Review of Novel Communication Techniques for Autistic Individuals

Using Eye-Gaze Tracking as an Indicator of Cognition

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Spelling to Communicate	S2C
Rapid Prompting Method	RPM
Augmentative and Alternative Communication	AAC
Picture Exchange Communication System	PECS

ACKNOWLEDGEMENTS

This research project was inspired by my own brother, Vikram Kumar, who is a non-speaking autistic individual who has shaped my passion and life's work.

Based on this research introduced to me by Professor Gregory Abowd who has seen great success with his son Aidan, I filmed clips of spellers and sent them back to my family in Dubai. This work then inspired my parents and brother to move to Atlanta for 6 months to pursue Spelling to Communicate and has allowed for my own brother, to communicate after 27 years of having no voice.

Thank you to Ivan Riobo, a Georgia Tech alumni, who mentored me as I sat through and observed several of his STEM classes at the Hirsch Academy in Decatur, Georgia where he taught young autistic children fascinating topics using letter boards.

I am grateful to have met Reese Blankenship, a speller that founded the ReClif fitness-based therapy and community center to empower other autistic individuals like himself through different sessions that helped him strengthen his brain-body connections and eventually communicate with his family.

A very special gratitude goes out to all the parents, families and spellers who have worked so hard to be a voice for this community, and who haven't given up hope.

ABSTRACT

For the 1 in 68 individuals in the United States on the autism spectrum, the use of interactive tools and technologies has grown significantly over the past few years to augment daily living capabilities (Sanchack, et al.). For the subset of these individuals who are unable to communicate verbally, researchers are beginning to explore how applications of these technologies can be used to augment existing communication capabilities. This research explores how one such therapy method, called *Spelling To Communicate* (S2C), can be quantified, using eye-gaze tracking techniques, to pave the way for future studies that could demonstrate cognitive competence in these non-verbal individuals. With a small-scale pilot examination to measure the fixation in eye movements while spelling on a letter board, this research provides insights into the various approaches and challenges associated with distinguishing independent communication from prompted communication when spelling with a partner. The results from this study suggest that through the use of eye-gaze tracking, S2C may be a viable technique to enable independent communication; however, more research is required to confirm this hypothesis.

1. INTRODUCTION

According to a study conducted by the CDC in 2018, approximately 1 in 68 children is diagnosed with an autism spectrum disorder in their monitored network of 11 locations, with a male-to-female ratio of 4.5-to-1 (Sanchack, et al.). Autism is defined as a disorder of cognition, social interaction and communication where repetitive interests and behaviors are commonly observed. The severity levels for ASD vary across the spectrum based on the requirement for support, severity of impairments in functioning and limitation of social initiation and response. Autistic behavior and cognition revolve, not as much on the presence or absence of specific cognitive abilities, but on how efficiently, rapidly, and flexibly these abilities can be performed across changing cognitive demands (Murphy, et al.). Autism is more common in males than in females, with a ratio of 4:1 reported across several samples (Fombonne).

1.1 Autism in adulthood

While there the autism spectrum varies significantly from one person to the next due to individual differences, there are patterns of development that are observed as the autistic individual moves from infancy to adolescence to adulthood (Kientz, et al.). Although current research focuses primarily on children with autism and early detection of developmental differences, there is increasing recognition that Autism Spectrum Disorder is a lifelong neurodevelopmental disorder. Yet, a key gap in research exists exploring how autism manifests in adulthood and what support systems are most effective for the older segment of the autistic population (Kientz, et al.). While there are institutions that serve health and education services for children, service provision for autistic adults is still in its infancy (Murphy, et al.).

1.2 Increased use of technology

The use of interactive technologies for the population at large has grown significantly over the past few years, and with that autistic individuals have adopted technology into daily living with increased frequency of use (Mazurek, et al.). As online platforms are becoming more integrated into the lives of individuals on the spectrum, researchers are beginning to delve into how the use of such systems and other software services could augment the capabilities of families and individuals alike. Hence, it is important to understand how technology can be used for screening and diagnosis, educational goals for intervention monitoring, and for communication purposes.

1.3 Non-speaking individuals

Autistic individuals with fewer verbal communication capabilities are often assumed to be cognitively impaired and are therefore excluded from educational settings and testing sessions due to difficulties completing standardized protocols. While literature aimed at increasing understanding of this population is emerging, there is still difficulty in comparing these different methods and discerning which are effective means of communication against those that are merely prompted in full by a communication partner (Bal, et al.). Hence, this study explores how different tools can be used to assess cognitive competence in autistic adults with lack of verbal communication capabilities. Understanding the use of such tools for diagnosis, monitoring and communication is critical to advance research on this under-studied population.

