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Eye Gaze Access to AAC Technology for Persons with Amyotrophic Lateral Sclerosis

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Keywords: amyotrophic lateral sclerosis, AAC, eye-gaze access, eye tracking, speech generating devices

Acknowledgements: This research was supported in part by the Munroe – Meyer Institute Foundation and the Barkley Trust. The authors wish to thank the Muscular Dystrophy Association for its support of our research. The authors especially wish to thank the participants with ALS and their families who have supported this research project.

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Abstract

The purpose of this study was to describe a group of individuals with amyotrophic lateral sclerosis' training and use of the Eye-gaze Response Interface Computer Aid (*ERICA*) with *Type & Talk* or *LifeMate 1.1* communication software. Fifteen persons with ALS participated in the study, and all but one successfully used *ERICA* as his/her primary communication device. The sole participant who discontinued use experienced the onset of impaired eyelid control during training. Results indicate that *ERICA* was used to support a number of different communication functions, such as face-to-face interaction (100%), group communication (43%), phone calls (71%), e-mail (79%), and internet access (86%). In an effort to optimize eye gaze tracking to support communication, a number of environmental, positioning, and calibration adjustments are reported.

Eye Gaze Access to AAC Technology for Persons with Amyotrophic Lateral Sclerosis

Individuals diagnosed with amyotrophic lateral sclerosis (ALS) experience progressive loss of motor function throughout their body; a subset will eventually have control only over eye movements. The disease leaves many unable to speak; and often, motoric impairments limit access to augmentative and alternative communication (AAC) through traditional means (e.g., head or extremity movements). To clarify the clinical research objectives, we describe features related to disease progression, eye gaze movement, and fundamentals regarding eye gaze interfaces.

Progression of ALS

Yorkston, Miller and Strand (2003) describe ALS as a disease that rapidly destroys motor neurons throughout a person's spinal cord and brain. Deterioration of motor neurons may start in the spinal nerves (spinal presentation), cranial nerves (bulbar presentation), or a combination of the two. The cause is unknown, but both sporadic and familial forms have been identified. Some symptoms of ALS include muscle weakness, slow movements, increased muscle tone, fasciculations, atrophy, and a strained, strangled or breathy voice. Complete loss of muscle movement occurs for some individuals; however, extraocular muscles that control eye movements, and the sacral segment of the spinal cord that controls bowel/bladder functions, are usually spared. In addition to muscle difficulties, frontotemporal cognitive changes (Irwin, Lippa, & Swearer, 2007; Neary, Snowden, & Mann, 2000) and emotional lability are possible. Life expectancy varies depending on the type of presentation (e.g., bulbar vs. spinal), but an individual with ALS typically does not often live longer than five years.

Although respiratory failure is usually the cause of death (Yorkston et al., 2003); tube feeding (Oliver, 2004; Langmore, Kasarskis, Manca & Olney, 2007; Miller, Mitchell, Lyon, & Moore, 2007) and mechanical ventilation (Bach, 1993; Bach, 2002, Cazzoli, 1996) can prolong life expectancy to varying degrees.

Eye Movements in ALS

Although eye movements of individuals with ALS are typically spared (Yorkston et al., 2003), occasional deficits are identified. Palmowski et al. (1995) detected subclinical changes in eye movement over time, using electro-oculography, in seven of eight individuals with ALS. Five of these individuals also showed changes in eye movements on clinical exam. Oculomotor (e.g. ocular motor) apraxia, described as a loss of voluntary control of eye movement as it changes focus while moving from one target to another (saccade), with preservation of reflexive movements, may also occur in individuals with neurological deficits (Rambold et al., 2006; Zadikoff & Lang, 2005). Individuals with oculomotor apraxia may evidence reflexive eye movements influenced by head movements, blinks, or objects in motion. Okhi, Kanayama, Nakamura, Okuyama, Kimura, & Koike (1994) identified reduced saccade velocity, particularly when bulbar signs were present. Some oculomotor deficits impacting voluntary eye movement, eyelid opening/closure control, or muscle weakness, that may have a potential impact on successful use of eye gaze as an access method to AAC, have been documented (Okhi et al., 1994). As summarized by Cohen and Caroscio (1983), two main categories of oculomotor deficits have been identified among individuals with ALS, those with: (1) deficient voluntary movements on specific tasks, and less

commonly, (2) a weakness of eye muscles, although deficits in either category may be subtle.

