Global Journal of Intellectual & Developmental Disabilities
ISSN: 2575-8586

Review Article
Volume 4 Issue 4 - June 2018
DOI: 10.19080/GJIDD.2018.04.555645

Glob J Intellect Dev Disabil

Eye Movements While Processing Syntactically Ambiguous Sentences in Adolescents with Autism Spectrum Disorders: Preliminary Outcomes and Benchmarking Data

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Submission: June 06, 2018; **Published:** June 26, 2018

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Abstract

Research regarding eye-movements during the processing of syntactically ambiguous text provides important insights into the processes underlying text processing and comprehension. This report presents results of a pilot study that compared reading times and comprehension of syntactically ambiguous passages of 18 adolescents with higher functioning autism spectrum disorders (HFASD) and 16 typically developing control participants. The goal of this exploratory study was further to investigate the comprehension difficulties of children with HFASD using more direct, online analysis of reading abilities. Results suggest that control participants demonstrated patterns typically observed when readers encounter syntactically ambiguous sentences and that the HFASD participants did not use disambiguating information in the same manner as typically developing readers.

Keywords: Autism Spectrum Disorders; High Functioning Autism; Comprehension; Eye-tracking

Introduction

Many school-aged children with higher functioning autism spectrum disorder (HFASD) function in a range of intelligence that permits them to receive their education within regular education classrooms de Bruin etal.[1],Fleury et al.[2]. Despite the ability to receive education within regular education classrooms, individuals with HFASD often are at risk for academic difficulties Sansosti, Powell-Smith, Cowan [3]. One specific area of difficulty demonstrated empirically in the extant literature is reading. Research has indicated that students with HFASD, typically demonstrate ability for word and non-word decoding and text reading skills, yet have difficulties understanding the meaning of written text (e.g., Estes et al. [4]; Huemer & Mann [5]; Minshew, Goldstein, Siegel [6]; Nation et al. [7]; Norbury &Nation [8]; Ricketts et al. [9]). The majority of the contemporary literature describes individuals with HFASD with symptomology similar to reading comprehension disabilities despite average to above-average intellectual ability.

To date, a large portion of the extant literature examining differences in reading comprehension between typically and atypically developing readers has relied on the product of reading comprehension (i.e., reaction time) rather than the processes involved in reading comprehension. Put differently, comprehension was measured offline as the product of processing Cain & Nash [10]. While offline measures are important, they do not permit understanding regarding online cognitive processing of written language when reading. Eye movements during reading can provide helpful information regarding comprehension processesRayner et al. (2006).

Despite the popularity of using eye-tracking methodology to examine reading in typically developing samples, a paucity of similar research exists investigating the online reading processing of individuals with ASD. To date, only a few studies exist that have used such methodology to gain insight into the processes underlying text processing and comprehension in individuals with ASD (e.g.Au-Yeng [11]; Caruna& Brock [12]; Howard et al. [13];Sansosti et al. [14]; Saldana &Frith [15].

What can be gleaned from the aforementioned studies is that while individuals with HFASD may not display significant problems with comprehension of text, they do not express the same patterns of eye movements as do typical readers? Note that primary focus of previous investigations has focused on semantic ambiguity (e.g., ambiguous homographs) or inference

building. Future research should aim to investigate whether any differences in reading abilities of individuals with HFASD are present during syntactic ambiguity, as this presents unique challenges for processing and unique opportunities to compare the reading abilities between individuals with HFASD and their typically developing peers. While a review of syntactic ambiguity is beyond the scope of this paper, we offer a brief understanding. Syntactic ambiguity defined is the presence of two or more possible meanings within a single sentence or sequence of words. In a syntactically ambiguous sentence/phrase, the intended meaning is determined by the context assumed by the reader.

