-study to answer a simple, but important, question pertaining to eye-blinks based BCI command design: *do users prefer shorter characters (and hence longer words) or shorter words (and hence longer characters) when performing commands?* (Fig.1 and 2, where **B** denotes an eye-blink) We present a simple eye-blink language consisting of words and characters and use real user-experiments to study the aforementioned trade-off.

{BB BB BB BB}

Figure 1: Shorter Characters

{BBBB BBBB}

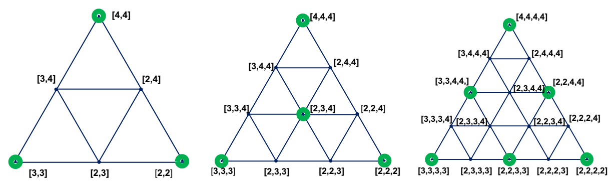
Figure 2: Shorter Words

2. EYE-BLINK COMMANDS

We use the multiplicity of eye-blinks to construct eye-blink words, and represent them with numerals (for e.g. “2” represents a double blink). A command thus consists of a sequence of words separated by “non eye-blinks”, and is represented with numerals enclosed in square brackets separated by “,”s (for e.g. [2,3] denotes a double eye-blink followed by a non eye-blink, and then a triple eye-blink). Generically, this can be represented as,

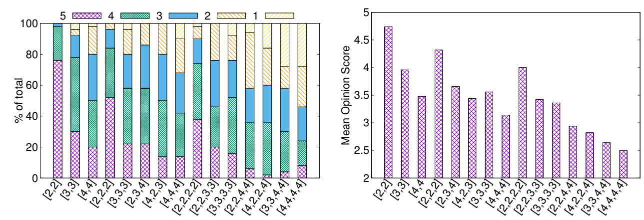
$$\{\ [A_1, A_2, \ldots A_n] \mid i, A_i \in \mathcal{N} \text{ and } A_i \leq M\ , i \leq N\}$$

where M and N represent the lengths of the character and the word respectively. A character cannot be “1” (or single-blink) because of the high natural frequency of its occurence (leading to false positives). We also restrict the scope of our study to a maximum value of 4 for both M and N. This results in 117 different permutations and 31 unique combinations of commands. Since the sum of the total number of double-blinks (#2), triple-blinks (#3) and 4-blinks (#4) is equal to the command length (i.e., #2 + #3 + #4 = N), the 31 command combinations can be mapped in a 3D space with three axes as #2, #3 and #4. These commands lie on 3 parallel planes, which are shown in Fig. 3. To reduce the experimental complexity, we select a set of *representative commands* such that all commands in Fig.3 are within a 1-hop distance from the representative commands while minimizing the cardinality of the representative set. This results in 13 different commands (marked in Fig.3 with green circles). We add two additional commands ([4,2,3] and [4,2,2,4]) in order to study the effect of permutation in command usability, making it a total of 15 commands for experimental analysis.



(a) N=2 (b) N=3 (c) N=4

Figure 3: Eye-Blink Commands



(a) Cumulative ratings (b) MOS

Figure 4: Experimental Results

3. EXPERIMENTAL INSIGHTS

For the user study, we ask 50 users to perform the 15 blink commands, and rate them on an mean opinion score (MOS) scale of 1 to 5 (1 being most difficult, 5 being very easy). Fig.4a, and 4b show percentage distribution of MOS scores for each command, and the average MOS score aggregated over 50 users, respectively. The following interesting and non-intuitive insights can be observed:

- Longer commands with shorter word lengths are preferred over shorter commands with longer word lengths. For e.g. [2,2,2,2] is more comfortable (MOS: 4.0, % of 5s: 38%) as compared to [4,4] (MOS: 3.48, % of 5s: 20%).
- Thus, for a given BCI application with a required vocabulary size, N should be increased before M to ensure user comfort.
- For a particular character combination, different character permutations impacts usability (e.g. [2,3,4] and [4,2,3] has % of 5s as 22% and 14%, and MOS of 3.66 and 3.44 respectively).

Exploring the command usability with different permutations and extending the analysis to other BCI modalities is a part of ongoing work.

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