Communication Difficulties in ALS

According to Yorkston et al. (2003), speech difficulties are characterized by mixed dysarthria; features consistent with spasticity, weakness, reduced rate, hypernasal resonance, abbreviated utterances, harsh and/or breathy vocal quality, disrupted prosody, and inappropriate silences may be perceived. With ongoing disease progression, ALS ultimately leads to anarthria, or a complete loss of the ability to speak. A means of communication is needed to maintain social closeness, provide information, make decisions, and indicate basic wants and needs. Augmentative and alternative communication (AAC) techniques can range from no/low technology to high technology. Low technology systems are those that do not include voice output and may include handwriting, topic boards, alphabet boards, and eye-linking partner-supported systems. Given the severity of the communication impairment experienced by persons with ALS, voice output AAC technologies are often considered to supplement or replace natural speech. Doyle and Phillips (2001) indicated that persons with ALS often use eye gaze access as an interface to access AAC, particularly in advanced stages of the disease. Hansen, Torning, Johansen, Itoh, and Aoki (2004) recommended that, due to changes in motoric abilities throughout the course of the disease, individuals with ALS must be prepared to use multimodal input to access AAC of all types. For persons who use AAC, multimodal input and familiarity with technology facilitates communication with a variety of caregivers, provides access to technology support, gives alternatives to continue

communication while facing fatigue, and provides access adaptations to accommodate for changes related to ALS progression.

Yorkston et al. (2003) report that AAC must be implemented in a timely manner due to the challenge for families in making decisions during a critical time, secondary complications that make treatments difficult, lack of time or energy to pursue treatments, and increased emotional lability. Ball, Beukelman, and Pattee (2004) found that 96% of persons with ALS who participated in their study accepted AAC technology, either immediately or after a brief delay. None of their participants discontinued use of AAC technology until within a few weeks prior to death. Although there was limited discussion of specific technologies used, these researchers also stressed the importance of timely intervention. Early intervention allows for: (1) relationships to develop among the person with ALS, the family, and other care providers; (2) education about the disease and potential interventions at a controlled, timely pace; (3) gradual introduction of AAC technology to increase acceptance; (4) provision of appropriate interventions (e.g., feeding tube placement, AAC assessment) at critical times before consequent problems become crises; and (5) appropriate time to learn to use AAC technology for functional communication.

Fundamentals of Eye Gaze Interfaces

There are many ways to use eye gaze to interface with a computer or AAC technology. Some options include: (1) surface electrodes placed around the eye to provide data on relative eye movement within the head, (2) remote video imaging of a specific feature on the eye to measure eye movement, (3) contact lenses to track eye

movements, and (4) shining an infrared beam into the eye to track visual line of gaze (Donegan et al., 2005; Jacob, 1991).

Eye gaze interfaces can be an effective means of input because eye gaze is natural and fast, eye muscles display little fatigue, eye gaze carries information about the person's focus, and most commonly there is nothing attached to the individual which is necessary for operation of the system (Bates & Istance, 2003; Hyrskykari, Majaranta & Rähä, 2005). There are however, some drawbacks associated with eye gaze interfaces. Bates and Istance (2003) also indicate that eye gaze may be (a) inaccurate within a small area (approximately 1°), thus making it difficult to select small items; (b) effortful, because many eye movements are subconscious and thus effort is required to bring them under conscious control; (c) difficult, because the eyes are being used for both input and output, thus requiring careful coordination of reading for input by putting eye selection output aside. The technology can also be expensive, difficult to calibrate, involve lengthy training, may be hindered by prior visual problems, and it often requires an ideal set-up for use (Bates & Istance, 2003; Donegan et al., 2005). In considering other head movements, research has reported that using an "eye mouse" was less accurate and resulted in large amounts of nonproductive time (e.g., mis-selections, calibration, correcting errors), compared to "head mouse" and "hand mouse" access (Bates & Istance, 2003; Hansen et al., 2004). However, Bates and Istance (2003) reported a significant drop in nonproductive time when participants were experienced (i.e., given 15-30 hours of training). To date, the literature is deficient of information on how persons with ALS respond to the use of eye gaze technology as an access method for AAC.

Historically, eye gaze interfaces have been difficult to implement for functional communication, due to equipment sensitivity to body movements during calibration, problems with extraneous lighting sources, and other environmental factors. Recently, eye gaze interfaces have become a more common access method for AAC technology. Several of these products are currently available for use by persons with complex communication needs and are being used with increasing frequency by persons with ALS. At the time of this study, some frequently-used systems included the Eye-gaze Response Interface Computer Aid (*ERICA*)¹ from Eye Response Technologies, the MyTobii P10² from Tobii Technology, LC Technologies, Inc., and the EyeTech SGD-Quick Glance³ from EyeTech Digital Systems. One product, the *ERICA*, identified as being implemented predominantly in this geographic region, was available for trial by all participants during their AAC evaluation, and was therefore selected for use in this study.