1.4 Eye-tracking techniques

Since the eyes are a major indicator of a foci of attention, several studies employ eye tracking software to observe direct gaze by monitoring cognitive arousal on a neural level, while the verbal and gestural prompts are given by the communication partner. Eye tracking is the process of measuring either the point of gaze or the motion of an eye relative to the head (Rudy). This eye movement provides insight into the participant's cognitive arousal, it demonstrates the principles of neuroplasticity and eventually showcases that intensive training over a period of time redirects motor neural pathways. These gradually restore communicative ability by improving connections and rewiring the brain. Currently, there is a growing body of evidence to suggest that early intensive behavioral intervention based on applied behavior analysis improves cognitive ability, language, and adaptive skills (Sanchack, et al.).

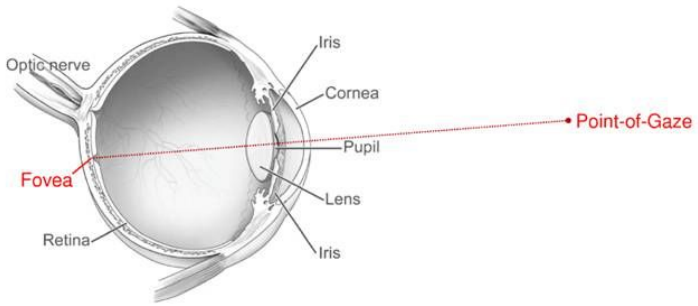

Figure 1.1: *Eye gaze tracking demonstrates point of gaze. Reprinted from from ("Overview").*

The *Spelling to Communicate* teaching technique, developed by Elizabeth Vosseller who has worked with individuals with complex communication and sensory-motor differences since 1995,

uses letter boards and keyboards (Figure 1.2). This teaching method, that uses very similar techniques to Soma Mukhopadhyay's Rapid Prompting Method, aims to develop a means of interactive learning by having individuals with autism point to letters on a board presented at different locations in space. With the aid of sensory "prompts," from communication partners, this evokes a response without cueing any specific option. Despite behaviors, the academic focii of every RPM lesson are designed to activate the reasoning part of the brain so that the student engages with the learning material (Mukhopadhyay). The prompts are meant to draw and to maintain attention to the communicative task – making the communicative and educational content coincident with the most physically salient, attention-capturing stimulus.

***Figure 1.2**: A standard stencil letter board used in S2C. Reprinted from ("About Us").*

2. METHOD AND MATERIALS

2.1 Selection of Experimental setup

Currently, the need exists for such research due to the ongoing scientific debate about whether the communication produced during RPM is valid and produced independently by the participant ("The Vexing Question..."). Hence, this review pilot paves the way to further quantitative research centered around distinguishing independent communication from prompted communication that is instigated by the partner, rather than the individual ("We Need Answers..."). Currently, studies limit tests to behavioral effects with little supporting evidence that measures quantitatively whether the effects are consistent with the claimed mechanisms. Hence, this research aims to act as a catalyst to encourage and guide future research aimed directly at filling this knowledge gap.

Designing communicative methods and interactive technologies to support the health and wellbeing of individuals with autism and their families has always been an area of growing

interest in the field of human-computer interaction. While there is no current literature on this novel form of therapy, there are a few studies that have explored Rapid Prompting Method and have conducted studies assessing its validity. This method is similar to S2C, in that it removes the demand for simultaneity: reducing cognitive load and allowing communication to take place asynchronously. Similar to the Picture Exchange Communication System (PECS), RPM demands selection from a limited repertoire of choices, and visual tools are used to teach communication. These tools include books, letter boards, or stencils, and the teacher's drawings or writings (Chen, et al.). This study on S2C is similar to a preliminary study conducted by Chen et al. on RPM as it employs gaze tracking to obtain results much in the same way. However, one critique is that gaze may not be the only index of engaged attention. Data from Chen et al.'s preliminary, exploratory study *de facto* show a direct, positive relationship between prompting and response rate, and suggest an increased response fluency with increased success over time (Chen, et al.).

