Growth in Narrative Retelling and Inference Abilities and Relations with Reading Comprehension in Children and Adolescents with Autism Spectrum Disorder

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Abstract

Purpose: Extant research indicates that children and adolescents with autism spectrum disorder (ASD) without an intellectual disability (ID) often experience difficulty comprehending written texts that is unexpected in comparison with their cognitive abilities. This study investigated the development of two key skills, narrative and inference abilities, that support higher level text comprehension and their relation to semantic knowledge, ASD symptomatology, and age. Three questions were addressed: 1.) What was the nature of narrative and inference skill development over time? 2.) What was the relation between narrative or inference development and semantic knowledge, ASD symptomatology, and age? 3.) Did initial narrative and inferencing skills, and the development of these skills, predict reading comprehension outcomes?

Methods: Data from 81 children and adolescents with ASD without ID (FIQ $\geq$ 75) between the ages of 8-16-years-old at timepoint 1 were collected at 15-month intervals across three timepoints. ASD symptomatology was assessed with the ADOS-2. Standardized narrative retelling, inference, reading comprehension, semantic knowledge and cognitive assessments were administered. Latent growth curve models were conducted to examine narrative and inference skill development, and conditional growth models were fit to examine the relation between growth trajectories and covariates (semantic knowledge, ASD symptomatology, age) as well as with the reading comprehension distal outcome.

Results: Narrative retelling skills followed a linear trajectory of growth and were a relative strength in this sample, while inference skills were well below average and declined over time relative to age-normed standard scores. Semantic knowledge explained significant heterogeneity in initial narrative and inference skills, whereas ASD symptomatology was only related to initial narrative retelling abilities and age was only related to initial inference abilities. Timepoint 3 reading comprehension skill (in the below average range) was significantly explained by initial narrative retelling and inference abilities.

Conclusions: The results of this study indicate that narrative retelling and inference skills are important for successful reading comprehension for individuals with ASD without ID and that semantic knowledge underpins these skills. Furthermore, the observation that ASD symptom severity was associated with narrative retelling skills is consistent with the hypothesis that problems in narrative reading skills are associated with the autism phenotype. Finally, inference skill was a particular challenge for individuals in this sample, although age was positively associated with better performance on the assessment.

Implications: These findings suggest that narrative and inference skills, in addition to semantic knowledge, are important to target beginning in elementary grades to improve reading comprehension outcomes for children and adolescents with ASD without ID.

Additional materials: 68 references, four tables, one figure

Introduction

Individuals with autism spectrum disorder (ASD) without intellectual disability (ID) now comprise 69% of children with an ASD diagnosis in the United States (Maenner et al., 2020). School-aged children within normative range of cognitive ability spend increasingly more of their day in general education accessing the core curriculum (White et al., 2007) although many struggle with the academic, social communication, and behavioral expectations in school (Mckeithan & Sabornie, 2019; Sparapani et al., 2016). One established area of underachievement is in the area of reading comprehension (Brown et al., 2013; McIntyre, Solari, Gonzales, et.al., 2017; Nation et al., 2006; Solari et al., 2019). This impairment limits students' ability to learn new information from text, thereby creating barriers to accessing the core academic curriculum as well as potentially impacting longer-term educational and vocational outcomes (Kutner et al., 2007). Previous cross-sectional studies have reported variability in word recognition and text reading skills in individuals with ASD (e.g., Brown et al., 2013), but despite relative strengths in foundational reading skills for some, many individuals with ASD exhibit deficits in higher-order reading and language comprehension skills such as narrative and inference abilities (e.g., McIntyre, Solari, Grimm., et.al., 2017). In a longitudinal analysis using data from 3,421 students with disabilities in the Special Education Elementary Longitudinal Study (SRI International, 2002), Wei et al. (2011) reported that students with ASD demonstrated growth in reading comprehension skills over time, but their rate of growth was significantly lower than that of a sample of students with learning disabilities. Additionally, both groups showed similar growth deceleration over time, suggesting that children from either group were very unlikely to catch up to their typically developing (TD) peers (Wei et al., 2011). In order to address delays and deficits in reading achievement, it is important to understand which facets of reading comprehension pose the greatest challenge for students with ASD and what cognitive, language, and social communication characteristics are associated with these difficulties. This study focuses on the development of narrative and inferential abilities in a sample of children and adolescents with ASD by examining associations between growth trajectories and ASD symptomatology, lexical-semantic (meaning of words) knowledge, age, and reading comprehension outcomes.

Reading Comprehension

The Simple View of Reading posits that reading comprehension is the product of decoding and linguistic comprehension skills (Gough & Tunmer, 1986). While decoding skills are an essential component of the model, this study focuses solely on linguistic comprehension skills, or the cognitive and oral language processing required to create meaning from the decoded words in order to understand written texts. A large base of empirical evidence suggests that linguistic comprehension skills are underpinned by lexical-semantic knowledge, structural language skills including phonology, morphology, syntax, and compositional semantics, as well as by narrative and inferential skills (e.g., Cain & Oakhill, 2008; Roth et al., 200).

Narrative Skills

Narrative skills develop before reading and are oral sequences of real or fictional events that rely on the understanding and utilization of story structure (Lynch et al., 2008). The ability to produce a coherent, high quality narrative has been shown to have positive associations with structural language, literacy and social skills, and improving narrative skills in TD children is associated with better comprehension (Johnston, 2008). Extant research reports that measures of story retelling and story structure account for significant variance in reading comprehension in school-aged children without ASD, even beyond the contributions of lexical-semantic and structural language skills (Oakhill & Cain, 2012; Snyder & Downey, 1991).

Narratives can be analyzed at the macro- and micro-structure levels. The macro-structure of a story refers to the organization and coherent sequencing of story grammar components (e.g., character, setting, and plot). Micro-structure level skills include lexical-semantic knowledge, structural language ability, pronominal referents, and story register (Justice et al., 2006; Manolitsi & Botting, 2011). Narrative retelling tasks are a common form of narrative assessment that typically require one to recount a story without the aid of a picture book or other visual supports that help control attention and organize language production (Banney et al., 2015). These tasks can be challenging because they create demands on memory as well as an interpersonal demand to attend to and engage with the assessor (Losh & Gordon, 2014).

