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Clinical Screening Protocol for RSVP Keyboard BCI Use

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Abstract. We report on development of a clinical screening instrument designed to determine whether people with locked-in syndrome have the requisite minimal skills to use the RSVP Keyboard™ BCI for spelling. A multidisciplinary clinical team identified skills needed and then modified existing subtests or tasks from clinical batteries to screen for hearing, visual perception, sustained visual attention, auditory comprehension, spelling, reading comprehension and literacy, and memory. The screening instrument was administered to 12 individuals with LIS. Testing took no more than an hour. All had reliable yes/no responses and could use eye pointing. Nine were accurate 100% on all tasks; three missed single items on tasks. The tool is appropriate for screening people with different diagnoses leading to LIS to determine if they have skills needed for possible BCI introduction.

Keywords: RSVP, spelling interface, locked-in syndrome, clinical protocol, screening tool

1. Introduction

In order for an individual with locked-in syndrome (LIS) to rely on a brain computer interface (BCI) for spelling, he/she must have adequate cognitive, sensory, seating and positioning, and language skills to perform requisite tasks. We identifed requisite skills for the RSVP Keyboard™, and developed screening tasks to determine if individuals with LIS possess basic functionality for its use. RSVP Keyboard™ is a BCI that relies on rapid serial visual presentation of symbols (letters, backspace, space) with P300 detection. This non-invasive system selects letters by joint evidence from a language model and EEG signals. Using a 200 to 400 ms stimulus time, one large letter is presented at a time on a monitor, thus reducing the visual-perceptual demands of a complicated display.

Assessing cognitive and communication abilities of individuals with LIS presents a number of challenges. Many assessment tools require verbal and/or written responses, which people with LIS are, by definition, unable to provide. Neuropsychological tests have been adapted for patients with classical or incomplete LIS, using yes/no questions that can be answered with eye or facial movements [Lakerveld et al., 2008; Schnakers et al., 2008; Rousseaux et al., 2009]. The range of cognitive and communication skill levels in this group is expansive, from individuals with ALS who may present with solely motor neuron impairments to adults with traumatic brain injuries which affect executive function, learning and memory. Due to this variability among people with LIS, a screening protocol is needed to determine whether patients can understand instructions, learn and complete the tasks required to effectively be introduced to the challenges of the BCI systems. We report on the RSVP BCI screening protocol, designed to determine whether an individual with LIS has the requisite sensory, cognitive, language skills to learn to use the non-invasive RSVP Keyboard™ for communication. The protocol includes structured interview questions, subtests from existing assessment tools that have been adapted for minimal motor responses, and new tasks developed to evaluate skills that are not adequately addressed elsewhere.

2. Material and Methods

Twelve participants with LIS were screened. We cast a wide net in our definition of LIS, including those individuals who are unsuccessful at using use oral speech or writing for language expression because of severe speech and physical impairment, and recruited 10 with incomplete LIS and two with classical LIS: 6 with amyotrophic lateral sclerosis (ALS), 1 with CVA, 1 with severe spastic-athetoid cerebral palsy, 1 with spastic quadriplegia secondary to arterial venous malformation, 1 with Duchenne muscular dystrophy, 1 with spinocerebellar ataxia, and 1 with progressive supranuclear palsy. Three participants were women, 9 were men.

A multidisciplinary clinical team identified the following skills as requisite for use with the RSVP Keyboard™: Visual perception, sustained visual attention, hearing, auditory comprehension, expressive language, memory and attention; reading comprehension and literacy, spelling. Probes about pain interference, medications, motor function, seating and positioning were deemed necessary for learning and use of the BCI. Items came from the following test batteries: PROMIS-P; Coma Recovery Scale- Revised; Western Aphasia Battery; Functional Linguistic Communication Inventory; Boston Naming Test. Tasks were adapted for motor-free responses using a clear,

Plexiglas eye gaze board [Goosens' and Crain, 1987] or binary choices with eye blinking, eye movement or consistent, reliable movement of the head, foot or hand. The eye transfer board or ETRAN is a transparent plastic board that contains 4-8 stimulus items placed in the corners. It is held up between the examiner and the patient. The patient looks at a test stimulus and the examiner can see eye pointing to the items (i.e., find the picture of the pencil; spell CAT). It is used for spelling, reading, and language comprehension screening tasks.

3. Results

Participants completed the screening protocol in a single session lasting one hour or less, and they reported that administration time was appropriate for their abilities and endurance. All participants with LIS could reliably indicate yes/no responses, using dysarthric speech, eye movements, blinking, or movements of the head, feet, or hands and eye pointing to the ETRAN board. All participants demonstrated hearing within functional limits for conversation. All could see well enough to read and to identify pictures and objects. Two participants reported experiencing diplopia. Six participants reported problems with pain, though none reported that pain interfered with memory, concentration, or the ability to process new information. Two participants stated that their pain 'sometimes or rarely' made them feel discouraged; one stated that pain was 'rarely' so severe that he could think of nothing else. Two participants (or their caregivers) reported mild difficulties with memory and/or attention. Nine participants scored 100% on all RSVP BCI screening tasks. The remaining three participants missed items on a single task. Eleven participants completed the screening protocol in a seated position, and one was assessed while lying in bed. The materials used in the protocol proved to be easily adjustable for a variety of positions. Two participants (both with spasticity due to either CP or AVM) demonstrated frequent, uncontrolled movements of facial and respiratory muscles, which could potentially interfere with accurate EEG signal acquisition when using the RSVP Keyboard™.

4. Discussion

The RSVP BCI screening protocol is designed to assess the requisite skills for use of the RSVP Keyboard™ by people with LIS. Field testing demonstrates that the instrument can be administered in the home environment to people with LIS resulting from a variety of diagnoses. Administration typically lasts one hour, and varies depending on the response time, yes/no communication method, and fatigability of individual participants; all agreed that the screening time was reasonable for the target population. With questions for sensory (vision, hearing), cognition (attention, memory), communication (expressive and receptive language, reading, literacy, spelling), motor (seating, positioning) skills and pain/medication considerations, the screening instrument appears to address important behaviors that affect BCI learning and use.

The RSVP BCI screening protocol requires only yes/no and eye gaze responses, allowing for use with people with classical or incomplete LIS. Results paint an initial picture of the patient's basic level of function in requisite skill areas. Because subtests were chosen or designed to resemble or duplicate actual RSVP tasks, results are considered good estimations of a patient's potential to learn to use the RSVP Keyboard™ for communication. The general benefit of this screening tool is that we now have a relatively short, comprehensive cognition and communication screen that can be used by the LIS population and addresses the specific skills that are important for BCI learning and use. It is time for the BCI clinical community to design a standard protocol of requisite skills that should be administered so that we have a common means to describe behaviors necessary for BCI learning and use.

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