Eye-gaze Response Interface Computer Aid (ERICA)

The *ERICA* is an AAC technology system that allows for multiple means of access (e.g., direct selection with hands using the touch screen or keyboard, direct selection using eye gaze and an onscreen keyboard, direct selection using a head tracking device and an onscreen keyboard, scanning selection using movement from various muscles to activate a switch) which may be adapted as the individual's needs change through the progression of ALS. *ERICA* (with *Type & Talk* or *LifeMate 1.1* software) provides an onscreen keyboard, full words, command keys, abbreviation expansion, Windows-based programs (e.g., word processing, games, internet/email), and environmental controls. *ERICA* tracks an individual's eye gaze using a camera

mounted at its base and directed at the individual. The camera emits a harmless, low-power, infrared light using a Light Emitting Diode (LED) to measure the “*glint*” and “*bright-eye*” reflections from the individual’s eye. In this way, the *ERICA* obtains the individual’s point-of-regard (Eye Response Technologies Inc., 2006) and tracks movement on the computer screen. The *glint* is “a bright point of infrared light reflected off the corneal surface of the eye” and *bright-eye* is “created by infrared light being absorbed and reemitted from the retina through the pupil” (Eye Response Technologies Inc., 2006, p 1.1.1). *ERICA* utilizes a dwell feature for a predetermined amount of time and mouse clicks to select items on the screen (Lankford, 2000; Eye Response Technologies Inc., 2006). To accommodate for some individuals’ difficulty accessing small items, the *ERICA* zoom technology allows a small area of the screen to enlarge when an individual fixates their gaze on an item (Lankford, 2000). When the area enlarges, the individual can then further focus the direction of eye movement to select the small item easily. The optimal environment for *ERICA* use is under fluorescent lighting; and some anecdotal clinical difficulties using *ERICA* under incandescent lights, halogen lights, and sunlight have been reported. *ERICA* can be adjusted for people who wear glasses or contact lenses, or who have nystagmus (Eye Response Technologies Inc., 2006). At the time this study was initiated, *ERICA* with *Type & Talk* or *LifeMate 1.1* software was the primary eye gaze system with wide commercial availability that accepted Medicare assignment for funding in the USA. Therefore persons with ALS in the region where the research was completed were obtaining this system more frequently than other available systems.

A national coverage determination effective on 1 January 2000 of Medicare benefits resulted in coverage of speech generating devices, considered durable medical equipment, for its beneficiaries. Additionally, legislation effective 1 July 2001 established that all persons diagnosed with ALS become Medicare-eligible immediately, thereby waiving the 24-month waiting period for disability associated with other disabling conditions. As a result of these two national developments, the majority of individuals with ALS were covered by the Medicare system of funding for durable medical equipment (i.e., speech generating devices). It is noteworthy that other funding agencies (e.g., Medicaid, private insurance, Veteran's Administration) commonly use Medicare coverage decisions to form their own policy. As a result, many also began speech generating device coverage during this time.

Although other eye gaze systems were on the market at the time of this study, most were not accepting Medicare assignment for funding and no participants were available to be recruited who were using other systems. Since the time this study was completed, additional eye gaze technology manufacturers have begun accepting Medicare and other private funding mechanisms. As a result, eye gaze technologies have become more mainstream and have been added to technology offerings of other AAC manufacturers (e.g., ECOpoint™ from Prentke Romich Company, EyeMax from Dynavox) as well as technology and application upgrades for ERICA. It was the intent of this study to document use patterns of people who had extended experience with a single eye gaze system, rather than to compare the use of multiple systems by the same individuals.

Research Objectives

There is a particular interest among persons with ALS and their care providers in eye gaze tracking technology because of the potential to exploit the relative preservation of eye movements for communication, even with extended ALS progression. This technology offers a viable system of access to communication systems, and indeed, is among the only available functional options for a person with ALS to gain access to a communication system when all other motor skills have degraded and other access options have been exhausted. The purpose of this article is to describe the acceptance, training, and extended use/communication patterns of a group of individuals with ALS who, following AAC evaluation involving multiple systems and access methods, selected ERICA eye gaze tracking access for communication.

METHOD

Participants

Adults diagnosed with ALS were recruited through a regional Muscular Dystrophy Association (MDA) sponsored outpatient clinic in the Midwestern USA, regional long-term care units, and outpatient therapy settings. Participants were diagnosed with clinically probable ALS (Brooks, Miller, Swash, & Munsat, 2000) by a board-certified neurologist (author GL Pattee).