The first three years of life are a dynamic period of development where the brain demonstrates the greatest plasticity and potential to alter the course of development. One major concern is whether or not the brain is adaptable to change once habitual neural loops are accustomed to. In a study on the neuroplasticity of individuals with autism, Dr. Losardo invited clinicians to enhance early intervention strategies by capitalizing on the factors of neuroplasticity to produce learning in individuals with ASD (Losardo). However, because gaze was used as a measure of engaged attention, for some autistic individuals, direct gaze may inhibit the ability to respond correctly (Chen, et al.). Future, larger-scale studies can explore and exploit this variation so as to characterize subtypes of individuals in whom the effects and effectiveness of this therapy may differ.

A myriad of systems have been developed to monitor and track various aspects of young autistic individuals' health. For example, the *ENSURE* system developed by Park et al. looked at how interactions with a child's pediatrician can be supported through interactive technologies, such as tracking temperature or medications (Rudy). Tang et al. developed a mobile application "*Estrellita"* for observing premature infants' daily living activities, prompting parents to do exercises at home, and reminders of upcoming appointments. "*VisiBabble"* is a tool for monitoring emerging speech in young children (Tang, et al.), whereas *"Child's Play"* uses sensor-enabled toys to monitor children's development (Westeyn, et al.). Other research focus has been storing health-based data in a way that was enjoyable. Though they do not have the specific goals of improving parent reporting, they influenced the proposed solutions for storing the data in a way that was user- friendly and accessible. However, while these studies employ technology for the early-detection of developmental disabilities, this study focuses specifically on non-speaking autistic individuals and their communication forms.

In another study conducted in China, researchers studied the comparison of three different eye-tracking tasks for distinguishing autistic from neurotypical children, with the attempt of characterizing autism's underlying neurocognitive networks, as well as everyday function and dysfunction (Kou, et al.). Because eye-tracking is non-invasive and does not require motor responses, this technology is studied by Kou, et al. who observes eye-movement in young children and infants. Based on the reviews of several studies, Kou et al. detailed certain indicators that identified individuals with ASD included reduced looking at faces, and disengagement of attention.While these studies focus on the gaze of autistic individuals in social settings by playing video clips, this literature does not demonstrate the use of eye-gaze for the purpose of communication through letter boards or keyboards. However, the study provides insights of several methods used to demonstrate how eye-tracking measures may be useful in aiding diagnosis and treatment of autism. Eye movements can be grouped into fixations, which refers to stabilize gaze on a static target, and saccades, which refers to the eye rotation in between fixations (Kou et al.). Our study leverages eye-gaze tracking to measure both saccades and fixation points across a letter-board to monitor whether such a study could provide insights into the communication capabilities of individuals on the autism spectrum.

2.2 Experimental setup

Participant data is collected through observational studies where Dr. Ivan Riobo interviewed neurotypical spellers and compared those results to an autistic non-speaking speller, with the assistance of a communication partner. The studies took place at therapies centers called The Hirsch Academy and ReClif in the Atlanta metro area ("Creating a Letterboarding..."). Both centers employ the S2C methodology and are staffed with therapists who are certified in this teaching course, to engage students in 1-hour long sessions ("About Us"). Here, communication partners teach students to spell using letter boards and verbal gestures to prompt communication. The study had an enrollment of 5 participants who are examined over the course of 2 weeks. Of the participants, 2 are neurotypicals and 3 are spellers, all whose levels of communication capabilities vary. They share similar profiles as they are between the ages of 10-12. The inclusion criteria for this study is as follows; the participant has been diagnosed with Autism Spectrum Disorder and has impeded motor function that prevents uninhibited communication.

Following a standard set of open ended questions, communication partners would prompt an independent response from the participants. The 4 questions used in these sessions were as follows: *"What is your name?"; "In what school do you study?"; "What does Ivan teach at Hirsch Academy?"; "How would you describe your day?"*

Their responses were recorded and compared with neurotypicals'. The *Tobi software 4C tracking device* (Figure 2.1) was used to track the eye movement across letters on the letter-board in response to the question prompted by the communication partner. We specifically measured how much time it took to reach the target through gaze ("saccade") and how much time they would stay there ("fixation"). The movement of the eyes across the letterboard was recorded and compared to neurotypical participants in order to detect differences among participants and find whether autistic spellers moved their eyes towards target areas.

