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Effects of Varying Presentation Rate and Sequence Length on User Performance with the RSVP Keyboard BCI

B. Peters[1], D. Erdogmus[2], A. Fowler[1], A. Mooney[1], B. Oken[1], U. Orhan[2], B. Roark[1], M. Fried-Oken[1]
[1]Oregon Health & Science University, Portland, OR, USA; [2]Northeastern University, Boston, MA, USA

Correspondence: M. Fried-Oken, OHSU, P.O. Box 574, Portland, OR, 97239. E-mail: friedm@ohsu.edu

Abstract. This study investigated the effects of varying two presentation parameters of the RSVP Keyboard™ brain-computer interface (BCI) on user performance. Character presentation rate was set to either 5 or 2.5 Hz, and the number of characters per sequence was set to either 10 or 28. Participants completed a word copying task under the resulting four conditions, and typing rate and error rate were calculated. Both presentation rate and sequence length were found to significantly affect typing rate, with 5 Hz being faster than 2.5 Hz and 10 characters per sequence being faster than 28. Neither parameter had a significant effect on error rate.

Keywords: BCI, augmentative and alternative communication, P300, typing rate, rapid serial visual presentation

1. Introduction

Brain computer interface (BCI) shows great promise as a communication method for people with locked-in syndrome (LIS) and others with severe disabilities. The RSVP Keyboard™ is a non-invasive, P300-based BCI system designed for use as a typing and communication tool by people with LIS. Its unique features include rapid serial visual presentation (RSVP) of stimuli [Orhan et al., 2012] and an integrated language model which is combined with information from P300 responses to support spelling accuracy [Orhan et al., 2011].

One drawback to the RSVP Keyboard™ and other BCI-based typing and communication systems is their relatively slow rate of text generation. This study was designed to examine whether a faster character presentation rate or reduced character sequence length would increase typing rates for users of the RSVP Keyboard™.

2. Material and Methods

A convenience sample of eight adults without disabilities (two men and six women) was used. Participants reported within normal sensory, cognitive, communication abilities. Three were from minority groups, and three were non-native but fluent speakers of English.

Experimental sessions took place in a quiet room at OHSU. Electroencephalography (EEG) signals were recorded using a 16-channel g.USBamp (g.tec, Graz, Austria) with active electrodes in a cap at approximate 10-20 locations, with a reference electrode at TP10 and ground at FpZ. Stimuli were presented on a laptop screen following the RSVP paradigm and consisted of 28 characters, including the letters of the alphabet plus "<" for backspace and "_" for space. To generate the EEG classifier, participants completed calibration sessions consisting of 50 sequences of 10 characters. Prior to each sequence, participants were shown a target character, which they were instructed to detect when it reappeared in the 10-character sequence. Classifier accuracy was estimated from the area under the curve (AUC) of true positive versus false positive rate for target versus non-target classification.

During the task, phrases were presented one at a time at the top of the laptop screen, with a target word designated in a contrasting color. Phrase sets were chosen from the *New York Times* portion of the English Gigaword corpus. Participants were instructed to copy the target word using the RSVP Keyboard™, and to correct any errors by selecting the "<". Participants copied two or three target words for each condition; the participant would attempt a third word only if she did not copy the first two correctly. The program moved to the next phrase when one of the following criteria was met: the target word was copied correctly, the participant spent ten minutes attempting to copy a word, five consecutive incorrect characters were chosen, or 32 sequences were presented.

Before beginning the experimental conditions, participants completed a calibration session with characters presented at 2.5 Hz, and then attempted a "warm-up" word copying task. For the warm-up task, characters were presented at 2.5 Hz and 28 characters per sequence (the default settings for the RSVP Keyboard™ in previous work), and target words were chosen to be highly predictable by the language model, and therefore easy to copy.

After the warm-up, participants completed a word copying task under four different conditions. Presentation rate was set to either 2.5 or 5 Hz, and sequence length to either 10 or 28 characters, resulting in the following conditions: 2.5 Hz/10 characters, 2.5 Hz/28 characters, 5 Hz/10 characters, and 5 Hz/28 characters. The 10-character sequences

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included the eight most likely letters as determined by the language model (taking into account posterior probabilities from prior sequences), plus "_" and "<". The 28-character sequences contained the full set of stimuli and were divided into two 14-character blocks. Phrase sets were chosen such that all target words were four letters long and were equally predictable by the language model. Each participant completed the four conditions in a different order, with conditions with the same presentation rate kept together to avoid additional re-calibrations. Participants re-calibrated at the appropriate presentation rate prior to each pair of conditions with the same rate. If a participant did not achieve an AUC of 0.85 or above on her first attempt, she could re-calibrate a second time.

Typing rate was calculated for each condition by dividing the number of characters in the final output by the time, in minutes, required to complete the condition. Error rate was calculated by dividing the number of incorrect selections by the total number of selections for each condition. If an incorrect letter was selected, only the "<" was accepted as correct for the following selection.

3. Results

A repeated measures ANOVA found that both presentation rate ($F(1,7) = 5.851$, $p = .046$) and sequence length ($F(1,7) = 150.669$, $p = .000$) had significant effects on participants' typing rates. Participants were able to produce more characters per minute with a presentation rate of 5 Hz than with 2.5 Hz, and with 10 characters per sequence rather than 28. Neither presentation rate ($F(1,7) = .004$, $p = .954$) nor sequence length ($F(1,7) = .320$, $p = .589$) had any significant effect on error rate. These results are presented in Table 1.

The condition with the highest mean typing rate used settings of 5 Hz for presentation rate and 10 characters per sequence ($M = 3.93$, $SD = 1.410$). This condition was compared to the next fastest condition (2.5 Hz and 10 characters per sequence, $M = 2.63$, $SD = .762$) using a paired samples t test. The difference in typing rate between these two conditions approached significance ($t(7) = -2.312$, $p = 0.054$).

Table 1. *Typing rate and error rate results. Data are presented as mean (SD), range.*

Presentation Rate [Hz]	*2.5*		*5*		*p*
Sequence Length [characters/sequence]	*28*	*10*	*28*	*10*	
Typing Rate [characters/minute]	1.49 (.972), .69-3.75	2.63 (.762), 1.67-3.72	1.92 (1.056), .58-3.93	3.93 (1.410), 1.78-6.76	Rate: .046 Length: .000
Error Rate [%]	20.3 (27.46), 0-68.8	9.0 (13.70), 0-36.4	14.9 (18.23), 0-51.5	15.2 (22.43), 0-66.7	Rate: .954 Length: .589

4. Discussion

The results of this study indicate that a faster presentation rate (5 Hz vs. 2.5 Hz) and shorter sequences (10 characters vs. 28) can increase typing speeds for healthy participants completing a word copying task using the RSVP Keyboard™ BCI, without any increase in error rate. Similarly, [Sellers et al., 2006] found that shorter inter stimulus intervals allowed subjects to produce text at a higher bit rate using the P300 Speller (with row-column stimulus presentation). Adjusting stimulus display parameters such as these may make the RSVP Keyboard™ and other BCI-based typing tools more effective for users with a variety of needs and abilities. Future research will examine the effects of varying presentation rate and sequence length on the performance of participants with LIS.

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