Fifteen adults (5 female, 10 male) who ranged in age from 39 years to 73 years ($M = 52.9$ years) participated in the study. Participants represented 15 consecutive people with ALS seen at three locations for AAC evaluations. These participants were

recruited because they had independently chosen *ERICA* as their primary means of communication via AAC technology. During the same time frame, other individuals with ALS excluded from this study (but receiving AAC evaluations in the same clinical settings) chose other AAC technologies for communication (e.g., Dynavox MT4®/V®, Dynavox DV4®/Vmax®, TobyChurchill, LTD LightWriter®). Participants included in this study selected *ERICA* following their individual AAC evaluation completed by a speech-language pathologist with a minimum of 5 years experience with ALS and AAC. Each AAC evaluation included a minimum of three other communication device options from various AAC manufacturers commonly used by persons with ALS at that time. At the time of evaluation, persons with ALS had the *ERICA* and the HK EyeCan VisionKey™ available for trial during their assessment. The evaluating speech-language pathologist was available to provide expert consultation regarding all of the systems throughout the individual's AAC evaluation and intervention. Prior to data collection, participants had used *ERICA* with *Type & Talk* or *LifeMate 1.1* software as their primary means of communication for a minimum of one month. The study examined participants' performance using *ERICA* at one point in time and was conducted during October-December. At the time of data collection, all of the participants used *ERICA* to communicate support communication and respond during the data collection process.

The Hollingshead Four Factor Index of Social Status (ISS) (Hollingshead, 1975) was calculated for illustration of the participant sample in comparison with the general US population. The ISS uses education, occupation, and marital status to determine a composite social status. For each participant, a composite score was computed $[(\text{occupation value} \times \text{weight of } 5) + (\text{education value} \times \text{weight of } 3) = \text{ISS}]$. In homes with

two employed adults, the scores were averaged to obtain one score per family. ISS education scores range from 1 (less than 7 years schooling) to 7 (graduate professional training), and ISS occupation scores range from 1 (farm laborers/ service worker) to 9 (higher executives, proprietors of large businesses, and major professionals). Total ISS raw scores range from 8 to 66, with higher scores reflecting higher SES. Participant's ISS scores ranged from 11 to 57 ($M = 34$), which reflects a range of social status. A sampling of each level of socioeconomic status was identified, with the majority of scores surrounding the mean (indicating the ISS-defined "middle" social class). The scores of participants are consistent with those of the general population of the US in composition.

Each participant's speech status at the time of the original AAC evaluation was obtained from the speech-language pathologists who completed the assessment procedures. Twelve participants were referred by their treating physicians (i.e., neurologists specializing in ALS) for AAC assessment according to the Ball, Beukelman, and Pattee (2002) guidelines for persons with ALS, which recommend referral when speaking rate in sentences reaches approximately 125 words per minute, either with or without intelligibility reduction, on the Speech Intelligibility Test (Beukelman, Yorkston, Hakel & Dorsey, 2007). Two were referred after their speech intelligibility was mildly reduced, and one was referred when she was completely unable to speak functionally and required immediate support with equipment from an AAC technology loan bank. Table 1 illustrates sentence intelligibility and speaking rate scores for all participants.

Six of the 15 participants (40%) were supported by mechanical ventilation at the time data was collected and had no functional use of their extremities. Others were

considering the option of mechanical ventilation as their respiratory function decreased. Ten participants lived in their own home, while five resided in assisted living ($n = 2$) or long-term care facilities ($n = 3$). All participants obtained funding support to purchase their system prior to acquiring *ERICA*. The sources of funding included: Medicare (46.7%), Medicaid (26.7%), private funding (either insurance or self-pay) (20%), and the Veterans Administration (6.7%).

Questionnaire Development

To evaluate overall effectiveness of this eye gaze technology for functional communication, the researchers developed an informal 30-item questionnaire. To establish content validity, items were selected for inclusion that focused on aspects described by participants' personal experience with *eye gaze access* and consensus among five SLPs with clinical expertise in implementing the *ERICA* communication system. Questions were developed relative to goals of the research project and addressed impairments associated with the ALS diagnosis. Questionnaire items requested participant's rationale for the selection of the *ERICA* instead of the other systems considered during the AAC evaluation. To address training and communication aspects, additional questionnaire items were designed to explore eight contributors to successful implementation identified by persons with ALS, care providers, and clinicians. Individual items profiled length of use, amount of training provided, physical status (e.g., body, head movement), eye status (e.g., movement, color, corrective lens use), locations of use (e.g., site, environmental lighting), system positioning, and practice needs.