2.3 The Eye-Gaze Tracking Hardware

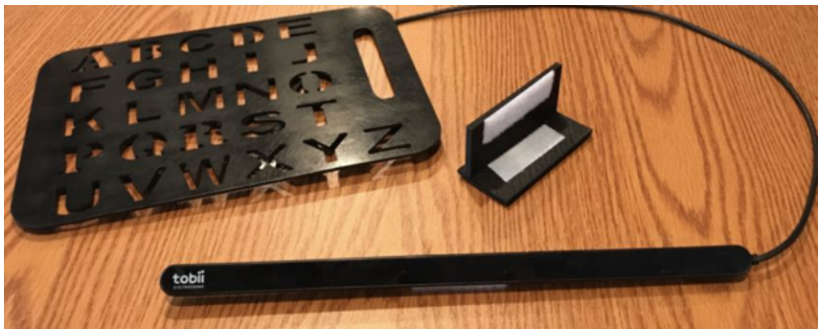

Figure 2.1*: Use the Interactive Communicative Tools and eye tracking device. Reprinted from "Creating a Letterboarding...".*

The eye gaze tracker is attached to the letterboard in order to track the eye movement of the individual with autism as they are using the letterboard. By tracking the progression of this eye movement over time, the goal is to observe signs of improved target areas. Our study will specifically track fixation points and the saccades as identified as having a direct link to motor control. Fixations are used to calculate the amount of time spent of gaze towards a particular location, which demonstrates engagement of attention and the time needed to process the stimulus at that location. (Eckstein, et al.) Saccades reflect the shifts in individual attention that is either voluntary or automatic and stimulus-driven and its accuracy has provided insights for individuals' cognitive control capacity. Pupil dilation is modulated by norepinephrine and reflects mental effort (Eckstein, et al.). Such ocular measures indicate additional information well beyond accuracy and response times as a result of their high temporal resolution, making it possible to measure how individuals respond to cognitive task demands on a moment-by-moment basis. These tracking rates range from 25 to 2000 measurements per

second, which enables faster eye trackers reaching sub-millisecond temporal resolution, similar to EEG (Eckstein, et al.).

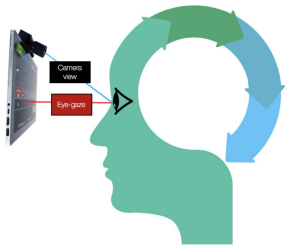

***Figure 2.2**: Positioning of eye-gaze tracking device in relation to camera view (created by the Author).*

2.4 The Letter Board

Communication boards are augmentative devices (AAC) that increase one's ability to communicate. While they vary in size, these devices contain the letters of the alphabet or images of items, or short phrases. These boards can be made from different materials, ranging from a laminated piece of paper to an electronic board with an electronic voice which speaks for the user. Individuals with limited verbal communication skills work with communication partners to point to elements on the board to spell words. Outside of autism, several individuals diagnosed with amyotrophic lateral sclerosis have supplemented their speech by pointing to letters on an alphabet board or by identifying the topic on a communication board (Beukelman, et al.).

Spelling to Communicate leverages letter boards, which are approximately 8 inches by 11 inches that contains letters of alphabet placed in order. Since different letter boards are preferable to each individual, some letter boards involve laminated papers (leftmost in Figure 2.3), some involve stencil boards with letters ingrained in them (rightmost in Figure 2.3), and others involve sensory boards that are made out of cardboard with foam letters mounted on them (Figure 2.3 mid).

***Figure 2.3**: Three types of letter boards used in S2C therapy. Reprinted from "About Us".*

There have been some user centered design communication apps for children with autism spectrum disorders, which use a certain self described “continuous cycle of user feedback to help inform and improve the functions and the capabilities of the technology” (Chen, et al.).

One such app, the Tobii *DynaVox,* uses a similar board mechanism to S2C, yet differs in that it is centered around the categories of verbs or objects that are accompanied with an image. Other studies have demonstrated that with systematic instruction, a solution like the aforementioned can be effective to teach multi-step skills with a software called *Proloquo2Go*.

However, there have been several limitations with these technologies including the inability to control the need for a verbal cue. Additionally, *DynaVox* and *Proloquo2Go* restrict the amount individuals can convey as they are confined to a limited set of buttons per screen. Comparatively, the letter boards give autistic spellers the freedom to type open ended responses once they are more proficient with typing. Additionally, the tendency of the subjects to exhibit challenging behaviors (e.g., aggression, self-injury, tantrums) resulted in a contrived requesting task as opposed to a more natural task in the board mechanisms in question (Alzrayer, et al.).

