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Eye-gaze Profiles of Children with Autism Spectrum Disorder in Relation to Fast-mapping Abilities

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ABBREVIATIONS

ASD: Autism Spectrum Disorder
TD: Typical Development
CSD: Communication Sciences and Disorders

ABSTRACT

Children learn new words through a process termed fast-mapping, which involves pairing novel words and objects after minimal exposure. There have been studies conducted to understand the fast-mapping processes in children with typical development (TD); however, this phenomenon has received less attention for children with autism spectrum disorder (ASD). In addition, there was limited information that investigated the eye-gaze patterns and fast-mapping abilities of children with ASD and TD. The purpose of this study was to compare the eye-gaze patterns of children with ASD and TD in relation to fast-mapping. Ten children diagnosed with ASD and twenty children with TD, ages 5-7 participated. Participants were matched on nonverbal intelligence and receptive vocabulary skills. The Tobii 1750 eye-tracking system was used to capture eye-tracking measures. Overall, the results revealed that children with ASD were able to fast-map novel images and text at a similar rate to children with TD, despite having fewer fixations and shorter total fixation duration on novel stimuli.

INTRODUCTION

Researchers have studied typical language development for many years. The information gained has provided insight into how children acquire novel words. There has been limited research, however, to investigate the relationship between eye-gaze patterns and language development in children with typical development (TD), as well as children with Autism Spectrum Disorder (ASD). It has been hypothesized that children with ASD are visual learners, however, little is known about the eye-gaze patterns of children with ASD. It is, therefore, essential that researchers gain a better understanding of the eye-gaze patterns of children with ASD in relation to fast-mapping.

Typically Developing (TD) children acquire new words at a rapid rate during the first year of life and continue to build on this vocabulary growth throughout childhood. It is thought that children learn new words through a process termed fast-mapping, which involves pairing novel words and objects after minimal exposure [1]. In addition, theories regarding word learning constraints have been used to help explain how children develop strategies to further enhance vocabulary development. Three distinct constraints facilitate word learning by narrowing down the set of possible word meanings, these include: whole object (i.e., children assume new words by naming whole objects rather than parts of objects) [2], taxonomic (i.e., children generalize a previously learned label to a range of other objects based on the similarity of the original referent) [2] and mutual exclusivity (i.e., children prefer only one label per object [2]. Word learning constraints are not considered to be the only explanation of vocabulary development in children, but instead are thought of as strategies children rely on to acquire new words. There have been numerous studies conducted to understand the fast-mapping processes involved in acquiring spoken language in TD children; however, this phenomenon has received less attention for children diagnosed with ASD [1,3-6].

Most research investigating the fast-mapping abilities of children with ASD has focused on joint attention in relation to learning spoken vocabulary. Results of previous research studies have implied that impairments in joint attention might make it difficult for children with ASD to fast-map novel words [7,8]. It has been hypothesized that joint attention may affect language acquisition in preschoolers with ASD due to the presence of the following characteristics: (a) being uninterested in the speaker, (b) failure to orient to the speaker, (c) not being responsive to different emotional states, (d) restricted interests, and (e) trouble incorporating different cues during social interactions [9]. In addition, the fast-mapping abilities of school-aged children with ASD have been found to be impaired because of using personal focus of attention as a strategy for forming word object associations instead of using the speaker's eye-gaze [7,8]. It should be noted that the children with ASD did not fail to learn the novel words, but instead, selected items of self-importance as referents versus following the speaker's eye-gaze to the target stimuli [7,8].

The few studies that have been conducted to investigate word learning constraints in ASD have provided more insight into the skills and processes that children with ASD appear to use when fast-mapping novel words. Some evidence has been provided that children with ASD do not fast-map in the same manner as TD children. Williams [10] found that children with ASD appeared to be able to fast-map in a similar fashion to TD children, however, they seemed to be using word learning constraints in a less effective and efficient way. This suggested that some of the core deficits of ASD impeded children's ability to fast-map or these deficits contributed to the strategies the children with ASD used during the fast-mapping process.

Most children diagnosed with ASD also exhibit deficits in joint attention, theory of mind, the ability to manage attention, and the capacity to understand abstract language concepts which appear to impact their ability to fast-map both spoken and written words [8,9,11,12]. The degree to which these deficits impact fast-mapping skills remains unknown. Dawson and colleagues [13] found that joint attention was the best indicator of concurrent and future language ability. Children with ASD in this study performed significantly worse on measures of social orienting, joint attention, and attention to another person's distress.

Attention to social stimuli (e.g., faces, emotions, voices) is apparent early in the development of typically developing children. A failure to orient to social stimuli has profound effects on language development [14,15]. McDuffie et al. [16] discovered that the joint attention skills of children with ASD were also highly associated with expressive language; however, a significant correlation between joint attention and receptive language was not evident.

Theory of Mind (ToM) refers to the ability to attribute mental states, such as beliefs and desires to the self and others, as well as predict behavior [17]. Studies have highlighted the importance of being able to recognize and understand a speaker's intent to learn novel words [11,18]. Baron-Cohen [18] suggested that impairments in ToM could impact the development of acquiring new words. Parish-Morris et al. [19] found that receptive vocabulary was associated with interpreting and understanding the intentions of others. It was hypothesized that since children with ASD often demonstrate impairments in ToM, they may also have difficulties learning new words, especially when social cues are less apparent.

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Central coherence refers to the ability to process information to "see the big picture" versus focusing solely on the details [20]. Children with TD process information in a more holistic manner and children with ASD tend to focus on specific details when taking in new information making it difficult to generalize information [20]. Children with ASD demonstrate deficits in central coherence, also termed weak central coherence, which affects the underlying process of fast-mapping to learn new words. According to central coherence theory, children with ASD tend to focus on ambiguous details of objects, thus, creating the potential to miss important information needed to fast-map novel words [19,20].