Procedures

Each participant completed the entire questionnaire during one visit with one of the authors (i.e., Ball or Fager). Sessions varied in duration from 1 hour to 3 hours, depending on communication rate, amount of information provided by the participant and caregivers, and other procedures resulting in session interruption. A care provider was present during each session to assist in corroborating the information provided by the person with ALS and expand responses to questions, as requested by the person with ALS. Visits were either conducted at the regional medical center ALS clinic where the participant received care or in the participant's place of residence (e.g., home or skilled nursing facility), based on the participant's preference. Participants responded to the questionnaire using multiple modalities, including *ERICA*, facial/hand gestures, caregiver response with confirmation (yes or no) of agreement from the participant, and residual speech. At the time of data collection, all participants had severe limb involvement and were all positioned in a wheelchair or bed during the interviews. All of the participants' self-report responses were rated on the questionnaire. Because this study was more descriptive in nature and to accommodate for the participant's fatigue associated with disease, no test-retest or inter-rater reliability measures were conducted.

RESULTS

Results pertaining to individual questionnaire sections including system selection, use environments, and corrective lenses and lighting are presented. One case involving oculomotor apraxia is discussed.

System Selection

On the questionnaire item used to determine why participants had selected *ERICA* for their communication system, participants indicated three reasons; that: (1) eye tracking technology was the only option available to them, as they no longer had sufficient limb or head movement for the other methods of access (53.3%); (2) they were unable to learn to scan accurately and efficiently enough to be satisfied with those methods on other technologies (13.3%), and (3) they wanted the most access options possible to accommodate for potential motoric changes in the future and provide alternatives when a preferred method resulted in fatigue (33.3%). That is, participants in the third group preferred to access communication using touch screen or head tracking as their primary method, but realized that they required eye gaze tracking when fatigued. Participants reported that eye gaze tracking access was especially important to them if they were considering the option of mechanical ventilation, with foreseeable extensive loss of muscle function associated with prolonged ventilator use. Table 2 indicates a summary of these results from the participants.

Use Patterns

At the time of data collection, the mean duration of *ERICA* use was 8.6 months, with a range of 1 to 36 months (Table 2). Fourteen of 15 participants continued use of *ERICA* following the survey. Two participants had used a different AAC system prior to obtaining the *ERICA* and was no longer able to access the system (LightWriter, Toby Churchill) because of losing hand control. One participant discontinued because of persistent difficulty controlling his eyelids, which developed rapidly during the initial

training period. In fact, he was unable to proceed with *ERICA* use following that initial training. As a result, he is included in no data analyses beyond the initial training times and the remaining data presented in this report are for fourteen participants.

The fourteen participants who successfully implemented *ERICA* used it to support a variety of communication functions. One hundred percent of them used *ERICA* to support face-to-face communication, while 43% also used it to communicate in groups. When electronic communication options were considered, 71% used *ERICA* to communicate over the telephone and 79% communicated by e-mail. Eighty-six percent of participants used *ERICA* to access the internet, and 43% used it to access other computer functions and programs (Table 2).

Use Environments

Six participants (43%) reported that they only used *ERICA* while seated in a recliner, lift chair, or wheelchair (Table 2). Three (21%) used *ERICA* only in bed, and one (7%) only at a table. Four participants (29%) used *ERICA* at multiple sites within their homes. These environmental use patterns were extensively influenced by the physical abilities of the individual participant. Some were so limited physically, that they spent nearly all of their time in bed. Some were in power wheelchairs during the day and then in bed in the evening. Others were in bed or in a specialized chair at a table. For 100% of participants, a mounting system was selected that combined the ability to attach to a wheelchair frame or seat base and, with easy removal, could be placed on a separate wheeled pedestal. It could then be rolled to various locations in the home and adjusted for height differences encountered by positioning in a chair or bed. The

participants all agreed that this combination mounting system provided them with the greatest number of functional communication opportunities.

Eye Color, Corrective Lenses and Lighting

Although 14 participants were able to use *ERICA* as their primary AAC technology, several experienced access issues that were successfully resolved. Fifty percent of participants ($n = 7$) used *ERICA* while wearing prescription glasses (Table 2). Because of the lens or frame, each person was required to optimize the position of the LED camera angle to completely separate the eye “glint” from the reflection of the glasses frame or lens. Three of these individuals had reflective lenses (i.e., no anti-reflective treatment). Of these, two indicated that the reflective nature of their lens interfered with *ERICA* use initially. This was resolved when the participant became aware of the need to optimize their position and separate the two reflections on the *ERICA* camera.