Inference Skills

The ability to make accurate inferences about written text is essential for proficient reading comprehension. Inference skills have been shown to relate to later reading comprehension skills in 4th to 6th graders beyond the contributions of vocabulary, verbal IQ, and the autoregressive effect of reading comprehension, suggesting a possible causal link (Oakhill & Cain, 2012). Inferential processing is made up of two primary levels. First, to establish local coherence a reader integrates information between individual sentences to link them together and make sense of causal, temporal, and spatial relationships in the text utilizing bridging inferences. Bridging inferences are utilized to fill in information, such as pronominal referents, or to connect adjacent phrases and paragraphs to build a coherent understanding of the text. For example, one might read, "Joey opened the jar of peanut butter. His dog ran over excitedly." A reader could infer that Joey's dog loved peanut butter, which would link the two sentences together and help the reader understand why the dog was excited.

Second, to establish higher-level global coherence of a text, a reader must make knowledge-based inferences that incorporate information from the text with their background knowledge and ideas from long-term memory. This background knowledge can be memories of experiences, other texts, previous excerpts within the same text, or information in long-term memory (Graesser et al., 1994; Kintsch, 1988). Knowledge-based inferences help readers make sense of the details that are only implicitly mentioned or to supplement the information stated in the text. Facilitation of deeper comprehension occurs as the reader constructs causes and motives that explain why events or actions occurred, allowing the reader to infer themes or global messages in the text (Graesser et al., 1994). A simple example of a narrative passage requiring a knowledge-based inference is, "Claire slipped on the icy steps. Her mother immediately called for help." A reader with background knowledge about living in very cold places would know that slipping on ice could result in a painful fall that might lead to serious injuries such as a broken limb or concussion. Integrating this knowledge with the text would provide deeper understanding of the possible consequences of falling as well as an explanation for the mother's behavior. Children who are poor comprehenders despite being fluent text readers may exhibit more difficulty generating knowledge-based inferences than skilled comprehenders even when the knowledge base is strictly controlled, indicating that the difficulties are not just due to a lack of background knowledge (Cain et al., 2001).

Theoretical Framework: Construction-Integration Model

In order to contextualize the relations between narrative retelling, inference, and reading comprehension, this study utilized the Construction-Integration Model (Kintsch, 1988). It is a cognitive view of reading that provides a useful framework for investigating factors that underpin reading comprehension challenges in individuals with ASD. Kintsch (1988) described reading comprehension as an iterative process where one interacts with text and generates mental representations while reading. This model posits a construction phase wherein information from the text and related knowledge from memory are automatically activated in order for the reader to create meaning from the written text. Then, during an integration process information stored in memory is integrated with that of the text in a process that persists throughout reading allowing the reader to continually update their mental representation of the written text.

Kintsch (1998) described different levels of cognitive representation and processing of texts ranging from surface level to full integration. Beginning with the surface level, a reader retains basic memory for the specific words and phrases in the text but has minimal comprehension. Next, at the text base level, a reader engages in lower-level processing of all the information explicitly stated in the text, including lexical-semantic and structural information, to build an accurate memory representation of the text. Minimal inferential processing is required at the text base level other than bridging inferences. If a reader has a well-constructed text base in memory, they can recall and retell the text base (e.g., narrative retelling), answer explicit questions, recognize text base components, and accurately summarize the text (Snyder & Caccamise, 2010).

While text base level processing allows some engagement with text, it is a relatively shallow representation. At the deepest level of comprehension, a situation model is developed utilizing knowledge-based inferences. A well-constructed, coherent situation model is required to answer implicit or inferential comprehension questions, identify the main idea, explain cause and effect, discuss themes, and make connections to other texts or generalize to other contexts.

This model emphasizes the role text base structure and inference play in proficient reading comprehension. However, numerous studies suggest that problems with utilizing narrative structure and with inferential thinking are common among individuals with ASD. The role these challenges may play in reading comprehension achievement for individuals with ASD is not yet fully understood.

Narrative and Inference in Individuals with ASD

One method for assessing the quality of a text base level representation of a narrative story is to ask the reader to retell the story. Prior research has demonstrated that lexical-semantic and structural language skills are associated with the ability to produce a narrative (Justice et al., 2006; Manolitsi & Botting, 2011; Norbury & Bishop, 2002), and narrative assessments are thought to be sensitive to aspects of language difficulties in individuals with ASD (Botting, 2002). Manolitsi and Botting (2011) found that both macro- and micro-level narrative skills were significantly related to receptive language skills in a sample of 13 Greek children with ASD (4-13 years old) but were not related in a comparison sample of Greek children with specific language impairment (SLI). Furthermore, the children with ASD had more difficulties than those with SLI with aspects of retelling such as telling events out of sequence and communicating causal relations between events. Diehl et al. (2006) utilized a narrative retelling task wherein a child heard a recorded story while looking at a corresponding wordless picture book. The child was then asked to retell the story with the book removed from view. Seventeen children with ASD without ID were closely matched on age (6-14 years old), IQ, and receptive and expressive language (i.e., lexical-semantic and structural skills) with TD controls. While the groups did not differ on story length or syntactic complexity, children with ASD recalled fewer discrete events in a coherent manner in their retellings than TD controls. The authors noted that while the participants with ASD may have a basic understanding of the story, they may lack a deeper comprehension of the story which is necessary for constructing appropriate causal inferences required to tell a coherent story. Another study reported that story recall by 30 Finnish children with ASD without ID (6-11 years old) included fewer relevant details than TD controls matched on age and gender (Barron-Linnankoski et al., 2015). Williams et al. (2006) found that a sample of 38 children (8-16 years old) with ASD without ID performed significantly poorer than IQ- and vocabulary-matched TD controls on the same story recall assessment used in the current study. This literature supports examining the hypothesis that challenges in the development of narrative retelling and the relation with language skills such as lexical-semantic knowledge may contribute to our understanding of reading comprehension deficits in children and adolescents with ASD.

In order to probe difficulties constructing a situation model of a text, inference skills may be assessed. Several studies have examined inferential skills in individuals with ASD. Studies assessing the ability to make bridging inferences in the context of written text have identified varying levels of proficiency. Saldaña and Frith (2007) found that 16 adolescents with ASD did not differ from age- and vocabulary-matched TD controls when making bridging inferences in two-sentence vignettes for either social or physical information. But, there was wide variation in receptive vocabulary, making it unclear as to whether or not the group means masked the challenges of the adolescents with poorer semantic skills. Other studies have reported relative difficulties making bridging inferences from text, especially with regard to mental state verbs or while reading social scripts (Dennis et al., 2001).