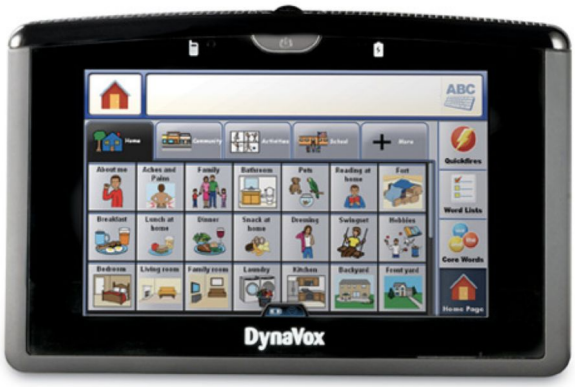

***Figure 2.4**: The Tobii DynaVox communication device. Reprinted from Boon.*

The goal of Spelling to Communicate is to work with, rather than against an autistic, detail oriented, low control attention style by making educational and communicative content coincident with attention the attention capturing stimulus. By aligning questions with the object of the student’s attention, the communication partner accomplishes communicative ability by pointing to letters to spell words (Chen, et al.). In the S2C methodology, the questions progress from known questions to semi-open questions where students have the opportunity to demonstrate cognition. The idea is that students will gradually move away from responses that

may seem to be ‘regurgitation’ towards abstract responses unique to the speller’s own interpretation. When the transition to more open-ended questions is complete, the speller’s responses provide a measure of both their true critical thinking abilities as well as their ability to spell.

2.5 The Communication Partner

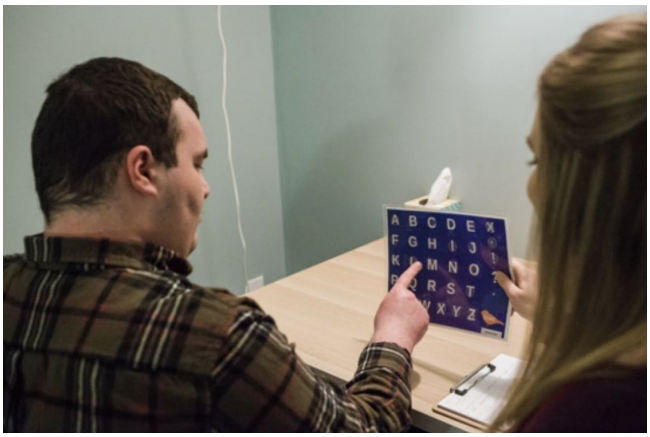

Figure 2.5: *Communication partner positioning alongside a speller. Reprinted from ("Creating a Letterboarding...").*

The communication partner is the individual who works as the teacher, prompting the autistic speller to type through verbal cues, visual gaze and physical gestures. For individuals with lower spelling proficiency, the partner will ask a series of questions in a “teach-ask” format in which the autistic individual listens to their partner present a short module then answers question about what was previously taught. If the speller is incapable of independently deriving an answer, the partner may guide the individual to the correct response, though this assistance is increasingly less required for more experienced spellers (Mukhopadhyay).

With the introduction of guided prompting, it must be stated that there is criticism to the S2C methodology, noting the inherent possibility that partners may be the main driving force behind an individual’s communication efforts (“The Vexing Question..."). Although, these concerns will very likely remain until there is sufficient quantitative results to support cognitive competence, there may be evidence to suggest that a communication partner could indeed be required even if the spellers were cognitively competent. Bordin’s theory, described as the “working alliance” in counseling, recognizes that effective interventions in are wholly dependent on the quality of the bond (mutual feelings of liking, trust, and caring) that the partners share (Bordin). Technologies and strategies alone do not matter.

2.6 Positioning of the Letter Boards

The letterboard is kept at a stationary position, mitigating the risk of sensory overstimulation by holding the letterboard at multiple positions in space. This lack of movement allows observers to better focus their attention on the boards.

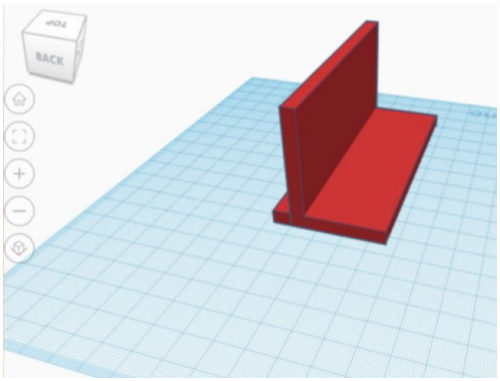

Figure 2.6: *A graphical representation of the positioning of a letter board holder that fixes the device at eye-level. Reprinted from "Creating a Letterboarding…".*

2.7 The Cognitive Load of the Spelling to Communicate Method

Spelling through pointing or typed text, unlike conversational speech, is an asynchronous communication medium. There is no temporal pressure to maintain a flow of conversation nor high cognitive load tasks that require several faculties at once: throat, tongue, lips (Alzrayer, et al.). Hence, pointing to letters to spell is more accessible for certain autistic individuals than spoken language due to the decreased degree of required cognitive control. For some individuals, it can serve as their exclusive form of communication, even when speaking is not possible.