Germaine to the current investigation, the literature regarding ambiguous sentence processing indicates that young readers experience greater difficulty processing ambiguous sentences than adult readers (e.g.,Lorsbach et al. [16]) and that low working memory span individuals have greater difficulty with ambiguous sentences than do high working memory span individuals (e.g. Kemper et al. [17]). Even more relevant to the current investigation, it is evident that children identified as poor readers have more difficulty comprehending ambiguous sentences than those labeled as good readers (e.g., Nation &Snowling [18]). Thus, the literature suggests that using garden-path sentences would allow us to determine if adolescents with HFASD display atypical patterns of eye movements and have poorer comprehension for syntactically ambiguous sentences than their typically developing peers.

Purpose of this Study

The goal of the current study was to determine if adolescents with HFASD process syntactically ambiguous text in the same manner as typically developing readers.Two key components of our investigation were employed to meet our specific aims: 1) We adapted syntactically ambiguous passages from previous research that demonstrated that syntactically ambiguous sentences increase reading time and change patterns of eye movements compared to unambiguous sentences (e.g., Sturt et al. [2,19]we recruited adolescents with HFASD and typically developing peers carefully matched on other verbal processing skills.

Methods

Participants

Eighteen target participants (17 males and one female) with a primary diagnosis of a higher functioning autism spectrum disorder(e.g., High Functioning Autism, Asperger's Syndrome, Pervasive Developmental Disorder-Not Otherwise Specified) were recruited from a local chapter of the Autism Society of America (ASA) in Northeast Ohio. Inclusion criteria used to select appropriate target participants included average to above-average word reading accuracy and average to above-average receptive vocabulary. Median age of the target participants was 15.5 years (range of 11 to 17 years). In addition, 16 control (typically developing; nine male and seven female) participants were recruited from a local school district in Northeast Ohio. Inclusion criteria for control participants were the same as those for the target participants. Median age of the control participants was 15.0 years (range 11 to 18 years). All participants were given a $15.00 gift card to a national retailer in exchange for their participation in the study. Parental consent and informed assent was obtained from all individual participants included in the study.

Materials and Apparatus

Participants were tested individually on all tasks. Two standardized assessment tools were used to measure reading accuracy, reading comprehension, and vocabulary of both target and control participants. The Gray Oral Reading Test-Fourth Edition (GORT-4; Weiderhold & Bryant (2001) was used to assess levels of oral reading ability of all participants. Reliability of the GORT-4 is high; all average internal consistency reliability statistics are .90 or above. In addition to the GORT-4, the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn (2007) was administered as a measure of vocabulary to all participants in the study. The PPVT-4 is an individually administered, norm-referenced test of receptive vocabulary and a screening test of verbal ability. Psychometric properties of the PPVT-4 are strong with reliability statistics ranging from .85 to .97.

Eye-movement data were collected using an ASL-6 Eye Tracker, a non-invasive system that tracks gaze positions of participants on a flat computer monitor. The ASL-6 was set at a sampling rate of 120 HZ with accuracy of 0.5° of visual angle. For purposes of this experiment, the eye tracker was configured without the use of a chin rest. This configuration was selected because the task demands of the current study were minimal. Such a configuration is suited for children (e.g., Nadig&Sedivy(2002)) and is of particular importance for identifying the nature of reading comprehension difficulties in children with HFASD. The ASL-6 was interfaced with two compatible computers: one that controlled the presentation of stimuli via E-prime® experiment programming software (Schneider et al. (2012), and one that allowed for real-time eye tracking during the experimental tasks.

Experimental Task

The experimental task and stimuli in this study were adapted from Sturt et al. [19]Experiment 2. In the current study, 28 sentences that use reflexive pronouns to disambiguate attachment made up the experimental stimuli. Each item included two critical verbs, both of which could utilize either a noun phrase or a tensed clause. Each sentence was used to generate both an ambiguous and an unambiguous item (high ambiguous and high control respectively as designed by Sturt et al. [19]). While the Sturt et al. also included a manipulation of high attachment and low attachment; we only used high attachment as our stimuli. We based our rationale for this decision on Sturt et al.'s findings that ambiguity was found to increase reading times in both high

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and low attachment conditions, but high attachment was found to maximize the effects of ambiguity. Our goal is to determine if typically developing adolescents and adolescents with HFASD differ in the way they process syntactically ambiguous texts, therefore, maximizing the effect of ambiguity is key to this exploration. A final simple sentence was added to the text to add distance between the final region and the end of the text (see below).