Difficulties making knowledge-based inferences are more commonly reported in samples with ASD (e.g., Wahlberg & Magliano, 2004), especially with social information regarding intentionality or mental states (e.g., le Sourn-Bissaoui et al., 2009). Tirado and Saldaña (2016) found that while 21 participants with ASD without ID (11-20 years old) did not have difficulty with online inferencing while reading longer texts even when inferring emotions of main characters, they did display difficulty answering inferential questions about those same emotions after reading. Additional studies have found that language abilities support inferential processing and may be more important predictors than an ASD diagnosis. In a study of 47 children with ASD (7-12 years old), Lucas and Norbury (2015) reported that vocabulary knowledge and verbal working memory but not an ASD diagnosis predicted inference ability. In addition, in a sample of 86 children and adolescents (10-16 years old), and adults (17-45 years old) with ASD without ID, Bodner et al. (2015) found that individuals who had well-developed meta-linguistic skills did not display an overall problem with inference but demonstrated a particular difficulty with inferences about social information. The authors noted that inference difficulties may not be a specific cognitive characteristic of ASD, as their participants were able to make inferences about physical and mental states, particularly with increases in age and language skill. Taken together, this literature supports examining the hypothesis that problems in the development of inferential ability may be related to language skills such as lexical-semantic knowledge and may contribute to problems in reading comprehension achievement for individuals with ASD.

Current Study

Building upon an existing theoretical framework and empirical studies, this study investigated the development of the narrative and inference skills of individuals with ASD between the ages of 8 and 18. Development of these skills was investigated over a 30-month period, with data collection occurring at three separate timepoints. Growth in narrative and inference skill was examined as well as their relations to ASD symptomatology, lexical-semantic knowledge, and reading comprehension. As such, this study addressed the following three research questions:

(1) What was the nature of narrative and inference skill development over time?
(2) What was the relation between narrative and inference development with ASD symptomatology, lexical-semantic knowledge, and age?
(3) Did initial narrative and inferencing skills, and the development of these skills, predict reading comprehension outcomes?

Based on previous empirical work, it is hypothesized that the narrative and inferencing abilities of individuals will grow over time, although they may not keep pace with those of TD populations. It is also hypothesized that ASD symptomology, lexical-semantic knowledge, and age will be significantly related to narrative and inference skills. Finally, as previous studies have suggested a significant relation between narrative or inference abilities and reading comprehension, it is hypothesized that this will also be true in a sample of school-aged children with ASD.

Method

Participants

This research was conducted in compliance with university Institutional Review Board policies and written parental consent and child assent was obtained prior to data collection. Study participants were recruited through a university research subject tracking system, local school districts, and word of mouth. Ninety-three children, ages 8- to 16-years-old, with a community diagnosis of ASD enrolled in a longitudinal research project on academic, social, and cognitive development participated in this study. All children enrolled in the study had previous ASD diagnoses confirmed by trained researchers using the Autism Diagnostic Observation Schedule-2

(ADOS-2), Module 3 or 4, at the first session. Full-scale IQ (FIQ) was assessed with the Wechsler Abbreviated Scale of Intelligence-II (WASI-II). All children had FIQ scores ≥ 75. While all 93 participants met criteria for ASD on the ADOS-2, 12 individuals were ineligible for this study due to FIQ < 75 (timepoint 1 sample $N = 81$, timepoint 2 $N = 69$, and timepoint 3 $N = 64$). Exclusionary criteria included major medical conditions that could be associated with extended absences from school, neurological disorders (e.g., cerebral palsy), significant sensory or motor impairments, psychotic symptoms, or an identified syndrome other than ASD (e.g., Fragile X).

Procedures and Measures

Trained members of a research group collected all data during one-on-one assessment sessions in a university-based child assessment laboratory. Each of three timepoints (TP1, TP2, and TP3) was comprised of two 2.5-hour sessions and the timepoints were each separated by 15 months for a total of 30 months between TP1 and TP3. Novice testers were trained to reliability through a 3-phase protocol: 1) explicit instruction on each assessment, 2) observation of experienced testers during which the novice tester double scored the assessment, and 3) live administration of assessments with an experienced tester scaffolding and double scoring until reliability was reached. Aspects of these data have been previously reported (citations removed during blind review).

Diagnostic Measure

The ADOS-2 (Lord et al., 2012) is a diagnostic assessment for ASD that was utilized by trained researchers in this study to evaluate current functioning in two core domains: 1) Social Affect and 2) Restricted and Repetitive Behaviors. It has been shown to have strong predictive validity compared to best estimate clinical diagnoses (Charman & Gotham, 2013). Total scores were used to confirm community ASD diagnoses; a cutoff score of seven places a child on the autism spectrum. Furthermore, total scores were used as covariates in this study's analyses to investigate the relation of ASD symptomatology with the latent intercept and slope factors.

Cognition and Verbal Measure

The WASI-2 (Wechsler, 2011) provided measurement of verbal and nonverbal cognitive ability. Two verbal subtests, Vocabulary and Similarities, assessed expressive vocabulary and semantic reasoning and formed the Verbal Comprehension Index (VCI) which is used in analyses as the measure of lexical-semantic knowledge. Two nonverbal subtests, Block Design and Matrix Reasoning, measured timed visual spatial processing and problem solving and yielded the Perceptual Reasoning Index (PRI). Scores from all four subtests are used to calculate an age-normed standard score ($M = 100$, $SD = 15$) measurement of FIQ. The FIQ index has reported internal consistency (0.96) and test-retest reliability for children ages 6-16, $r = 0.94$ (Wechsler, 2011). In this sample, internal consistency Cronbach's alpha coefficients were 0.89 for Vocabulary, 0.88 for Similarities, 0.87 for Block Design, and 0.92 for Matrix Reasoning.

Narrative Retelling Measure

The Story Memory subtest from the Wide Range Assessment of Memory and Learning, Second Edition (WRAML-2; Sheslow & Adams, 2003) measured the participants' ability to listen to stories and utilize narrative macro-structure to organize and retell concrete story details related to characters, setting, and plot elements. In this standardized measure, a tester read a total of two stories aloud to each participant. Immediately after each story, the child was asked to retell all the parts of the story they could remember. The number of correct elements recalled were totaled across both stories for a raw score that was also converted into age-normed scaled score ($M = 10$, $SD = 3$). Similar to publisher reported alphas (alphas = 0.91-0.92; Sheslow &

Adams, 2003), internal consistency Cronbach's alpha from this sample was 0.95 for Story Recall.