3. DISCUSSION

Over the course of the study, there were several components that our team analyzed and collected. We currently define the four main success criteria based on 12-13 S2C sessions over the course of the study, which include but are not limited to: spelling accurately by tap-and-point (assessed by comparing the accuracy of the letters tapped); increase in fluency (assessed by the decrease of saccades between consecutive alphabets/ letter in question); less frequency of prompting being required of the speller; and speller progress through the different levels of letter-boards. Targets strategically become smaller, as spelling capabilities show improvements.

3.1 Key Observations

In order to capture key elements of eye movement and path of attention, the eye-gaze tracking device identified the fixation and saccades, demonstrating cognitive processes. Fixations refer to the visual field when the eyes stop scanning about the scene and hold the central foveal vision in place so the system can absorb information about the environment. These gaze points are specific spatial locations, as indicated by Figure 3.1. When the participant's eyes are kept aligned with the target for a period of time, image details are allowed to be processed. In contrast, saccades are the type of eye movement used to move the fovea rapidly from one point of interest to another. The fast movement during a saccade, causes a weaker image quality on the retina and thus information intake usually occurs during the fixation period (Rucci and Poletti).

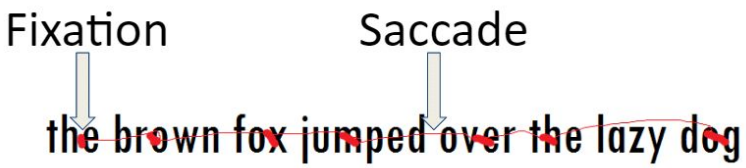

Figure 3.1 *Fixation versus the saccade of eye-gaze tracking. Reprinted from Madi and Khan.*

Based on these studies, there were three key observations that provided valuable insight into the behavior of autistic individuals in their process of communication, as well as in the success of the eye-gaze tracking technology. These are detailed in the section below.