Another area that potentially impacts how children learn new words is their ability to attend to specific stimuli [19]. Children with ASD often have difficulty engaging in and shifting their attention from one object to another [20]. These children may be missing important information when attempting to learn new words because of their focus of attention. Parish-Morris et al. [19] found that children with ASD demonstrated difficulties shifting their attention from a preferred item to fast-map a novel word of a less desired object. These authors also discovered children with ASD were more likely to attend to the specific target object when multiple cues were implemented (e.g., touching, pointing, verbalization). The results indicated that both the ASD and TD groups responded correctly to the social information to focus their attention on the specific object. The findings of Parish-Morris and colleagues [19] are in direct contrast to previous research conducted by Baron-Cohen et al. [12] and Preissler and Carey [8] which suggested that children with ASD do not use social cues, such as eye-gaze, to focus and control attention to a target object. One possible explanation for this discrepancy could be that Parish-Morris and colleagues [19] broadened their definition of social cues to include pointing, touching, and verbal interjections.

There has been limited research with children on the autism spectrum to investigate the relationship between eye-gaze patterns and language development as it relates to fast-mapping. Recent research indicates that deficits in eye-gaze processing might be related to the impaired language and social development typically seen in children with ASD [21]. The foundation for language acquisition could be in eye-gaze processing. Eye-gaze processing is thought to develop into joint attention, which is crucial for imitation and acquiring new knowledge and skills [21]. For example, expressive labels for objects are thought to be partially acquired by children as they follow joint eye-gaze to an object while another person pronounces the corresponding label for the object.

Studying eye-gaze movements could help researchers learn more about how TD children and children with ASD process visual information to acquire new words. Important underlying concepts of how children learn new information can be gained by further examining eye-gaze patterns. Information such as: where children look, how long they look at a stimulus, how many times they look at a target, or what information children pay attention to can all be analyzed by examining eye-gaze patterns.

The purpose of this study was to compare the eye-gaze patterns of children with ASD and TD in relation to fast-mapping. The eye-gaze patterns for the ASD and TD children were used to describe the eye-gaze characteristics associated with each group. The rationale for including eye-gaze data from both the ASD and TD groups was to describe the eye-gaze patterns associated with each group, as well as, to compare group trends. Specifically, the following research questions were examined: (1) What are the eye-gaze patterns of children with ASD as compared to TD children when presented with novel images or text? Measured by: (a) time to first fixation, (b) fixation count, and (c) total fixation duration; and (2) Is there a difference in fast-mapping abilities of novel words and/or images between children with ASD and TD children? Measured by: (a) receptive image/text identification score.

METHODS

Participants

Ten children (6 males; 4 females) diagnosed with ASD and 20 TD children (5 males; 15 females) participated in this study. These children ranged in age from 5 to 7 years. All participants were recruited from various locations in central Kansas. The study was approved by the University Institutional Review Board.

Eligibility requirements for participants with ASD included having an existing medical diagnosis of ASD as well as normal hearing and vision. Participants were also required to score ± 1.5 SD from the mean on both the *Peabody Picture Vocabulary Test, Fourth edition (PPVT-4)* [22] and the *Raven's Colored Progressive Matrices* (CPM) [23] (**Table 1**). The *Raven's Progressive Matrices (RPM)* [23] is a nonverbal assessment of intelligence. There are three forms of the *RPM*. For this study, the *Colored Progressive Matrices (CPM)* was used. The CPM can be used with children ranging in age from 5 to 11 years and with individuals who exhibit intellectual impairment. This assessment tool can be presented with moveable pieces without the intellectual processes required for success being altered [23].

Two groups of children with TD were created such that one group of ten children was matched to the ASD group on chronological age (TD-Age) and another group of ten children was matched on receptive vocabulary (TD-Language) based on the standard score received on the PPVT-4 [22]. Participants with TD were excluded from the study if they had a diagnosis or were receiving services indicative of a developmental delay, language delay, or learning disability. Participant demographics and assessment data are in **Table 1.**

All qualifying assessments were administered by two, second year graduate students from a Communication Sciences and Disorders (CSD) program who were trained and supervised by the primary investigator, who is a licensed/certified speech-language pathologist. All qualifying assessments were conducted at the university speech-language hearing clinic where the testing room was structured so that visual and auditory distractions were minimized. A work system was provided so that the children would be aware of the sequence of tasks that were to be completed. Each testing session lasted approximately 1 to 1.5 hours per participant.

	ASD Group (n = 10) M (SD)	TD-Age Group (n = 10) M (SD	TD-Language Group (n = 10) M (SD)
Sex (Males:Females)	6:4	2:8	3:7
Chronological Age (months)	76 (7.5)	77.0 (10.03)	73.4(7.2)
Raven	77.5 (12.5)	74.5(14.7)	70.5(15.4)
PPVT-4	91.4 (13.2)	113.1(4.5)	103.5 (7.6)

Table 1: Demographic and Assessment Data

Equipment

Apparatus

A Pentium IV-based PC with 96 dpi 17" monitor with a resolution of 1280 by 1024 pixels was used. The monitor was integrated with the Tobii 1750 eye-tracking system running at 50Hz and was used to capture eye-tracking measures. The Tobii 150 eye-tracking system samples the position of the participant's eyes every 20 ms (i.e., 50 Hz). This system is a dual-tracking (i.e., both eyes rather than one), video-based eye-tracker that uses dark pupil corneal reflections to compute the participant's point of regard in relation to the stimuli presented on the monitor. The Tobii 1750 is characterized by the unobtrusive addition of the eye-tracking hardware (i.e., high resolution camera and near infra-red light-emitting diodes) to the monitor frame. This design promotes more natural participant behavior by not placing unnatural restrictions on the participant (e.g., helmets, head rest). Tobii Studio™ software was used to detect and collect participant eye movement data during the testing procedure.

Stimuli

Participants were presented with a total of 12 different pseudowords and images via the computer system described previously. The pseudowords were first developed by Jusczyk, Luce, and Luce [24] and have been replicated in additional studies [25,26]. The novel images used in this study were unfamiliar black and white line drawings, first developed by Apel and colleagues (1994). These images have been designed to not represent known objects or images to assess accurate fast-mapping skills.

Work system

All participants used a work system that included both picture icons and photographs to indicate the activities that would occur, the sequence of activities, and the reinforcement to be received at the conclusion of the assessment. Visually structured instructions are often helpful for children with ASD to reduce stress, anxiety, and frustration [27,28].

Procedure

The experiment was conducted in a room that had been adapted to minimize visual and auditory distractions. The participants were first introduced to a work system which provided the children with the sequence of tasks that

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were to be completed for the day and the reinforcement that they would receive at the completion of the research session (i.e., preferred snack item).