Inference Measure

The Auditory Reasoning subtest from the Test of Auditory Processing Skills, Third Edition (TAPS-3; Martin & Brownell, 2005) assessed higher order linguistic processing related to making knowledge-based inferences and explaining idioms (e.g., "dragging her feet") in both social and nonsocial contexts. Participants were read short vignettes comprised of two to three sentences and asked to respond orally to one question per vignette. A (modified) sample vignette requiring knowledge-based inferencing is as follows: "After his friends left to go to the skateboard park, Max asked his mom when the cast on his leg would come off. Max said he wasn't sure if he ever wanted to skateboard again. Why wouldn't Max want to skateboard again?" Raw and age-normed scaled scores (M = 10, SD = 3) were computed based on the number of vignettes answered correctly. Similar to publisher reported alphas (alphas = 0.91-0.96; Martin & Brownell, 2005), internal consistency Cronbach's alpha in this sample was 0.87 for Auditory Reasoning.

Reading Comprehension Measure

The Gray Oral Reading Tests – Fifth Edition (GORT-5; Wiederholt & Bryant, 2012) provided a standardized assessment of reading comprehension. The standardized, individually administered test is comprised of 16 progressively more complex passages read aloud by the examinee. After each passage, the tester removed the text from view and asked five open-ended questions that require an oral response. Questions probed for recall of details, synthesis of the main idea, understanding of causal relations, inferential thinking, and ability to make predictions. Raw and scaled scores (M = 10, SD = 3) were computed. Internal consistency Cronbach's alpha from this study for Comprehension (0.90) was generally consistent with the publisher (Wiederholt & Bryant, 2012) reported alphas for their norming sample (alphas = 0.90-0.96) and for an ASD subsample (alpha = 0.97).

Data Analysis Plan

Latent growth curve models were conducted to examine the development of narrative retelling (WRAML-2 Story Recall) and inferencing skills (TAPS-3 Auditory Reasoning) across the three timepoints. Two separate models were run, one for each skill. Subsequently, for each model, we included GORT-5 Reading Comprehension from the third timepoint as a distal outcome, which was predicted by the latent growth parameters. Additionally, these models with the distal outcome also controlled for ASD symptomatology (ADOS-2), lexical-semantic knowledge (WASI-II VCI), and age at the first timepoint. All models were conducted using M*plus* 7.4 (Muthén & Muthén, 1998-2016) with full information maximum likelihood with robust standard errors as the estimator. This estimator includes participants in the model as long as they have WRAML-2 Story Recall or TAPS-3 Auditory Reasoning data on at least one of the timepoints. This estimator excludes participants who were missing data on any of the covariates, but this was not the case for any participants. Thus, the WRAML-2 Story Recall model included 78 participants and the TAPS-3 Auditory Reasoning model included 76 participants.

Prior to fitting the latent growth curve models, mean scores for WRAML-2 Story Recall and TAPS-3 Auditory Reasoning at each timepoint were examined to inform what trajectory shapes might best capture participants' skill development over time. WRAML-2 Story Recall scores appeared to increase approximately linearly over time, however, TAPS-3 Auditory Reasoning scores appeared to increase between TP1 and TP2, but plateau between TP2 and TP3. Thus, for the unconditional models (i.e., without covariates or distal outcomes), a linear trajectory was specified for WRAML-2 Story Recall, but a level and shape model was specified for TAPS-3 Auditory Reasoning. A level and shape model (Raykov & Marcoulides, 2006) was chosen for TAPS-3 Auditory Reasoning because this model does not impose a growth trajectory onto the data. Rather, time scores for the first and third assessment occasions were fixed at 0 and 1, respectively, while the time score for TP2 was freely estimated, which represented the proportion of change between TP1 and TP2 relative to the overall amount of change across all timepoints. In the unconditional models, the primary parameters of interest were the latent intercept factor and the latent slope factor. The latent intercept factor, for both the WRAML-2 Story Recall and TAPS-3 Auditory Reasoning models, represents the average score (for each skill) at TP1. For the linear WRAML-2 Story Recall model, the latent slope factor represents the average amount of change in each skill between each timepoint. For the level and shape TAPS-3 Auditory Reasoning model, the latent factor represents the overall amount of change across all timepoints. Once these models were fit and checked for their viability, this study fit conditional models by including the covariates and distal outcome in each model, while retaining each model's growth trajectory specification. The latent intercept and latent slope factors were regressed on the covariates (ADOS-2, WASI-II VCI, and age), and the distal outcome (GORT-5 Reading Comprehension) was regressed on the latent intercept and latent slope factors. All covariates were mean-centered.

The adequacy of each model was assessed using commonly-employed fit statistics, and this study followed recommendations by Hu and Bentler (1999). Specifically, good fit was indicated by a non-significant chi-square goodness of fit test, values for the root-mean-square error of approximation (RMSEA) and standardized root mean square residual (SRMR) equal to or below 0.06 (values equal or below 0.08 were considered adequate fit), and values for the comparative fit index (CFI) and Tucker-Lewis index (TLI) above 0.95. Since a variety of fit statistics were utilized, this study considered these indexes holistically, rather than rely on a single fit statistic.

Results

Descriptive Statistics

Descriptive statistics as shown in table 1 demonstrate that the sample met criteria for ASD on the ADOS-2 and that measures of IQ are within normal range. The standard deviation of WASI-II VCI scores (*SD* = 16.02) was higher than expected for a standard score (*M* = 100, *SD* = 15) indicating slightly more variability in lexical-semantic knowledge than typical. On average, WRAML-2 Story Recall scaled scores in the overall sample were in the below average range at TP1, and in the average range at TP2 and TP3, as compared to the test's norming sample. Sample means for TAPS-3 Auditory Reasoning scaled scores were more than one standard deviation below average at all three timepoints and declined over time, and their GORT-5 Reading Comprehension mean scaled scores at TP3 were in the below average range. [table 1 about here]

Growth in Narrative and Inference Skills

Overall, as shown in figure 1, the unconditional growth models of WRAML-2 Story Recall and TAPS-3 Auditory Reasoning displayed differential patterns of growth in this sample of children and adolescents with ASD without ID. [figure 1 about here]

Narrative Retelling

Fit statistics for all models are presented in table 2. The unconditional linear model demonstrated good fit to the data. [table 2 about here] Unstandardized estimates are presented in table 3. The good fit of the linear specification indicated there were relatively equal amounts of growth between timepoints. The mean WRAML-2 Story Recall raw score for the latent intercept (TP1) was 24.99. However, the variance was statistically significant ($s^2 = 145.57$, $p < 0.001$), indicating there was variation around the mean of participants' initial scores on WRAML-2 Story Recall. The mean for the latent slope factor was 4.38, and this was statistically significant, indicating there was significant positive growth. Since this was a linear model, the latent slope factor score represents the average amount of growth between each timepoint. Thus, the average amount of total growth was 8.76. Additionally, the variance in the latent slope factor was not significant ($s^2 = 16.09$, p =0 .409), so participants demonstrated generally similar rates of growth.