For example,Sturt et al. [19], the unambiguous (control) sentence:

i. The social worker saw that the foster mother who accepted the little boy didn't really trust herself at all about anything.

ii. The little boy was also anxious about being placed in a new home.

Is modified in the ambiguous condition as follows:

a. The social worker saw foster mother who accepted the little boydidn't really trust herself at all about anything.

b. The little boy was also anxious about being placed in a new home.

We divided the items into two lists so that half of the items represent the ambiguous stimuli on one list and the unambiguous stimuli on the other list. We counterbalanced lists across control and target participants. We also generated fifty-six filler items of varying syntactic structure and comparable word count, some of which included the word, "that." Experimental and control items were combined with the filler items.

Procedure

Participants were tested individually in a quiet room. The GORT-4 and the PPVT-4 were administered individually prior to the application of the experimental task by a graduate student trained in the administration of psycho-educational assessment. Prior to beginning the experimental task, the researcher informed participants that the study concerned the comprehension of short passages of text presented on the computer screen. The researcher also informed participants that eye-tracking measures were collected. Participants were instructed to read at their normal reading rate and comprehend the sentences to the best of their ability. They also were informed that after each pair of sentences they would be required to answer a simple comprehension question and instructed to answer the questions as quickly and as accurately as possible. Then, participants were seated in front of the eye-tracker and calibration was performed. Participants were seated so that their eyes were approximately 65 cm from the eye tracker and such that the participants' gaze angle was less than 42° to the screen as recommended by the manufacturer. For the ASL-6 calibration, calculations are handled with the embedded firmware.

The calibration procedure took approximately 5 minutes to complete. Calibration began by having participants focus on an attention cue in the center of the monitor. The attention cue was a 14-point font "+" symbol. When the experimenter determined that the participant was fixated on the "+", the experimenter presented a display of nine "+" symbols evenly distributed on the monitor. The experimenter asked the participant to focus on the "+" symbol in the upper left corner of the screen and asked the participant to say "yes" when the participant was fixated on that symbol. The experimenter set the fixation point and then moved through the screen one symbol at a time moving from left to right and top to bottom. After all fixation points had been set, the experimenter asked the participant to focus on each of the symbols one at a time to ensure precise calibration. If the calibration was not precise, the experimenter restarted the calibration procedure until precise calibration was obtained. Following calibration, participants completed four practice items before completing the 84 task items.

The first item was preceded by the instruction "Press the space bar when you are ready to begin." On each trial the signal "Ready?" was presented in the middle of the screen for 2 s, followed by a fixation cross for 500ms and then the short text item. In the Sturt, et al. [19] study, eye-tracking measures did not differ significantly when the position of line breaks in text was placed early in the text versus late. Therefore, we used only late line breaks as in [1]. To aid in analysis of eye-tracking data, two blank lines were inserted between each line of text.

When participants completed reading the item, they pressed the space bar to see the related comprehension question. The question was displayed until a response was recorded or for a maximum of 4 s. Participants responded by pressing the Q key for responses on the left and P for responses on the right of the screen. For example, the question pertaining to example (1 shown above) was presented as follows:

Who did not trust herself about anything?

Q = The social worker

P = The foster mother

The termination of the question screen will be followed by a 500 ms pause and then the "Ready" signal beginning the next trial.

Analytical Plan

Due to the exploratory nature of this study and our interest in detecting different patterns of eye-movements during processing of syntactic ambiguity, data were collected on all regions of the passages. Our goal was to determine if target participants visually processed the passages differently from the control participants. In order to make this determination, we examined data from the syntactic components of the sentence structure.