Of the 14 participants who were successful with the *ERICA*, nine (64%) had dark (brown, black) and 5 had light eye color (blue, green, hazel). The one participant who was not successful with implementation also had light eye color.

Many participants adjusted environmental lighting to optimize *ERICA* access. Ten participants (71%) reported that they dimmed lights or closed shades on external windows to achieve optimal success. Four (29%) switched from incandescent to fluorescent light bulb use in their home, and three (21%) relied solely on overhead lighting and discontinued the use of floor and table lamps.

Instruction and Troubleshooting

Fourteen participants indicated that they received sufficient instruction from their speech-language pathologist and practice to demonstrate proficient ability to use *ERICA* as their primary AAC technology. Table 3 contains a summary of the hours of instruction and troubleshooting required by participants. For all participants, the mean length of instruction was 5.0 hours (range 2-20 hrs) and the mean time provided for troubleshooting amounted to 2.27 hours (range 0-10 hrs). For this research project, instruction in system use includes that needed to activate the system for functional communication. Instruction of more detailed aspects of system use were not included in these data (e.g., development of an onscreen keyboard to meet vocational needs, integration of the communication system with email and word processing functions), nor were instructions provided outside of direct interventions provided by the treating SLP.

Two outliers were identified and removed from the remaining analyses because they illustrated specific difficulties with eye gaze tracking which, although they occurred, are not considered typical for persons with ALS. With these outliers removed, the mean instruction time for participants living in their own home ($M = 2.56$, range 2-4 hrs) was statistically different (shorter) than for those who lived in assisted living or long-term care facilities ($M = 4.0$ hrs, range 3-5 hrs), $t(10) = -2.75$, $p = .02$. The average troubleshooting time for participants living in their own home ($M = .11$ hrs, range 0-1 hrs) was statistically different (shorter) than for those who lived in assisted living or long-term care facilities ($M = 7.67$ hrs, range 0-10 hrs), $t(10) = -6.19$, $p < .000$. Although the outliers were removed from analyses because they are not typical, they are discussed individually as case studies because they illustrate two types of less common,

occasional problems that may arise, which are specific to eye gaze access of AAC technology.

Oculomotor Apraxia Case Study

One participant was living in his own home, had been using a ventilator for 15 months and had previously used direct access to a touch screen using his hands to access different AAC technology (i.e., Dynavox MT4). As the ALS progressed and he lost movement in his hands, he was no longer able to access the device using them or using another movement to activate a switch for scanning. He did have some minimal remaining head movement, but this was limited by the tracheostomy placement for his ventilator, thus eliminating the possibility of using head tracking technology for access.

The key factor in his intervention was that, in addition to ALS, this participant was diagnosed with oculomotor apraxia during the course of the MDA clinical evaluation. This impaired volitional eye movement was observed to interfere during initial training of *ERICA*. He was able to use eye gaze tracking to position the cursor on areas of the screen that were “marked” with a moving target (e.g., animations applied during calibration). However, when asked to spell words or messages, his eye gaze tracking accuracy became erratic and inaccurate. As a result, he required extensive training time (20 hours) and specific device programming to accommodate for this impairment.

The onscreen *ERICA* keyboard was altered, to circumvent problems with voluntary eye movements for spelling words, by presenting full utterances instead of alphabet. By reading full phrases or sentences in place of directing eye gaze to spell individual alphabet to form words, he successfully by-passed the apraxia that prevented functional use, and became a proficient communicator. This participant retained the

ability to read (i.e., possibly indicating greater automaticity of eye movements for reading tasks for this person), but was unable to direct his eyes in letter-by-letter formulation. As he read, the dwell function activated his utterances. As a result, once the initial training and programming period was complete (20 hours), he was independently able to communicate effectively with *ERICA*. Although oculomotor apraxia has been identified among persons with ALS, this continues to be recognized as a small subset of the general population of persons with ALS. However, as was observed by this participant, oculomotor apraxia should be a consideration during the evaluation and training process.

Research studies, although not specifically examining access for augmentative and alternative communication, have indicated that individuals can use saccadic movement for eye gaze access despite an oculomotor apraxia by utilizing eye blinks, head movement, or tracking objects in motion (Rambold et al., 2006; Zadikoff & Lang, 2005).