[table 3 about here]

Inferencing

Initially, this model suffered from a modeling problem caused by a negative but non-significant slope variance. Since this value was not significantly different from zero, this parameter was fixed to zero, and the subsequent model ran successfully. The level and shape model fit the data well (see table 3), which demonstrated participants exhibited growth in TAPS-3 Auditory Reasoning scores between TP1 and TP2, but development plateaued thereafter. The mean TAPS-3 Auditory Reasoning score for the latent intercept was 7.44, which was significantly different from zero. There was significant variation ($s^2 = 17.57$, $p < 0.001$) around the mean. Since the level and shape model specified 0 and 1 for the first and last timepoints, respectively, 1.77 represents the total amount of average growth between the first and last timepoints. The factor scores for the second and third timepoints (1.06 and 1.00, respectively) were approximately equal, which indicates plateauing between timepoints two and three. The variance parameter for the latent slope factor was fixed to zero due to modeling problems, but we reiterate that when this parameter was estimated, it was not significantly different from zero.

Thus, this study assumed there was no variation in the latent slope factor indicating that participants demonstrated generally similar rates of growth.

Associations with ASD Symptomatology, Lexical-Semantic Knowledge, Age, and Reading Comprehension

Narrative Retelling

The conditional growth model suffered from a similar problem as the unconditional TAPS-3 Auditory Reasoning growth model. The residual variance for the slope parameter was fixed to zero (which was not significantly different from zero when the problem occurred), which corrected the error. Similar to the unconditional model, this model demonstrated good fit to the data (see table 4). Regarding the covariates predicting the latent intercept, ADOS-2 and WASI-II VCI were statistically significant. Participants with higher ADOS-2 total scores performed more poorly on TAPS-3 Auditory Reasoning at the first timepoint. Conversely, participants with higher WASI-II VCI scores also achieved higher scores on the WRAML-2 Story Recall latent intercept. There were no statistically significant differences in terms of age. With respect to covariates of the latent growth factor, none of the covariates were significant. Therefore, there were no differences in growth in WRAML-2 Story Recall that could be attributed to ADOS-2, WASI-II VCI, or age.

GORT-5 Reading Comprehension was modeled as a distal outcome regressed on both the latent intercept and latent slope. The latent intercept was the only significant predictor, such that participants with higher WRAML-2 Story Recall scores at the first timepoint scored higher on GORT-5 Reading Comprehension at the third timepoint. Therefore, while early scores on WRAML-2 Story Recall were predictive of later GORT-5 Reading Comprehension, the developmental trajectories of WRAML-2 Story Recall were not predictive of later GORT-5 Reading Comprehension. [table 4 about here]

Inferencing

The conditional TAPS-3 Auditory Reasoning model demonstrated good fit to the data (see table 4). Two of the three covariates of the latent intercept were statistically significant. Participants with higher WASI-II VCI scores and older participants scored higher on the TAPS-3 Auditory Reasoning latent intercept. ADOS-2 Total Scores were not statistically significant. None of the covariates significantly predicted the latent slope factor, indicating individual differences in the growth trajectories could not be attributed to ADOS-2 Total Scores, WASI-II VCI, or age. GORT-5 Reading Comprehension was regressed on both the intercept and slope. As with WRAML-2 Story Recall, only the latent intercept significantly predicted GORT-5 Reading Comprehension. Participants with higher TAPS-3 Auditory Reasoning scores at the first timepoint scored significantly higher on GORT-5 Reading Comprehension at the third timepoint. However, participants' individual differences in longitudinal TAPS-3 Auditory Reasoning trajectories were not predictive of GORT-5 Reading Comprehension.

Discussion

Prior research indicates that reading comprehension skills in individuals with ASD align with oral language skills, as well as ASD symptomatology and social communication impairments (McIntyre, Solari, Grimm, et al., 2017; Ricketts et al., 2013; Solari et al., 2019). Higher-order cognitive and linguistic comprehension skills such as narrative production and inferencing are linked to proficient reading comprehension and have been shown to be challenging for many individuals with ASD (Norbury & Bishop, 2002; Tirado & Saldaña, 2016). In this sample of children and adolescents with ASD without ID, narrative and inference skills displayed differential patterns of growth. Narrative retelling skills followed a linear trajectory of improvement and standardized means increased from performance in the below average range at TP1 to the average range at TP3, which is an encouraging finding. This growth was not observed for inference skills for which standardized means were more than one standard deviation below average at TP1 and declined further by TP3. Lexical-semantic knowledge explained significant heterogeneity in initial narrative and inference skills, while ASD symptomatology explained additional variance in initial narrative skills and age contributed to variance in initial inference skills. Finally, reading comprehension skills at TP3 were below average and were significantly related to TP1 narrative and inference skills in this sample. Each of these findings is discussed in more detail below.

Narrative Skills

Predicting Initial Narrative Retelling Ability

ASD symptomatology and lexical-semantic knowledge, but not age, were significantly associated with macro-structure level narrative retelling skills at TP1. The finding that greater ASD symptomatology negatively impacted initial narrative retelling skills is consistent with the notion that difficulties understanding social and communication norms may make perspective taking while reading narrative texts more difficult (e.g., McIntyre et al., 2018; Ricketts et al, 2013), and that therefore highly social texts are more difficult to comprehend than those with lower social content for children with ASD (Brown et al., 2013; Gately, 2008). Additionally, the social communication requirements of retelling a story for an audience include aspects of pragmatic language such as an awareness of listener interest, monitoring listener comprehension and re-wording when needed, and the appropriate use of nonverbal cues (Manolitsi & Botting, 2011). The social nature of the passages that participants were asked to retell, as well as the social demands of the testing environment, may have made this assessment more difficult for participants with greater levels of ASD symptomatology.