Thus, the regions of (1) would be as follows:

The social workersaw (that)the foster motherwho acceptedthe little boy (pre-critical region)didn't really (first

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critical region)trust (filler region)herself (reflexive region)at all (spillover region)about anything (final region)

Relevant to the current study are the regions from the first critical region to the spillover region. Sturt et al. [19] found that in sentences containing syntactic ambiguity, first-pass reading times were longer in the first critical region, reflexive region, and the spillover region than in the unambiguous sentences. In their second-pass reading time analysis, Sturt et al [19]. found that readers spent a great deal more time rereading in the (high) ambiguous condition. We chose to aggregate our analyses of the critical regions (pre-critical through final regions). An independent samples t-test was used to examine group differences in total duration in the critical regions.

Latency and accuracy data were collected for responses to the comprehension questions. This data was analyzed using a 2 x 2 ANOVA with text (ambiguous vs. unambiguous) as a within subject's factor and group (control vs. target) as a between subjects factor.

Results

Figure 1 displays the mean sentence reading times of both ambiguous and unambiguous sentences by group. The results indicate there were no significant effects of group or sentence type, but did indicate a significant interaction, $F(1,32) = 4.81$, $p = .04$, partial $\eta 2 = .13$. The interaction indicates that the participants with HFASD did not spend significantly different amounts of time on the ambiguous sentences (M = 10153ms, SD = 4442ms) compared to the unambiguous sentences (M = 10426ms, SD = 4697ms), whereas the control participants spent more time on the ambiguous sentences (M = 11009ms, SD = 3786ms), than the unambiguous sentences (M = 9919ms, SD = 2817ms).

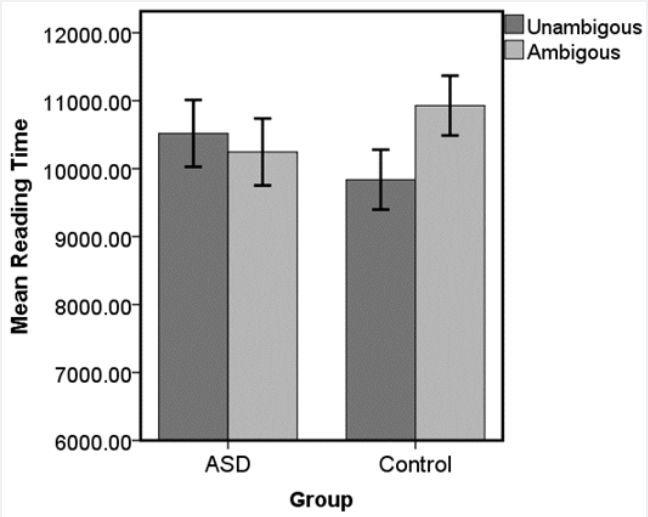

Figure 1: Mean Reading Times for Ambiguous and Unambiguous Sentences by Group.