The two graduate students who administered the qualifying assessments conducted all phases of the experiment. The primary investigator was always in the research room to monitor the research protocol and to supervise the graduate students. The research room included a desk with a computer monitor, eye tracker, and visual supports (i.e., work system). A booster seat with foam was placed on a chair for each participant. The participants were positioned approximately 70 cm from the computer monitor for all tasks.

Initially, a calibration process was performed. To visually prepare the participants for the calibration process, children were guided to follow a pre-made, red circle made with construction paper. The graduate student moved the red circle in different directions, allowing the participants to practice the calibration process. The participants were then seated approximately 70 cm from the computer monitor and a formal calibration of the Tobii 1750 eye-tracking system was performed. The calibration process involved having the participant fixate on a dot that appeared on the monitor in a random sequence of five different locations on the screen. This procedure was adjusted to the participant's specific eye-movements and established a reference for eye positions relative to different areas on the computer monitor.

Orientation to stimuli presentation

Participants were introduced to and familiarized with the structure and the expectation of the testing protocol. Participants were presented with three separate trials. During the image only task, participants were presented with a total of five unfamiliar images sequentially, with each image presented for 5 seconds at a time. The same process was repeated with novel, nonsense words, and again with unfamiliar images paired with text **(Figure 1)**. For all conditions the auditory cues were presented using a prerecorded digitized female voice that gave the label for each unfamiliar stimulus in a short sentence. The prerecorded voice was synchronized with each presentation of stimuli and was standardized across participants and tasks. For each condition a different set of images and text were presented.

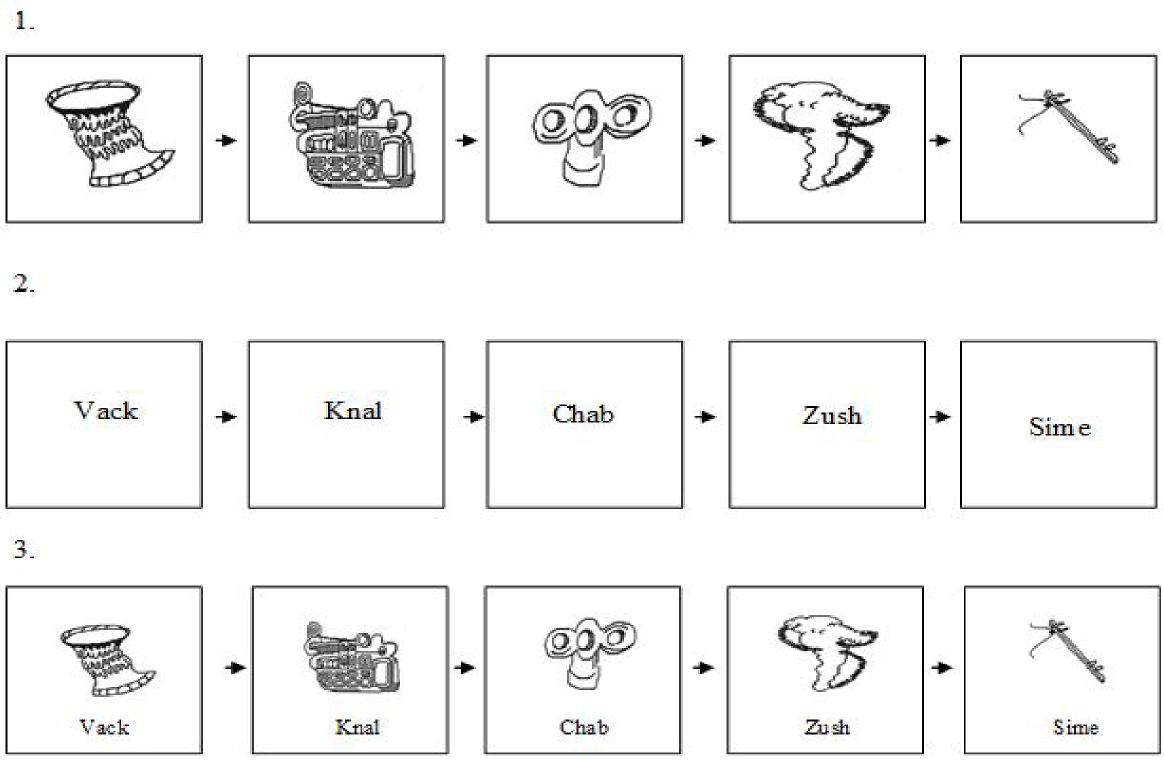

Figure 1: Randomized Orientation Trials

Condition 1. Image only: story and identification

Participants were presented with three different images across three different stories. Each image was presented three times and each presentation was paired with a different auditory cue (e.g., "This is a chuz." "The chuz is tall." "Jak has a chuz."). The participants were presented with the novel image and label a total of three times per story to facilitate the fast-mapping of the new vocabulary. Last, the participants were simultaneously presented with five different novel images on the computer screen and asked to identify the target novel image by pointing to the image in response to an auditory cue, (e.g., Which one of these is what this thing is called?). The last step was used to measure each participant's ability to fast-map the novel image with an auditory label.

To finish, a distractor task was presented between each condition of the experiment to control for any carry over effects from previous tasks. The distractor task was a short cartoon that contained limited audio. The same cartoon was used throughout the experiment to provide a sense of predictability and routine for the participants (**Figure 2).**