The finding that lexical-semantic knowledge was positively associated with concurrent narrative retelling abilities in this sample is consistent with prior research in TD samples (Johnston, 2008). Broader oral language abilities that also include syntax, morphology, and compositional semantics often display an atypical developmental trajectory in individuals with ASD (Eigsti et al., 2011; Tager-Flusberg, 2006). Together these skills have been shown to contribute to the ability to produce a coherent, high quality narrative, and narrative assessments demonstrate sensitivity to aspects of linguistic comprehension challenges in individuals with ASD (Botting, 2002). In prior studies with participants with ASD, lexical and structural language abilities have often been combined into an overall receptive and expressive language score or used to identify subgroups of participants with SLI, and they have been associated with narrative ability (e.g., Diehl et al., 2006; Manolitsi & Botting, 2011). However, this study provides new information about the role lexical-semantic knowledge alone plays in the macro-structure level narrative skills in children with ASD without ID. Interestingly, while children in the sample ranged in age from 8-16 years-old at TP1, age was not a significant covariate in these analyses after controlling for ASD symptomatology and lexical-semantic knowledge. The observation that strength and weakness in TP1 narrative retelling was associated with ASD symptom severity and lexical-semantic knowledge is consistent with the hypothesis that problems in narrative reading skills are associated with the autism phenotype.

Narrative Retelling Development

Difficulties with sequencing and describing causal relations between events may lead to difficulties moving from lower-level text base comprehension to the construction of a coherent situation model requiring inferences for students with ASD (Manolitsi & Botting, 2011). The students with ASD in this study significantly improved in their basic macro-structure narrative retelling skills over a 30-month period and individuals demonstrated similar growth rates over three timepoints, regardless of their initial raw scores. This is consistent with research in TD children indicating that children's narratives improve with age (Johnston, 2008). Furthermore, scaled scores indicated that the students made gains relative to the test's norming sample, moving from a low-average mean at TP1 to an average mean at TP3. These results indicate that on average, the students with ASD demonstrated more growth in the number of narrative details and events retold than their growth in age would predict. Having the foundational components required to construct a text base in memory can aid in answering explicit questions and summarizing texts (Snyder & Caccamise, 2010). While speculative, the growth observed in this sample could reflect their response to academic instruction and exposure to oral and written narratives in school and at home. As such, this is an encouraging result and may indicate that this is a strength upon which reading instruction can build.

Predicting Narrative Retelling Growth

Of interest in this sample is that neither age, initial lexical-semantic knowledge, nor ASD symptomatology was significantly associated with the growth rate of narrative retelling skills in this sample. This is notable because while we may assume that older children with milder ASD symptomatology and higher lexical-semantic knowledge skills might be better able to engage in the general education curriculum and potentially grow at a more accelerated rate than children with ASD and more extensive support needs, this study did not provide evidence of this. However, it may be necessary to include measures of the types and number of curricula and support the students are receiving in reading and language arts more broadly at school to more precisely examine the interactive role that education, ASD symptom severity, and lexical knowledge plays in the growth of narrative skills.

Relation of Narrative Retelling to Reading Comprehension

Narrative retelling at TP1 was a significant predictor of reading comprehension at timepoint 3. This was consistent with previous research that demonstrated that early abilities to understand story structure predicted performance on a later global assessment of reading comprehension skill that was independent of earlier comprehension skill in typical development (Oakhill & Cain, 2012; Perfetti, Landi, & Oakhill, 2005). Alternatively, there was no relation between the rate of narrative retelling growth and reading comprehension outcomes in this study. This may be due to the importance of initial narrative retelling status and that despite significant differences at TP1, there was a lack of significant variance in growth rates over time within the sample. This finding suggests that narrative retelling is an important skill to target in early elementary grades to improve reading comprehension for children with ASD.

Inference Skills

Predicting Initial Inference Ability

Lexical-semantic knowledge and age, but not ASD symptomatology, were significantly and positively associated with inference skills at TP1. While this study only tested one facet of oral language, the findings are generally consistent with studies which have reported that inference difficulties may not be a specific cognitive characteristic of ASD. For example, Bodner and colleagues (2015) reported their participants were able to make inferences about physical and mental states, particularly with increases in age and metalinguistic skill. Other studies have demonstrated that vocabulary, receptive grammar, and diagnosis of language impairment impact inferential processing and may be more important predictors than an ASD diagnosis (Lucas &

Norbury, 2015; Norbury & Nation, 2011); individuals with ASD who have well-developed language skills have not displayed an overall problem with inference but have demonstrated a particular difficulty with inferences about social information (e.g., Kaland et al., 2005). Difficulties understanding social and communication norms may make perspective taking and inferential processing while reading narrative texts more difficult even for individuals with ASD without ID (Brent et.al., 2004; Jolliffe & Baron-Cohen, 1999; McIntyre et. al., 2018; Ricketts et al., 2013). One reason for this might be that theory of mind, or the ability to recognize and understand the thoughts and feelings of oneself and others, is required in order to make inferences about others' emotional and cognitive states in social situations and narratives (Happé & Frith, 2006) and also has been shown to be impacted by oral language levels (Norbury & Bishop, 2002). This is finding is of particular importance, especially since many school-aged children and adolescents with ASD have oral language deficits (e.g., Eigsti et al., 2011).

Inference Development

Students with ASD demonstrated growth in their inference raw scores between TP1 and TP2, but development plateaued after that regardless of their initial raw scores. Furthermore, scaled scores indicated that relative to same-age peers in the assessment's norming sample, their performance declined over time. On average students were performing 1.33 standard deviations below the norming sample at TP1 but were 1.54 standard deviations below the norming sample by TP3. Consistent with prior research, explicating knowledge-based inferences and answering questions about inferences was difficult for many in this sample (le Sourn-Bissaoui et al., 2009; Tirado & Saldaña, 2016; Wahlberg & Magliano, 2004).

Predicting Inference Growth

Similar to narrative retelling, in this sample none of the covariates were significantly associated with the growth rate of inference skills in this sample, indicating that individual differences in the growth trajectories could not be attributed to initial age, lexical-semantic knowledge or ASD symptomatology.

Relation of Inference to Reading Comprehension

Inference skill at TP1 was a significant predictor of reading comprehension at TP3 indicating that students in this sample with higher initial inferential ability scored significantly higher on a global reading comprehension assessment 30 months later. This is consistent with longitudinal research with elementary school-age readers without ASD who demonstrated that their ability to answer inferential questions predicted performance on a later global assessment of reading comprehension (Oakhill & Cain, 2012; Perfetti, Landi, & Oakhill, 2005). However, there was no relation between the rate of inference growth and later reading comprehension outcomes. Since this sample demonstrated little to no growth on the inference measure, and there was not significant variation in this pattern within the sample, it provides evidence that, as with narrative retelling, inference is an important skill to target in early elementary grades to improve reading comprehension for children with ASD.

