Selection Strategies for the RSVP Keyboard™ BCI: Different Strokes for Different Folks

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Abstract. Eight people with locked-in syndrome (LIS) and 18 healthy controls completed calibration sessions on the RSVP Keyboard™ P300 brain-computer interface (BCI) using the mental imagery-based selection strategy of their choice. We report here on BCI users' preferred strategies. Most people chose to rely on speech imagery, with motor imagery second, and sensory, visual or combined imagery used by one person each.

Keywords: Brain-computer interface, augmentative and alternative communication, P300, mental imagery, symbol selection

1. Introduction

The RSVP Keyboard™ is a P300-based spelling interface in which symbols are presented in a rapid serial visual presentation (RSVP) paradigm [Orhan et al., 2012]. The system detects the P300 response elicited when the user sees the desired symbol appear in a series of symbols, and users are encouraged to choose a mental image as a selection strategy, a conscious attempt to alter their brain activity. Here we present the strategies tried and preferred by people with locked-in syndrome (PLIS) and healthy controls when using the RSVP Keyboard™.

2. Material and Methods

Participants included eight PLIS (one classical, seven incomplete) with a variety of underlying diagnoses, and 18 healthy controls. Our definition of incomplete LIS encompasses people who are unsuccessful at using oral speech or writing for language expression due to severe speech and physical impairments. Experimental sessions took place at the homes of PLIS, and in a quiet university lab room for healthy controls. Electroencephalography (EEG) signals were recorded using a 16-channel g.USBamp and g.BUTTERFLY electrodes (g.tec, Graz, Austria).

Before attempting any typing task with the RSVP Keyboard™, users must calibrate the system. During each calibration session, participants are presented with either 50 or 75 sequences of symbols. Each sequence begins with a target symbol, followed by a fixation cross and then a series of 10 symbols. Participants are instructed to watch for the target symbol to reappear in the series of 10 symbols, and to "do something to change your brain activity" when it appears; this is the participant's selection strategy. Participants are provided with examples of selection strategies from various categories including motor, speech, visual, sensory, and auditory imagery. Each person is encouraged to choose a strategy that feels natural, or that is easy to consistently apply while using the RSVP Keyboard™. Before each calibration session, participants are given the option to continue using the same strategy, or to try something different. They are instructed not to switch strategies mid-session. Researchers record the specific strategies tried by each participant, as well as the final strategy used during the RSVP task. Final preferred strategies are determined either by asking the participant or by observing which strategy he or she chooses most often.

For each calibration, classifier accuracy is estimated from the area under the curve (AUC) of true positive versus false positive rate for the calibration target versus non-target classification, under a 10-fold cross-validation.

3. Results

Participants' selection strategies are categorized into five types of imagery: speech, visual, sensory, motor, or a combination of two types. Participants chose a preferred strategy based on ease of use, AUC score, or both. Three PLIS and seven control participants tried two or more types of strategies. The remaining participants were satisfied with their initial choice and did not try other options. Two PLIS and one control did not show a clear preference for any category. This may be the result of limited experience with the RSVP Keyboard™ (the two PLIS had only two calibration sessions each) or not being satisfied with any of the options tried (as with the control participant).

Table 1 indicates how many participants tried each category of selection strategy, and how many participants showed a preference for each category. Examples of actual participant strategies are provided. Speech imagery was the most popular type of selection strategy for both participant groups. Motor imagery was the second most popular

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category among controls, but not one PLIS used a purely motor imagery-based selection strategy. Two did try strategies combining motor and speech imagery, though neither one preferred the combination strategy. The motor components of both combination strategies (moving a finger and clicking a mouse) were small movements that these two participants (both with incomplete LIS secondary to advanced ALS) were physically able to do.

Median tests on AUC scores for all calibrations completed by PLIS, X^2 (3, N = 43) = 4.21, p = .240, and control participants, X^2 (3, N = 44) = 1.87, p = .601, indicated that selection strategy did not have a significant effect on classification accuracy for either participant group.

Table 1. *Selection strategies tried and preferred by PLIS and control participants.*

Imagery Category	*PLIS (N = 8)* Tried	*PLIS (N = 8)* Preferred	*Controls (N = 18)* Tried	*Controls (N = 18)* Preferred	*Examples*
Speech	8	6	17	11	Imagine saying or screaming symbol name Imagine saying “Bam!” or “Yeah!” or similar exclamation
Visual	1	0	2	1	Imagine a line or slash through target symbol Visualize a pleasant image
Sensory	1	0	0	0	Imagine being pinched on the arm
Motor	0	0	6	4	Imagine punching or grabbing target symbol Imagine swinging a golf club
Combination	2	0	1	1	Imagine saying “There!” and moving right index finger Imagine saying symbol name and clicking a mouse

4. Discussion

Selection strategy might be a variable that affects success in BCI use or strength of P300 signal detection. As such, it is valuable to determine what strategies are used by PLIS and healthy controls. Although speech imagery was the most popular selection strategy among both PLIS and control participants, it was not preferred by all participants. Some BCI users may benefit from strategies based on other types of mental imagery. These results are similar to those of [Friedrich, et al., 2012], who compared the event-related (de)synchronization (ERD/S) responses produced by a variety of mental tasks for potential BCI control, as well as participants’ opinions of those tasks. In that study, there was high variability among participants both in classification simulation results for each task pair and in self-ratings of the imagery quality, ease of use, and enjoyment of each task. In a similar comparison of mental tasks for BCI control, [Curran et al., 2003] found that visual and auditory imagery were more reliable than motor imagery, and study participants reported that the non-motor tasks were easier to perform and required less concentration. Both of these studies included only participants without disabilities.

Interestingly, PLIS avoided using motor imagery-based strategies, and those who tried them (in combination with other imagery) imagined movements they could make in reality. People with congenital motor impairments may lack experience with the movements they are asked to imagine, and those with LIS due to acquired conditions may begin to find motor imagery difficult or unnatural. Motor and sensory impairments may also be associated with changes in the brain itself. Therefore, strategies which can work well for users without disabilities, such as motor imagery, might not be ideal for some PLIS. The data presented here are not sufficient to determine whether certain selection strategies are better than others, or even whether using a selection strategy is preferable to no strategy at all. Future research in this area may be beneficial for determining optimal ways to improve BCI performance, particularly for users with LIS, since selection strategies may improve attention or be associated with EEG changes.

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