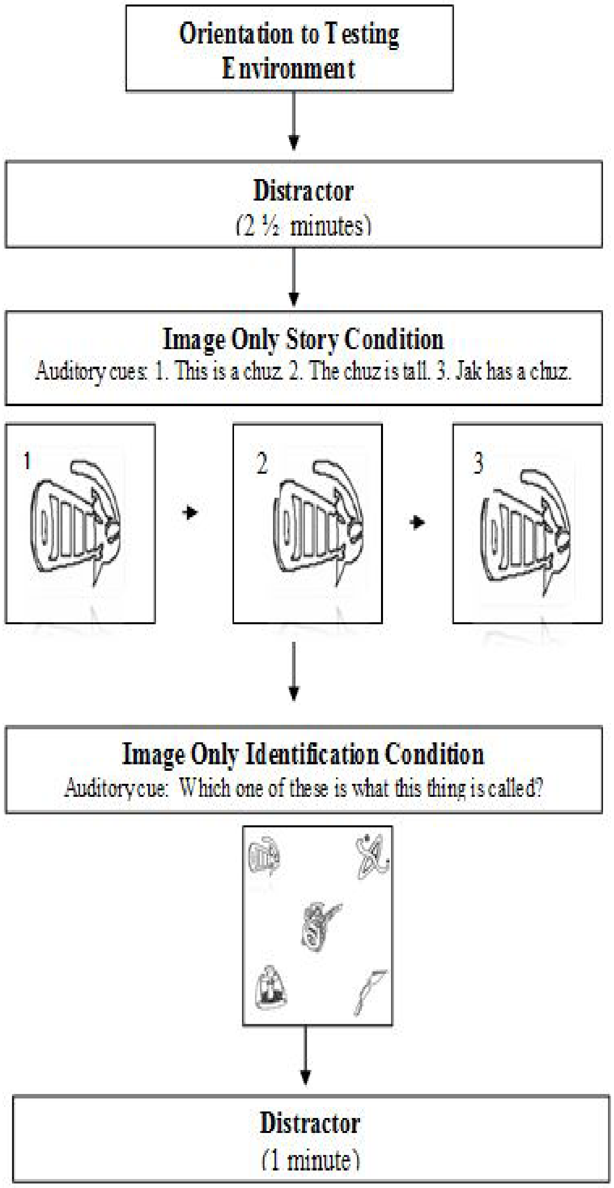

Figure 2: Protocol for Image Only Condition: Story and Identification

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Condition 2. Text only: story and identification

Participants were presented with novel words via text which was paired with a verbal cue labeling the novel word (e.g., This is a chuz.). The procedure used for the image only condition as previously described, was followed for the presentation of these stimuli (**Figure 3)**.

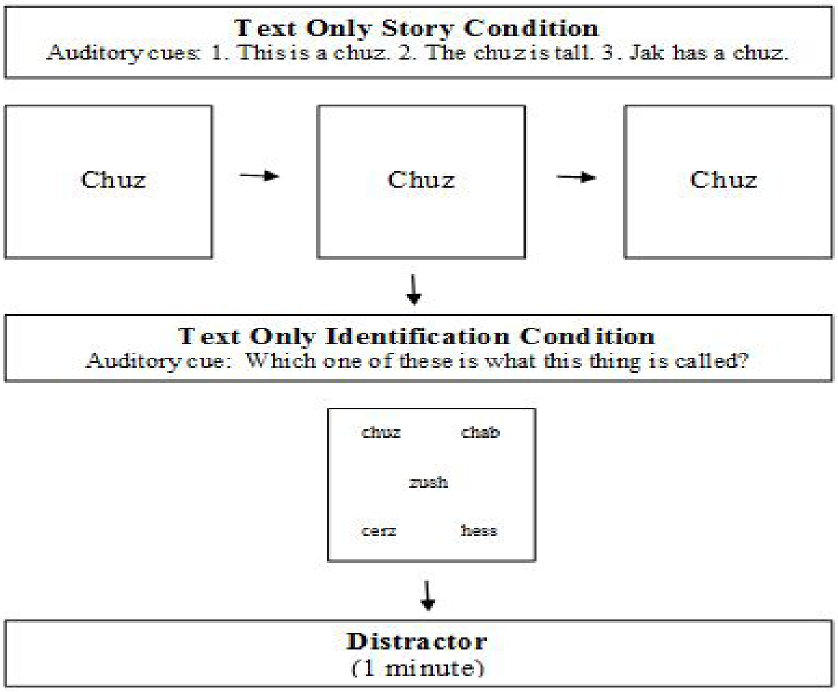

Figure 3: Protocol for Text only Condition: Story and Identification

Condition 3. Image/text paired: story and identification

Participants were presented with a novel image paired with a novel word that was positioned below the image with an auditory cue. The procedure previously described was followed for the presentation of these stimuli. In this condition, however, the participants were required to complete two identification tasks. First, the children were presented with five novel images paired with a different word located below the image and were asked to receptively identify the target image and word pair in response to the auditory cue (e.g., Which one of these, is what this thing is called?). Next, participants were presented with five different images all with the same word placed below each image and asked to identify the target response following an auditory cue **(Figure 4)**.

Condition 4. Image/text paired story: image/text separated identification

Participants were presented with similar cueing as provided in the text/image paired condition (novel images paired with novel words in combination with auditory cues). The identification process to assess fast-mapping abilities differed, however, from the text/image paired condition. First, participants were presented with five novel images (following the same positioning format previously described) and were required to point to the correct novel image in response to the auditory cue (e.g., Which one of these, is what this thing is called?). Participants then followed a similar identification process but with novel text instead of novel images **(Figure 5)**.