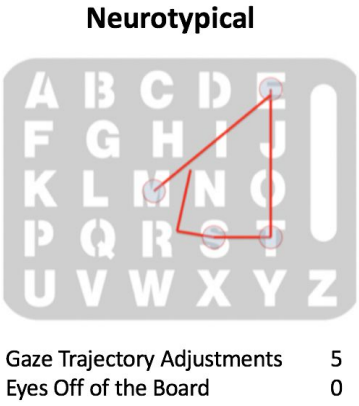

***Figure 3.2**: Spelling STEM - neurotypical speller. Reprinted from "Creating a Letterboarding...".*

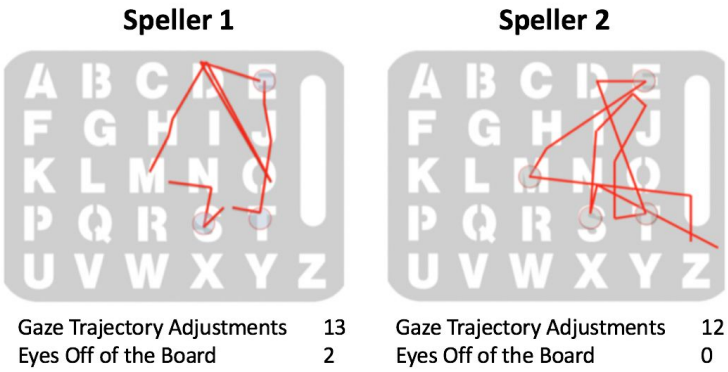

***Figure 3.3**: Spelling STEM - autistic speller. Reprinted from ("Creating a Letterboarding...").*

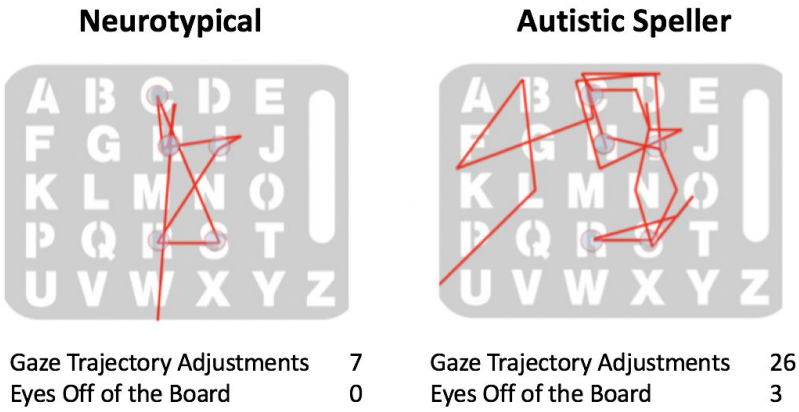

***Figure 3.4**: Spelling "Hirsch" neurotypical vs. autistic speller. Reprinted from ("Creating a Letterboarding...").*

3.2 Results

Firstly, when comparing the figure trajectory of the two spellers, there were a lot more movements required by the speller when compared to the neurotypical, as seen by the eye tracking paths on the letter boards when asked to spell STEM (comparing figure 3.2 and 3.3). Note that the direction changes for a neurotypical was five while the gaze trajectory adjustments for a speller was 12 on average - while one speller's eyes went off the board twice. This clearly

demonstrates the speller's visual requirement for more adjustment, providing insight that individuals on the autism spectrum require more work towards directing gaze at a certain focal point.

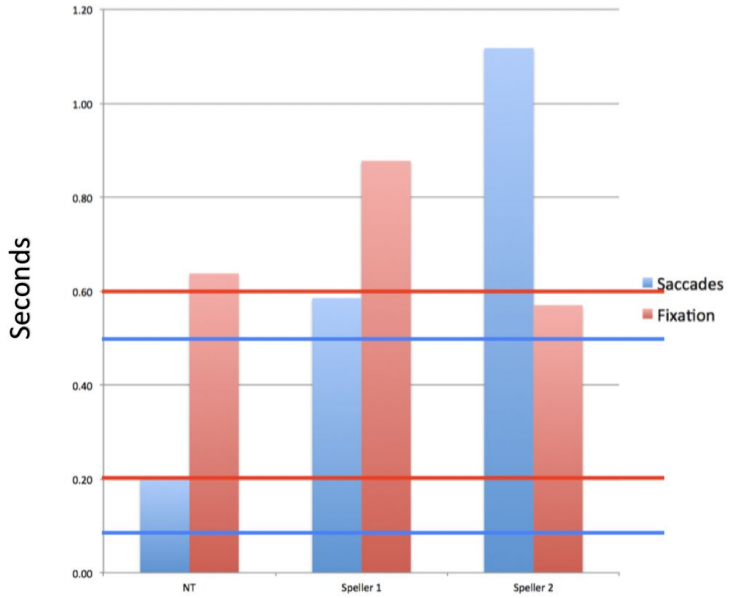

Figure 3.5: *A graph to depict the saccades and fixations of participants over a period of time. Reprinted from "Creating a Letterboarding...".*

Another key insight is the difference in time spent between points of interest and the focal point when humans typically absorb information. The graph in Figure 3.5 demonstrates how the saccades often vary as spellers with autism moved across focal points to eventually arrive at the correct option. In contrast, the fixation time for a neurotypical and speller was approximately the same, without any observed deviations. According to Figure 3.6 (also see Table 3.1), the gaze changing focus ranged between an average of 6.75 for the neurotypical speller and 28.36 for the autistic speller to spell STEM. In contrast, the fixation of the speller and a neurotypical is approximately the same, varying by ±9.1. The fact that participants spend a similar amount of time fixated at the focal point is an important insight to demonstrate the window for cognition.

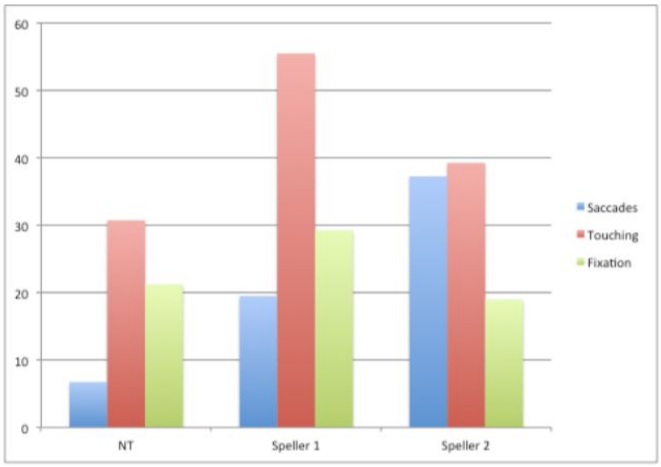

***Figure 3.6**: Comparing the gaze changing focus, touching and fixation. Reprinted from ("Creating a Letterboarding...").*