Implications for Practice

Returning to the Construction-Integration Model, this study provides evidence that reading comprehension subskills in children and adolescents with ASD without ID may be conceptualized at differing levels of text representation. Narrative retelling skills were stronger than inference skills initially, and also demonstrated a different growth pattern. The significant growth in macro-structure narrative retelling skill is encouraging and indicates that, at least for students with stronger lexical knowledge and lower ASD symptomatology, text base level representation of narrative texts can be a relative strength upon which to build. Reading instruction and supports focused on lower-level processing of the information explicitly stated in the text (e.g., lexical-semantic knowledge and story grammar elements), can solidify foundational understanding of narrative texts (e.g., Stringfield et al., 2011; Whalon et al., 2019).

In addition, developing the ability to make bridging inferences to link pronominal referents to the correct person or object and to connect adjacent phrases and paragraphs will improve construction of a coherent text base. However, while necessary, this is not sufficient for the deepest level of comprehension wherein a situation model is created through the integration of the text base with one's background knowledge utilizing knowledge-based inference skills. Evidence from this sample as well as other studies indicates this is a particular challenge for students with ASD (e.g., Wahlberg & Magliano, 2004). For some readers, a lack of well-connected social and perceptual background knowledge, a common impairment for individuals with ASD, may impact their ability to construct the knowledge-based inferences required for the creation of a situation model of a narrative text (Wahlberg & Magliano, 2004), so priming of relevant background knowledge is a key component of effective reading instruction. Furthermore, the significant relation between lexical-semantic knowledge and inference skills in this sample supports the notion that providing continued and targeted language interventions such as those that address developing the depth and breadth of vocabulary may positively impact inference skill development that is central to comprehension (Lucas & Norbury, 2015).

Limitations and Future Directions

There are several limitations to the current study that can be addressed in future research. To begin, one limitation of this study is the large age range. While we controlled statistically for age in these models and used age-normed assessments, future work should look at development within narrower age bands to better inform assessment and intervention in primary, upper-elementary, middle school and high school settings.

Next, this study relied on age-normed standardized measures of lexical-semantic language, narrative, and inference skills due to the wide age range and longitudinal nature of the project. However, this limits interpretation of the results and future research should utilize measures that permit a more fine-grained investigation of each of these constructs over time. Also, assessments that control for potential learning effects that might occur with repeated measurement are an important consideration. This study only included one facet of oral language: word level lexical-semantic skills. Future work should use a greater variety of expressive and receptive language measures that include structural language skills, as well as pragmatic skills, to examine the unique role each aspect of language plays in narrative, inference and reading comprehension skills for students with ASD. For example, if weak structural language skills affect inference skills, it is important to distinguish between children with ASD who have impaired structural language skills (ALI) and children with ASD with normal structural language (ALN; Norbury & Nation, 2011). Then if children with ASD do not have impaired structural language (ALN) but still have problems with inferencing, another source should be looked for. Having a larger battery of language measures would also inform the assessment and intervention work of interdisciplinary school teams (e.g., speech-language pathologists, special education teachers, and reading specialists).

Future research should utilize narrative assessments that allow for more in-depth coding of macro-and micro-structure level skills to better capture strengths and weaknesses in this population of students and might be more sensitive to growth. Linking narrative skills to structural language and reading comprehension in this population using a measure that assesses the cohesiveness, chronology, or causal relations of the narratives, can contribute to our understanding of the overall structure and quality of narratives in students with ASD and how it might compare to typically developing peers in the relation to reading development.

There are several areas of investigation that warrant attention with regard to understanding the relation of inference development and reading comprehension for students with ASD without ID. The inference measure used in this study was a general test of inference and idiom skills, so more targeted inference skill assessments would enable finer-grained analyses that might be more sensitive to change, especially at different ages. In addition, future research should investigate the factors surrounding storing, activating, and integrating background knowledge in order to better understand the cognitive underpinnings of inference difficulties experienced by school-aged children with ASD. Extant research indicates that difficulty suppressing irrelevant knowledge is a substantial problem for some readers with poor comprehension (Gernbacher & Faust, 1991; Rosen & Engle, 1997). However, it is not clear if this is due strictly to an inability to suppress irrelevant information or because these poor comprehenders lack well-connected knowledge networks that facilitate efficient information retrieval (Kendeou et al., 2014). While ASD symptomatology as measured by the ADOS-2 was not significantly associated with inference skills in this sample, restricted interests can limit the breadth of background knowledge in long-term memory (Broun, 2004) and if you have little or no experience with the content of a passage, it is difficult to answer inferential questions (Leslie & Caldwell, 2010). Inference generation also requires the coordination of many cognitive processes including executive function skills such as self-regulation, metacognition, attention, and working memory (Cain & Oakhill, 2008; Graesser et al., 1994; Singer et al., 1992). The generation of inferences requires deeper levels of processing and memory research has shown that deeper levels of processing lead to higher levels of retention and better retrieval (e.g., Craik & Lockhart, 1972). Future research should investigate the development of these cognitive processes in children and adolescents with ASD in order to probe the factors underlying their inferential processing challenges.

Collectively, this information will contribute to the development of reading comprehension strategies and curricula targeted to the social communication and cognitive phenotype of individuals with ASD.

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Table 1

Descriptive Statistics

Measure	*M (SD)*
Diagnostic (TP1)	
ADOS-2 Total Score	10.94 (3.65)
Cognitive (TP1)	
FIQ[b]	95.91 (15.01)
VCI[b]	104.68 (16.02)
PRI[b]	100.01 (14.31)
Age (Years)	
TP1	11.24 (2.19)
TP2	12.55 (2.10)
TP3	13.74 (2.12)
Narrative Retell (Raw Score)	
TP1	25.05 (14.57)
TP2	28.63 (15.11)
TP3	33.37 (14.64)
Narrative Retell (Scaled Score)[a]	
TP1	7.94 (3.31)
TP2	8.46 (3.70)
TP3	9.11 (3.14)
Inference (Raw Score)	
TP1	7.44 (5.22)
TP2	9.21 (5.78)
TP3	9.02 (6.01)
Inference (Scaled Score)[a]	
TP1	6.04 (2.77)
TP2	5.91 (2.66)
TP3	5.38 (2.71)
Reading Comprehension (TP3)	
Raw Score	34.11 (12.78)
Scaled Score[a]	7.77 (2.96)

[a]Scaled score, M=10, SD = 3. [b]Standard score, M = 100, SD = 15. TP = timepoint. Cognitive = WASI-II; Narrative Retell = WRAML-2 Story Recall; Inference = TAPS-3 Auditory Reasoning; Reading Comprehension = GORT-5 Reading Comprehension.