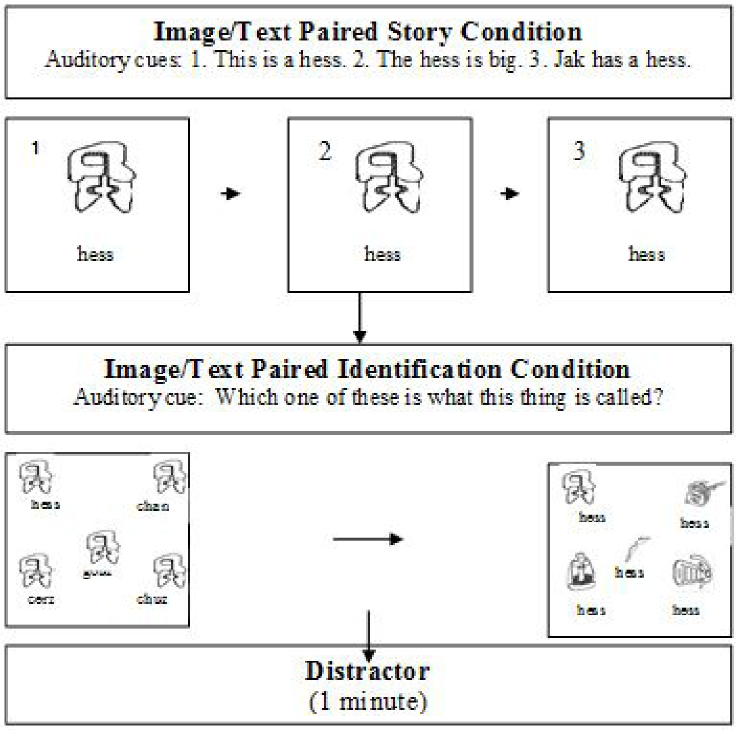

Figure 4: Protocol for Image/Text Paired: Story and Identification Condition

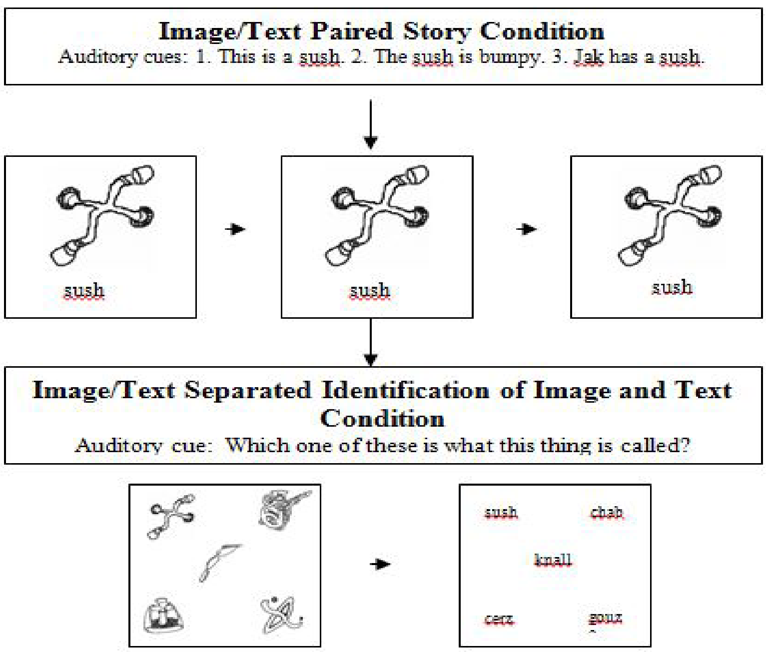

Figure 5: Protocol for Image/Text Paired Story and Image/Text Separated Identification of Image and Text Condition

RESULTS

The eye-gaze patterns of children with ASD and TD children were compared by collecting and analyzing eye-movement data from the experimental conditions. The eye tracking data were examined both in terms of the task as a whole and participants' visual fixations on an Area of Interest (AOI) within the screen content during a task. In addition, data were collected in terms of correct or incorrect identification of novel words and images. For the purpose of this study, AOIs were identified as either the novel image or the novel text. The eye-tracking measures of interest in this study were: (1) time to first fixation: time from when a stimulus is shown to the first fixation; (2) number of fixations: total number of visual fixations recorded on an AOI; and, (3) total fixation duration: average duration of fixations recorded within an AOI.

Each condition of the experiment contained three trials. Data were collapsed across the three trials and analyzed. A one-way analysis of variance (ANOVA) was used to analyze the eye-gaze and fast-mapping data for the image only and text only conditions. Tukey HSD post hoc analyses were conducted for significant ANOVAs. The text and image conditions were analyzed using a 2x3 mixed ANOVA. A Tukey HSD follow-up tests run for significant ANOVAs. Unless noted, Levene's Test of Equality of Error Variances was not significant for all eye-gaze measurements and fast-mapping scores analyzed, which indicated that the variance between groups was equal.

Condition 1. Image only: story

There was not a significant difference between the ASD and TD groups relative to the amount of time it took them to first fixate on the novel image, $p > .05$. On average, all groups took the same amount of time to fixate on the novel image (Table 2). There was a significant difference between groups in terms of the number of fixations, $F(2, 27) = 5.65$, $p < .01$, $\eta 2 = .30$ and post-hoc tests revealed that the ASD group had significantly fewer fixations than both the TD-Age and TD-Language groups (Table 2). There was also significant main effect for group membership and total fixation duration, $F(2, 27) = 6.54$, $p < .01$, $\eta 2 = .33$, and follow-up tests detected a reliable difference in the means between the ASD group and both the TD-Age and TD-Language groups. Overall, the ASD group spent less time looking at novel images than the two TD groups **(Table 2)**.

Measurement	ASD	TD-Age	TD-Language
	M (SD)	M (SD)	M (SD)
Time to First Fixation	.47 (.47)	.23 (.22)	.26 (.25)
Fixation Count	7.07 (1.99)**	9.18 (.99)**	9.39 (1.95)**
Mean Fixation Duration	.41 (.11)	.48 (.09)	.46 (.10)
Total Fixation Duration	2.93 (1.02)**	4.13 (.78)**	4.03 (.59)**

Note. ** p < .01

Table 2: Eye-Gaze Measurements for Image Only Story Condition

Image only: identification

There was not a significant difference in fast-mapping scores between the ASD group and the TD-Language or TD-Age groups, $p > .05$. The participants in the ASD group ($M = 2.3$, $SD = 1.16$) did not differ significantly on fast-mapping scores for images than those in the TD-Age ($M = 2.8$, $SD .63$) or TD-Language ($M = 2.2$, $SD = 1.32$) groups. Means and standard deviations are reported in **Table 3**.

Condition 2. Text only: story

There was not a significant difference between the ASD and TD groups in terms of the time to first fixation on the novel text, $p > .05$. All groups on average took the same amount of time to fixate on the novel text (Table 4). The relationship between group membership and fixation count on text was significant, $F(2, 27) = 4.52$, $p = .02$, $\eta 2 = .25$. Follow-up tests were conducted to determine the significant differences among the three groups. On average, the ASD group had fewer fixations on novel text than the TD groups (**Table 4**).

The relationship between group membership and total fixation duration was significant, $F(2, 27) = 4.46$, p .02, $\eta 2 = .25$. Follow-up tests were conducted to determine the significant differences between the three groups. The ASD group had less time looking at the novel text than both TD groups **(Table 4)**.