Transition Case Study: Head Mouse to Eye gaze

A second participant was living in her own home and had made the decision not to use mechanical ventilation to support her respiration. She had obtained *ERICA*, but initially preferred to use head tracking access (i.e., HeadMouse Extreme from Origin Instruments placed on the *ERICA*), which she used successfully for approximately 10 months. The ALS progressed, and although she had considerable residual head movement, she found that using head tracking technology resulted in extensive fatigue if used throughout the day. Because of the fatigue, she decided to move from head

tracking to eye gaze access. Although she had been proficient with eye gaze access during the evaluation (which resulted in her acquiring *ERICA*), she experienced difficulty transitioning to it following the prolonged period of head tracking access. Several factors were identified as problematic, including: reducing head movements to maintain eye position, dry eyes, positioning, and lighting during specific times of day. These factors were each discovered following extensive troubleshooting (23 hours) but were all ultimately resolved. First, she positioned padding and pillows beneath her head/neck to reduce her spontaneous head movements that had become a habitual component for her access using head tracking. Second, she had begun to experience dry eyes as a result of ALS progression, which had gone unnoticed. This was not a factor when using head tracking access, however, the dryness resulted in mineral deposits along the edges of her eyelids that reflected the *ERICA* LED signal and competed with the “glint” reading. Her physician prescribed moisturizing eye drops, which were applied liberally and thereby, eliminated the competing reflections. Finally, she had moved into different positioning preferences, which required changing the angle of the LED camera. When this was accomplished, there was a single external window in her preferred room that provided lighting, which interfered with her access during the late afternoon hours. Once identified, the window shade was drawn closed and the issues were readily resolved.

DISCUSSION

In summary, fifteen participants with ALS’ use of eye gaze tracking for access to AAC technology are reported. Fourteen of the 15 participants successfully used eye gaze tracking to access their primary AAC technology, *ERICA*. These outcomes are encouraging, as it is clear that eye gaze tracking is improving, and at a cost that can be

funded through typical AAC funding sources. These results indicate that many persons with ALS maintain functional eye control sufficient to utilize this technology on a routine basis, despite reports of sub-clinical eye movement changes (Palmowski et al., 1995). Results indicate overall successful implementation of this technology to support access to communication for persons with ALS.

Two factors appeared to influence the decision of these participants to select eye-tracking options: (1) a decision to make use of mechanical ventilation and (2) a desire for access to other communication and computer applications. Participants noted that obtaining mechanical ventilation came along with the need for a communication system that provides ongoing communication access as further physical changes occur. Given the extended survival expected from implementing mechanical ventilation while facing the progressive decrease in motor control, participants who chose AAC technology with an eye gaze tracking access option projected that it would provide them with the longest possible time frame for communication using a single system.

The second factor that was often discussed by participants was their frustration with the rapid decline in muscular function, and particularly with the lengthy time often required to obtain equipment that will accommodate for these rapid changes. The large percentage of participants who indicated a desire for AAC technology that would have multiple access options (e.g., touch screen, keyboard, scanning, head tracking, eye gaze tracking) indicated that they were more secure knowing that a variety of access options were available to them quickly, when they need them.

It is notable that a large number (86%) of participants used *ERICA* to access the internet and other computer functions and programs (43%). This indicates that many

people with ALS were required to pay privately for “unlocking” their system, since the majority would have been issued as dedicated communication devices, as required by many funding agencies in the USA.

For persons who are implementing eye gaze technology in various clinical settings, planning for instruction and troubleshooting time is imperative. For nearly all participants, the training time was 2.8 hours, as compared to the 15-20 hours of training suggested by Bates and Istance (2003). Instruction time was significantly lower for participants who lived at home compared to those who lived in assisted living or long-term care facilities. Likewise, troubleshooting time was significantly reduced for participants whose instruction was provided by family members compared those for whom instruction was provided by non-family members. In addition, troubleshooting time increased significantly for those living in assisted living or long-term care facilities.

Although longitudinal data were not obtained for this report, all participants who achieved success were noted to demonstrate continued use of *ERICA* at the completion of the study. This suggests that individuals continue to have success over time with *ERICA* and it remains a viable option throughout the course of the disorder.

Limitations and Future Directions

This preliminary report deals only with participants who chose the *ERICA* eye gaze tracking device. There was no attempt in this project to compare performance of persons with ALS using *ERICA* with any of the other commercially available or experimental eye-tracking systems. The relative success experienced by these participants in “everyday” use, should encourage additional research that compares different technologies and instructional strategies. Also, research that includes cost-

benefit analysis is needed. Research comparing systems may provide insights into which persons would receive the most benefit from specific features of each device. Profiles of design features targeting specific deficits may be developed to facilitate recommendations of specific systems.