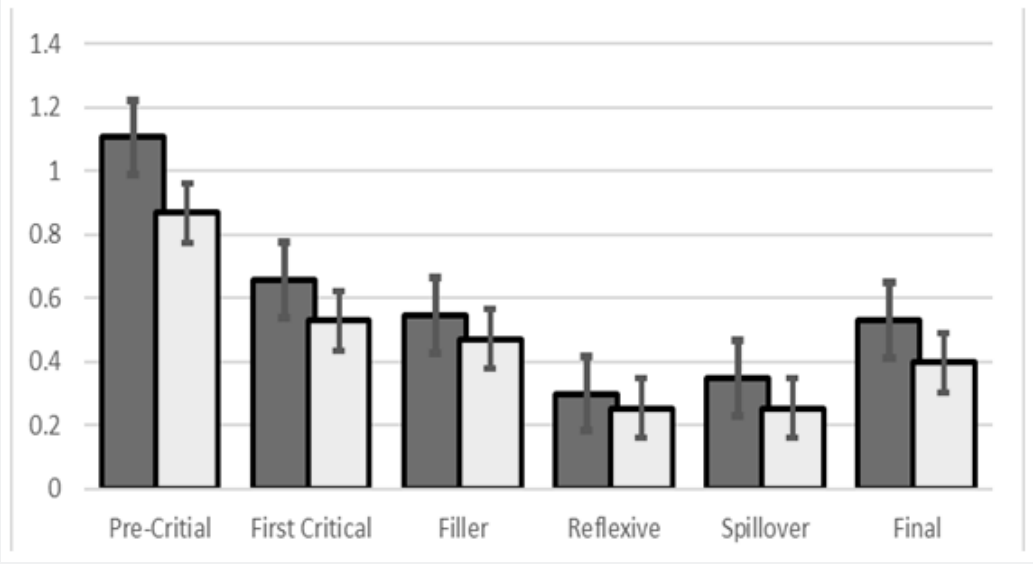

Figure 2: Mean Total Fixation Durations by Region and Group.

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Figure 2 displays the mean fixation durations for each of the critical regions of ambiguous sentences by group. Inferential statistics indicate that control participants spent a significantly greater amount of time in the critical regions while reading ambiguous sentences than the HFASD group, $t(32) = 8.20$, $p = .001$, 95% CI [.043, .074]

Regarding our last aim - determining whether participants with HFASD would comprehend the ambiguous sentences as well as the control participants- it appears that a significant effect of sentence type (mean accuracy for questions related to ambiguous sentences was lower than for unambiguous sentences) was, for the greatest extent, due to the participants with HFASD having poorer comprehension for the ambiguous sentences compared to the unambiguous sentences. This contrasts with the control participants' whose accuracy did not differ. Indeed, statistical analyses indicate no effect of group, but a significant effect of sentence type, $F(1,32) = 4.61$, $p = .04$, $\eta p2 = .13$ and an interaction that approached significance $F(1,32) = 3.84$, $p = .06$, $\eta p2 = .11$.

Discussion

The results of the study are informative regarding the reading processes employed by participants with HFASD. First, results demonstrated a group by sentence type interaction for reading time, suggesting that the adolescents with HFASD do not process the ambiguous sentences in the same manner as the typically developing adolescents. In this study, adolescents with HFASD did not exhibit the characteristically slowing pattern as did the typically developing readers. This finding suggests that the typically developing readers in our study were in fact "garden-pathed" by the sentences and the adolescents with HFASD were not. Second, adolescents with HFASD did not demonstrate typical patterns of eye-fixation while reading syntactically ambiguous sentences. The results of the experiment indicated that typically developing adolescent readers spent more time in the critical regions while reading than did the readers with HFASD, suggesting that individuals with HFASD do not slow their reading or fixate on critical regions of sentences to interpret meaning. Third, questions designed to test the comprehension of the ambiguous sentences suggest that the participants with HFASD did not comprehend the ambiguous sentences or unambiguous sentences, nor did they comprehend the ambiguous sentences as well as the typically developing readers.

Taken together, results of this exploratory pilot study demonstrate distinct differences in reading and comprehending syntactically ambiguous sentences between adolescents with HFASD and typical readers. It can be hypothesized that by spending less time on a sentence and less time trying to disambiguate the sentence by focusing on critical regions, individuals with HFASD are likely to misinterpret the meaning of the sentence. In simple terms, individuals with HFASD are less likely to slow down and try to resolve ambiguity within text. Results of the current experiment confirm such a hypothesis and provide further insight into the maladaptive reading patterns exhibited by adolescent readers with HFASD.[20-22]

Conflicts of Interest

Author CAW declares that he has no conflict of interest. Author FJS declares he has no conflict of interest. Author EG declares she has no conflict of interest.

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