Identification Stimuli	ASD	TD-Age	TD-Language
	M (SD)	M (SD)	M (SD)
Novel Images	2.3 (1.16)	2.8 (.63)	2.2 (1.32)

Note. Fast-mapping scores were taken from a possible total of 3
Table 3: Fast-Mapping Scores for Image Only Identification Condition

Measurement	ASD	TD-Age	TD-Language
	M (SD)	M (SD)	M (SD)
Time to First Fixation	.89 (.67)	.63 (.43)	.52 (.32)
Fixation Count	2.88 (1.37) *	4.57 (.83) *	4.46 (1.83) *
Mean Fixation Duration	.61 (.17)	.91 (.46)	.87 (.56)
Total Fixation Duration	1.93 (.88)*	3.01 (.77) *	2.89 (.99) *

Note. *p < .05.
Table 4: Eye-Gaze Measurements for Text Only Story Condition

Text only: identification

There was not a significant difference in fast-mapping scores between the ASD group and the TD-Language or TD-Age groups, $p > .05$. The participants in the ASD group ($M = 2.1$, $SD = 1.1$) did not differ significantly on fast-mapping scores for text than did those in the TD-Age ($M = 2.3$, $SD = .95$) or TD-Language ($M = 2.3$, $SD = 1.06$) groups **(Table 5)**.

Identification Stimuli	ASD	TD-Age	TD-Language
	M (SD)	M (SD)	M (SD)
Novel Images	2.1 (1.1)	2.3 (.95)	2.3 (1.06)

Note. Fast-mapping scores were taken from a possible total of 3
Table 5: Fast-Mapping Scores for Text Only Identification Condition

Condition 3. Image/text paired: story

An AOI rank order was calculated for both images and text to understand what participants looked at first. AOI rank order was defined as the order the Image AOI and Text AOI were fixated. The order was determined by calculating the time to first fixation for each AOI and assigning the appropriate rank. Analysis of AOI rank order was conducted to establish the fixation order of the Text and Image AOIs. A Wilcoxon test was conducted to evaluate differences between the rank order of the Image and Text AOIs. The results indicated a significant difference in first fixation between images and text for all three groups (ASD, TD-Language, TD-Age). All three groups fixated on the images first when presented with both images and text simultaneously. There was a significant difference for the ASD group, $z = -2.53$, $p = .01$. The sum of ranks for images was 49.5, while text was 5.5. There was a significant difference for the TD-Language group, $z = -3.16$, $p < .01$. The sum of the ranks for images was 55, and text was 0. There was a significant difference for the TD-Age group, $z = -2.53$, $p < .01$. The mean of the ranks for images was 49.5, while text was 5.5.

Differences for fixation count across images and text between the ASD and TD groups were analyzed. Box's Test of Equality of Covariance for the multivariate test was not significant, Box's M = 3.39, $F(6, 18168.92) = .50$, $p = .81$. There was a significant main effect for fixation count on images compared to text, $F(2,27) = 219.04$, $p < .001$, $\eta 2 = .89$. Follow-up tests were conducted to determine significant differences. Regardless of group membership (ASD or TD) there was a significant difference in the means between the fixation count on text and images. Overall, the participants had more fixations on the images than the text. There was not a main effect between group membership, $p > .05$. In addition, there was not a significant interaction between group membership (ASD or TD) and fixation count on images or text, $p > .05$.

Total fixation duration across images and text between the ASD and TD groups were analyzed. Box's Test of Equality of Covariance was not significant, Box's M = 5.68, $F(6, 18168.92) = .84$, $p = .54$. There was a significant main effect for images and text, $F(2, 27) = 102.12$, $p < .001$, $\eta 2= .79$ as well as between groups $F(2, 27) = 4.98$, $p < .05$, $\eta 2= .27$. There was not, however, a significant interaction between the ASD and TD groups across images and text, $p > .05$. Follow-up tests were conducted to determine significant differences. All participants had longer total fixation duration on images **(Table 6)**.

	ASD		TD-Age		TD-Language	
	M (SD)		M (SD)		M (SD)	
Measurement	**Text**	**Image**	**Text**	**Image**	**Text**	**Image**
Fixation Count	1.4(.73)	7.0(1.9)**	1.7(.87)	8.0(1.6)**	1.6(.80)	8.2(2.5)**
Mean Fixation Duration	.34(.11)	.36(.09)	.34(.12)	.41(.07)	.38(.18)	.51(.34)
Total Fixation Duration	.75(.29)	2.6(1.01)**	.95(.48)	3.1(.80)**	.91(.42)	3.3(.88)**

Note. ** p < .01

Table 6: Fast-Mapping Scores for Text Only Identification Condition

Condition 3. Image/text paired: story

There was not a significant difference in fast-mapping scores between the ASD group and the TD-Language or TD-Age groups, $p > .05$. The participants in the ASD group ($M = 4.2$, $SD = 1.48$) did not differ significantly on fast-mapping scores for text when compared to the TD-Age ($M = 4.7$, $SD = 1.77$) or TD-Language ($M = 4.5$, $SD = 1.78$) groups **(Table 7).**

Identification Stimuli	ASD	TD-Age	TD-Language
	M (SD)	M (SD)	M (SD)
Novel Text/Image Pair	4.2 (1.48)	4.7 (1.77)	4.5 (1.78)

Note. Fast-mapping scores were taken from a possible total of 6.

Table 7: Fast-Mapping Scores for Image/Text Paired Identification Condition

Condition 4. Image/text paired: story

A Wilcoxon test was conducted to evaluate differences between the rank order of the Image and Text AOIs. The results indicated a significant difference in first fixation between images and text for all three groups (ASD, TD-Language, TD-Age). All three groups fixated on the images first when presented with both images and text simultaneously.

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There was a significant difference for the ASD group, $z = -2.53$, $p = .01$. The sum of ranks for images was 49.5, while text was 5.5. There was a significant difference for the TD-Language group, $z = -3.16$, $p < .01$. The sum of the ranks for images was 55, and text was 0. There was a significant difference for the TD-Age group, $z = -2.53$, $p < .01$. The mean of the ranks for images was 49.5, while text was 5.5.

There was a significant main effect of image versus text for fixation count, $F(2,27) = 208.41$, $p < .001$, $\eta = .89$. Regardless of group membership (ASD or TD) all participants fixated more on images than text. In addition, there was a significant main effect between groups, $F(2,27) = 3.5$, $p = .04$, $\eta = .21$. Furthermore, there was a significant interaction between group membership (ASD or TD) and fixation count on images or text, $F(2,27) = 3.189$, $p = .05$, $\eta = .19$. The ASD group had fewer fixations on images than both the TD-age and TD-Language groups.