Table 2

Fit Statistics for All Models

Model	χ^2	*df*	*p* value	CFI	TLI	RMSEA [CI]	SRMR
Unconditional Narrative Retelling	0.01	1	0.909	1.00	1.00	0.00 [0.00-0.12]	0.00
Unconditional Inferencing	0.24	2	0.886	1.00	1.00	0.00 [0.00-0.10]	0.02
Conditional Narrative Retelling	12.78	10	0.236	0.98	0.97	0.06 [0.00-0.14]	0.05
Conditional Inferencing	10.84	9	0.287	0.99	0.98	0.05 [0.00-0.15]	0.04

Note. CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual. Narrative Retelling = WRAML-2 Story Recall; Inferencing = TAPS-3 Auditory Reasoning.

Table 3

Parameter Estimates for the Unconditional Models

	Narrative Retelling			Inferencing		
Parameter	Estimate	*SE*	*p*	Estimate	*SE*	*p*
Means						
Intercept	24.99	1.60	< 0.001	7.44	0.57	< 0.001
Slope	4.38	0.82	< 0.001	1.77	0.67	0.009
Variance						
Intercept	145.57	44.70	0.001	17.57	3.78	< 0.001
Slope	16.09	19.49	0.409	N/A[b]	-	-
Factor Loadings for Latent Growth Factor						
TP1	0.00[a]	-	-	0.00[a]	-	-
TP2	1.00[a]	-	-	1.06	2.39	0.017
TP3	2.00[a]	-	-	1.00[a]	-	-
Structural Parameter						
Intercept & Slope Covariance	-8.04	23.62	0.73	N/A[b]	-	-

Note. All estimates are unstandardized. [a]Fixed values. [b]Fixed to 0 due to modeling problems. TP = timepoint. Narrative Retelling = WRAML-2 Story Recall; Inferencing = TAPS-3 Auditory Reasoning.

Table 4

Parameter Estimates for the Conditional Models

	Narrative Retelling			Inferencing		
Parameter	Estimate	*SE*	*p*	Estimate	*SE*	*p*
Means						
Intercept	24.99	1.30	< 0.001	7.43	0.49	< 0.001
Slope	4.21	0.77	< 0.001	1.34	0.62	0.03
Residual Variance						
Intercept	63.85	16.57	< 0.001	5.59	1.84	0.00
Slope	N/A[b]	-	-	N/A[b]	-	-
Factor Loadings for Latent Growth Factor						
TP1	0.00[a]	-	-	0.00[a]	-	-
TP2	1.00[a]	-	-	1.49	0.54	0.006
TP3	2.00[a]	-	-	1.00[a]	-	-
Structural Parameters						
Intercept & Slope Covariance	N/A[b]	-	-	N/A[b]	-	-
Intercept Covariates						
ADOS-2	-1.26	0.32	< 0.001	-0.08	0.14	0.576
VCI	0.44	0.09	< 0.001	0.12	0.03	< 0.001
Age	1.08	0.63	0.088	0.55	0.24	0.023
Slope Covariates						
ADOS-2	0.06	0.06	0.377	-0.13	0.1	0.179
VCI	-0.04	0.03	0.244	0.06	0.03	0.071
Age	-0.35	0.37	0.353	0.30	0.18	0.108
GORT-5 Distal Outcome						
Predicted by Intercept	0.40	0.19	0.034	1.98	0.66	0.003
Predicted by Slope	-6.30	7.12	0.376	3.75	2.05	0.067

Note. All estimates are unstandardized. [a]Fixed values. [b]Fixed to 0 due to modeling problems. TP = timepoint. Narrative Retell =

WRAML-2 Story Recall; Inference = TAPS-3 Auditory Reasoning. VCI = Verbal Comprehension Index, WASI-II; GORT-5 Reading Comprehension.

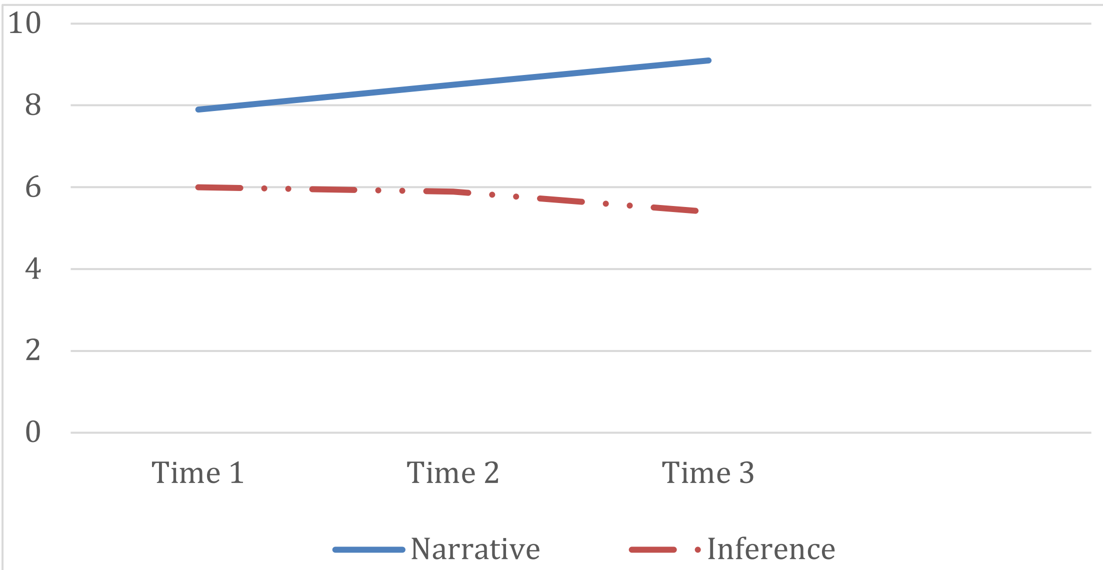

Figure 1. Growth patterns for narrative and inference scaled scores in the ASD sample.