Word "STEM" - Duration in Frames

	Gaze Changing Focus			Touching			Fixation		
LETTER	NT	Speller 1	Speller 2	NT	Speller 1	Speller 2	NT	Speller 1	Speller 2
S	12	37	82	41	100	23	32	35	19
T	4	6	6	23	40	52	24	20	12
E	5	7	39	31	40	47	17	28	23
M	6	28	22	28	42	35	12	34	22
AVERAGE	**6.75**	**19.5**	**37.25**	**30.75**	**55.5**	**39.25**	**21.25**	**29.25**	**19**

***Table 3.1**: Comparing the gaze changing focus, touching and fixation. Reprinted from "Creating a Letterboarding...".*

The third insight was that the participants with autism could accurately spell as there was indication of accurate movement of gaze towards the appropriate letters. Reaching appropriate target areas is an indicator of cognition, as seen through the accuracy of the letters typed, as well as the eye movements that led to them being chosen. Still, though, the sample size in this study is trivial and not enough to make any substantial claims. Rather these results and methodologies should be treated as a pilot so that future research can more easily assess a much larger sample size to make substantial claims. While the results from conducting a study of this nature can be valuable to suggest cognition, it must be emphasized that eye gaze alone doesn't directly test for cognition, and thus we would require additional techniques to verify results.

4. CONCLUSION

The field of autism research is still young, and we have much to learn (Damiano, et al.). More research is needed to better understand how to support non-speaking autistics in finding effective ways to communicate. Expanding upon the methodologies described in this research could be significant in a broader context, as quantitative evidence to demonstrate cognitive competence of non-speaking autistic individuals could lay the groundwork for countless possibilities.

Providing insights into the successful use of this communication form would also enable the future adoption of *Spelling to Communicate* as an effective, ubiquitous and accessible form of restoring communicative abilities. Another impediment that this disability places on individuals with autism is the inability to take tests, as these usually require a motor response such as speech, pointing, gesturing, touching or manipulating objects. If autism is attributed to a core motor cause, then those with motor planning and control issues significant enough to affect speech are currently unable to respond reliably to standardized testing. Hence, *Spelling to Communicate* may allow autistic individuals to voice their concerns and directly convey their thoughts, potentially augmenting their test taking capabilities. Educators can then tailor their teaching styles by assuming cognitive competence which challenges the common notion of their lower intelligence that commonly impedes educational accessibility. A change could result in an increased justification for accomodations in public school districts, furthering the quality of life and opportunities for those in the non-speaking autistic communities. Additionally, such studies would encourage workforce inclusion and diversity. Currently, employers often assume incapability of autism individuals and don't accommodate their needs, creating high barriers to entry into the workforce (Carr).

4.1 Limitations

The generalizability of the study may be limited because of the variability in clinical and demographic characteristics of the participants. To that end, the sample size needs to be greatly increased to increase the accuracy of this study. Moreover, one must take into account stakeholders' perspectives toward standardized communication help intervention to enhance requesting and other communicative functions (Alzrayer, et al.).

Despite the apparent limitations, there is some value to systematically diving into the current investigation demonstrated the effectiveness of systematic instruction on requesting behaviors with developmental disabilities, much like the pilot study conducted by this author. Future research should consider focusing on the "acquisition, maintenance, and generalization of advanced functions such as commenting, asking for information, and conversational skills"(Alzrayer, et al.) using various devices and modes with standardized test conditions, but still accounting for challenging behaviors, and a wider variety of environs.

4.2 Scope for Further Research

The goal is to develop new ways to document and understand the clinical phenomena that several families are facing. In terms of the technology, one area for future exploration is looking into other forms of tracking cognitive load as well as attention, which deviates away from the eyes, and into other forms of learning that dive deeper into the brain. One limitation is that this technology doesn't permit the collection of data of autistic individuals who commonly move or engage in repetitive stimming behavior, where sitting still is extremely challenging (Kapp, et al.). An area for improvement in the inclusivity of the technology would be to capture the movement of individuals who require movement.

Other areas for exploration with the technology are in applying machine learning classifications for possibly find patterns in speech that could be trained on several data sets. Analyzing vast amounts of such data would provide insights into the language, behavior and speech, providing further avenues to witness the evolution of different spellers from acquisition to proficiency.

DISCLOSURE STATEMENT

The author reports no conflicts of interest. The author alone is responsible for the content and writing of this article.

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