Possible differences in total fixation duration across images and text and between the ASD and TD groups were analyzed. Box's Test of Equality of Covariance for the multivariate test was significant, Box's $M = 14.49$, $F(6, 18168.92) = 2.16$, $p = .04$, indicating that the variances were not equal. There was a significant main effect for total fixation duration on images compared to text, $F(2, 27) = 101.02$, $p < .001$, $\eta = .80$. All participants demonstrated longer total fixation durations on images. The ASD participants had the least total fixation duration on images compared to the TD-Age and TD-Language groups. In addition, there was a significant interaction between ASD and TD participants and total fixation duration on images and text, $F(2,27) = 4.63$, $p = .04$, $\eta = .26$. Furthermore, there was a significant main effect between groups, $F(2,27) = 5.71$, $p < .01$, $\eta = .30$. Follow-up tests were conducted to determine significant differences. The ASD participants had greater total fixation duration on text compared to the TD-Age and TD-Language groups **(Table 8)**.

	ASD		TD-Age		TD-Language	
	M (SD)		M (SD)		M (SD)	
Measurement	**Text**	**Image**	**Text**	**Image**	**Text**	**Image**
Fixation Count	1.7(1.0)	5.6(2.3)**	1.7(1.0)	7.6(1.2)**	1.8(1.1)	.7(1.2)**
Mean Fixation Duration	.40(.10)	.34(.09)	.41(.11)	.46(.15)	.37(.09)	.43(.15)
Total Fixation Duration	1.0(.41)	2.2(.95)**	.94(.37)	.2(.81)**	.85(.37)	3.0(.53)**

Note. ** $p < .01$

Table 8: Eye-Gaze Measurements for Image/Text Paired Story Condition

Image/text separated identification

There was not a significant difference in fast-mapping scores between the ASD group and the TD-Language or TD-Age groups, $F(2, 27) = .46$, $p = .64$. The participants in the ASD group did not differ significantly on fast-mapping scores for text ($M = 1.7$, $SD = 1.42$) or images ($M = 2.3$, $SD = .95$) than those in the TD-Age (Text $M = 2.3$, $SD = .82$, Image $M = 2.3$, $SD = .82$) or TD-Language (Text $M = 1.8$, $SD = 1.14$; Image $M = 2.7$, $SD = .95$) groups. All participants correctly identified images more than text **(Table 9)**.

Identification Stimuli	ASD	TD-Age	TD-Language
	M (SD)	M (SD)	M (SD)
Novel Text	1.7 (1.42)	2.3 (.82)	1.8 (1.14)
Novel Image	2.3 (.95)	2.5 (1.08)	2.7 (.95)

Note. Fast-mapping scores were taken from a possible total of 3.

Table 9: Fast-Mapping Scores for Image/Text Separated Identification of Image and Text Condition

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Total fast-mapping scores: all conditions

Total fast-mapping scores across all conditions between the ASD and TD groups were analyzed. There was not a significant difference in total fast-mapping scores between the ASD group and the TD-Language or TD-Age groups, F(2, 27) = .46, p = .64. The participants in the ASD group (M = 12.6, SD = 5.30) did not differ significantly on total fast-mapping scores than those in the TD-Age (M = 14.6, SD = 4.43) or TD-Language (M = 14.1, SD = 4.89) groups **(Table 10)**.

Identification Stimuli	ASD	TD-Age	TD-Language
	M (SD)	M (SD)	M (SD)
Novel Text/and Images	12.6 (5.30)	14.6 (4.43)	14.1 (4.89)

Note. Fast-mapping scores were taken from a possible total of 3.

Table 10: Fast-Mapping Scores for Image/Text Separated Identification of Image and Text Condition

DISCUSSION

After a thorough review of the literature, there was a limited number of studies that used eye-gaze measurements to investigate the fast-mapping skills of children who were developing typically, or children diagnosed with ASD. The research in eye tracking has tended to focus on how children with ASD attend to faces [29-31]. The current research in fast-mapping has focused on whether children with ASD were able to use joint attention to fast-map novel stimuli [8,12, 16].

Image only story

Children with ASD performed similarly to both the TD-Age and TD-Language groups in terms of time to first fixation. All three groups took approximately the same amount of time to fixate on the novel image. Given that children with ASD are often challenged when presented with unfamiliar settings and activities, it was thought that it would take longer for the ASD group to orient and focus on the stimuli presented via the computer [27,28]. However, it may be that the highly structured physical environment and the fact that the children were seated so that they were physically and visually oriented to the computer provided the support needed for them to focus on the stimuli [16,27,28]. Additionally, the stimuli presented in the form of novel images may have been interesting to the children with ASD, thus, influencing their time to first fixation [8,16].

It was also found that the ASD group fixated less and demonstrated a shorter total fixation duration on the images as compared to both TD groups. The expectation was that the ASD group would demonstrate an increased number of fixations and total fixation duration. One possible explanation for these findings could be related to the ASD group having fewer fixations and shorter total fixation duration withthe presentation of the auditory stimulus.". Perhaps, the auditory cue prompted the children with ASD to visually attend to the stimulus; therefore, when the auditory cue ended, they looked away from the stimulus.

Another possibility may be related to the deficits children with ASD demonstrate with ToM (Baron-Cohen, 1995). The ASD group may have attended to the stimuli based on their own preferences, not recognizing there was a performance expectation. This concept is supported by Baron-Cohen et al. [12] in their study of children with ASD. They found these children used a personal focus of attention rather than social cues when learning new vocabulary. The TD groups may have been influenced by the instructional nature of the environment and the presence of authority figures; therefore, they attempted to comply with the performance expectations and directed their attention to the stimuli for increased durations.

Image only identification condition

Contrary to the researchers' expectations, on average the ASD group correctly identified approximately the same number of novel images as did both TD groups. During the image only story condition, the ASD group looked at the images less and for a shorter amount of time when compared to the TD group. However, the ASD group was able to perform equally for the image only identification condition when compared to both TD groups.

It was interesting to note that children with ASD did not fixate more on novel images during the image only story condition; yet, they were able to correctly identify the stimuli when presented with a choice of four images. McDuffie and colleagues [16] found that when attention following was specifically targeted, children with ASD were able to fast-map. In this study, attention was given to structuring the environment to eliminate distractions. This structure may have directed their focus to relevant stimuli, thus, optimizing their success with the fast-mapping tasks.