Participants in this study used either *ERICA Type & Talk* or *LifeMate 1.1* communication software. None of the participants used the recently updated *ERICA II hardware with LifeMate 3.0* communication software, which may influence success and necessary accommodations for implementation. Additional future research investigating other eye gaze assessment technology and software features that address specific deficits or needs of individuals would potentially provide a means to profile communication software for persons with ALS.

Many participants reported on their self-devised efforts to optimize lighting, body position, and camera position to enhance eye gaze tracking effectiveness. There continues to be a need for eye gaze tracking technology that requires less optimization and which supports more robust performance in a variety of conditions, including head/body movement, lighting, and position.

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Footnotes

1. Eye Response Technologies. (2003). *Eye-gaze Response Interface Computer Aid (ERICA)*. 100 2nd Street, Charlottesville, VA 22902.
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Table 1: Demographic characteristics of participants

Age	Sex	SES	ALS Onset	Intelligibility% Rate (wpm)	Ventilator	Residence	Eye Color	Corrective Lenses
51	F	39.5	Spinal	0 (0)	No	Home	Dark	Yes* ^P
50	M	38	Bulbar	0 (0)	No	SNF	Light	Yes ^P
50	M	32.5	Spinal	94 (174)	No	Home	Dark	Yes ^R
45	M	32	Spinal	65.6 (52)	Yes	SNF	Dark	Yes* ^{PA}
73	M	27	Spinal	65 (92)	No	SNF	Light	Yes ^B
41	M	32	Spinal	97 (166)	No	Home	Dark	No
58	F	33	Spinal	0 (0)	Yes	SNF	Light	Yes ^R
63	M	57	Bulbar	37 (62)	Yes	Home	Dark	No
52	M	41	Spinal	96 (121.4)	No	Home	Light	No
47	M	32	Spinal	97 (121)	No	Home	Dark	Yes ^P
48	M	28	Spinal	85.5 (96)	Yes	Home	Dark	Yes* ^B
60	F	11	Spinal	72 (82.5)	Yes	SNF	Dark	No
39	M	22	Spinal	92 (98)	Yes	Home	Light	No
63	F	37.5	Spinal	88 (99)	No	Home	Light	No
53	F	37	Bulbar	95 (147.5)	No	Home	Dark	No

Note. SES is measured using the Hollingshead Four Factor Index of Social Status (Hollingshead, 1975). A higher score on this index indicates a higher ranking in social position (e.g., minimum = 8, maximum = 66). Sentence intelligibility is reported as percentage accurate and speaking rate as words per minute. For eye color, “light” indicates blue/green/hazel and “dark” indicates brown/black. Corrective lenses with reflective frames are noted with an asterisk. “P” indicates progressive lenses, “R” indicates reading glasses, “B” indicates bifocal lenses, and “A” indicates anti-glare lens treatment.

Table 2. ERICA Use Patterns

Duration of Use	<u>M</u> = 10.77 mo.	Range = 1-36 mo.
Rationale for Selection	Eye is only access option	8 (53.3%)
	Multiple access option	5 (33.3%)
	Scanning too difficult	2 (13.3%)
USA Funding Sources	Medicare	7 (46.7%)
	Medicaid	4 (26.7%)
	Private	3 (20%)
	VA	1 (6.7%)
Successful Implementation	Continued	14 (93.3%)
	Discontinued	1 (6.7%)
Communicative Uses*	Face-to-face	14 (100%)
	Group	6 (43%)
	Phone	10 (71%)
	E-mail	11 (79%)
	Web	12 (86%)
	Other computer functions	6 (43%)
Environments*	Recliner/lift chair/wheel chair	6 (43%)
	Bed only	3 (21%)
	Multiple sites	4 (29%)
	Table only	1 (7%)
Lighting*	Dim lights/block windows	10 (71%)
	Switched to fluorescent bulbs	4 (29%)

Overhead lights only	3 (21%)
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Note. The number of participants is indicated in italics, thus indicating the questionnaire items that were obtained from participants who successfully used the ERICA. Items with * indicate $n = 14$, data collected with participants who successfully implemented ERICA.

TABLE 3. Instruction and troubleshooting time required for various participant groups.

Groups	Instruction Time			Troubleshooting Time		
	N	Mean (hr)	Range	N	Mean (hr)	Range
All participants	15	5.0	2-20	14	2.27	0-10
*Reside at home	8	2.56	2-4	8	.11	0-1
*Reside in assisted living/long-term care	4	4.0	3-5	4	7.67	0-10

*Two outliers removed