Luyester and Lord [32] reported that children with ASD were better able to fast-map when provided with additional cues and time with novel stimuli. For the current study, however, no visual prompts or cues were incorporated into the experimental stimuli. This was purposefully done to determine if the children with ASD would be able to fast-map without prompts. For the children with ASD in this study, it appears that visual scaffolding was not needed for them to be successful with fast-mapping.

Additionally, Parish-Morris et al. [19] reported that children with ASD demonstrated difficulties shifting attention from preferred to less preferred items which affected their ability to fast-map. Because children in this study were not required to shift their attention between two stimulus items and the stimuli being presented were novel and unfamiliar, this may have assisted the children with ASD to successfully fast-map. Given that no studies were found that have investigated the fast-mapping abilities of children with ASD in conjunction with eye tracking measurements, it is difficult to determine exactly why children with ASD were able to fast-map similarly to TD children. It appears, however, that for this group of children with ASD, they did not need to visually reference the novel images more than the TD groups to be able to successfully fast-map.

Text only story condition

It was expected that the ASD group would have a longer time to first fixation, more fixations and longer total fixation duration on text than both TD groups. It was found, however, that all three groups performed equally for time to first fixation. The ASD group demonstrated less fixations and shorter total fixation duration than did both TD groups.

Again, the environmental structure that was created and the use of auditory cues may have influenced how long the children with ASD visually attended to the stimuli. As in the image only story condition, the children with ASD may not have been influenced by the social expectations that adults typically have for children in these experimental conditions; therefore, once they had viewed the image they diverted their eye-gaze.

Text only identification condition

On average, the ASD group correctly identified approximately the same number of novel text stimuli as did both TD groups even though the ASD group looked at the text less and for a shorter amount of time. As in the image only identification condition, the ASD group did not need to visually reference the novel text more than the TD groups. Furthermore, because there was no competing stimulus [16] and the children were not required to shift their attention between stimuli during the story condition [19], the children with ASD were better able to attend to the relevant information to successfully fast-map.

Image/text paired identification condition

Like the other conditions, it was hypothesized that both TD-groups would have a higher receptive identification of correct novel text and image pairs compared to the ASD group. The results did not support this hypothesis, rather it was found that the ASD group on average identified approximately the same number of correct novel text/image pairs when compared to both TD groups. The ASD and TD groups had a comparable number of correct responses for the identification of novel text/image pairs. The ASD group was able to identify approximately the same number of correct text/image pairs even though they demonstrated a decrease in fixation count and total fixation duration. Thus, it appears for this ASD group, when presented with an increased number of visual stimuli and no additional visual scaffolding/prompting (Luyester & Lord, 2009) they were able to appropriately direct their visual attention (Preissler & Carey, 2005; McDuffie et al., 2006) to be able to correctly fast-map at the same level as the TD groups.

Image/text paired story condition

As with the other image and text story condition, it was expected that the ASD group would have an increased number of fixations and total fixation duration for novel images rather than novel text when compared to both TD groups. In addition, it was again expected that the ASD group would orient their visual attention to images before focusing on the text. However, as previously reported in the prior image and text story condition, it was found all three groups demonstrated more fixations and longer durations on images rather than text. Again, all the children may have found the novel images to be more interesting than text [10]; still, the children with ASD were able to shift their attention between the novel image and text stimuli [19].

Image/text separated identification of image and text condition

Similar to the other conditions, it was hypothesized that both TD-groups would have higher receptive identification of correct novel text and images compared to the ASD group. The results did not support this hypothesis, rather it was found that the ASD group on average identified approximately the same number of correct novel text and images when compared to both TD groups. All participants correctly identified novel images more than novel text.

Limitations

Given the heterogeneous nature of children on the autism spectrum, it can be difficult to include these children in investigations that compare them to children with typical development. Also, children with ASD have difficulties with new environments and unfamiliar situations. Consequently, this reduced the potential number of children that may have qualified for this study. This was the typical trend for the research referenced in this study.

In addition, there was limited research available that would assist in determining potential eye-gaze patterns associated with fast-mapping abilities in children (ASD and TD), no generalization can be made relative to how other children (ASD and TD) may have performed in the experimental conditions used in this study. Only a select group of children were included in this study. Therefore, it is not possible to know how children who did not meet the qualifying criteria (i.e., chronological age, receptive vocabulary skills, and nonverbal intelligence) would perform in a similar experimental condition.

CONCLUSION

Given that there was limited information regarding the fast-mapping abilities of children (ASD or TD) in conjunction with eye-gaze measurements, it was uncertain how the children would respond to the experimental conditions and the environment. The physical structure of the experimental set up, the use of visual work systems, and external reinforcers may have assisted in directing the participants to the testing stimuli and reduced potential distractors [27,28]

It was expected that children with ASD would demonstrate more fixations and longer durations on novel stimuli than the TD groups. It was found, however, that regardless of the condition the ASD group fixated less and for shorter durations on novel stimuli. Yet, the children with ASD were able to fast-map novel images and text similar to the TD groups without the need for additional visual prompts or structure. This may be because while this study required the children to demonstrate immediate recall of novel stimuli, they were not required to perform any additional tasks that demonstrated learning or the ability to transfer and generalize these fast-mapped concepts. This study also demonstrated that young children with ASD can successfully participate in research studies designed to explore the eye-gaze patterns associated with fast-mapping.

This research has a direct impact on clinical practice and intervention methodology. Previous studies have not specifically investigated the relationship between eye-gaze patterns and the development of acquiring new words and language for children with typical development or autism. The information obtained from this research study will help clinicians understand what information children with ASD attend to when learning new vocabulary and the similarities to children with typical development. This body of research could potentially impact clinician's implementation and development of Augmentative and Alternative Communication (AAC). As a result of this study, clinicians could potentially have a better understanding of the layout of visual information when considering AAC.

Given the limited research in the area of fast-mapping and eye-gaze measurements it would be important to expand this study to children of different age groups. In addition, it would be important to investigate how children with different cognitive and language abilities would perform given these same experimental conditions. Further, this study looked at the immediate fast-mapping responses of children relative to stimuli presentation. It would be interesting to examine the fast-mapping abilities of children with ASD when compared to TD children when a time delayed response is incorporated into the experimental design.

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