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Addressing the development of reading comprehension in students with ASD: a meta-analysis

by

Halley Eacker

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Abstract

The purpose of this study was to synthesize findings from single-case intervention studies on developing reading comprehension in students with autism spectrum disorders (ASD). A multi-level analysis was used to determine if there was an overall statistically significant effect of these interventions and if the effect was consistent across studies and participants. Results indicated a significant change in trend throughout the intervention phase across studies. Age had a significant impact on the intervention effect. The remaining moderators – study type, design, and quality – were not significant. Implications for practitioners and researchers, as well as considerations for future research are discussed.

Keywords: autism spectrum disorders, literacy, reading, reading comprehension, text comprehension, single case methodology, special education
Introduction

Reading is a multidisciplinary, functional skill that has relevance at home, work, and in the community. The ability to read and comprehend texts is paramount to cognitive and social development and impacts all areas of academic achievement. Social and cultural knowledge is often imparted through reading and discussing texts, facilitating the development of perspective-taking and empathy. Through reading, children acquire knowledge needed to navigate and thrive in their world.

For those diagnosed with autism spectrum disorder (ASD), reading may be an area of difficulty. ASD is a developmental disorder characterized by differences in social communication and interaction, repetitive or patterned behavior, and restricted interests (American Psychiatric Association, 2013). The disorder is detected by observation of developmental delays, particularly in receptive and expressive language, oral language and vocabulary (Kwok et al., 2015). Further, individuals with ASD differ in how they perceive, understand, and engage in social interaction. This is often observed as a lack of eye contact or challenges interpreting neurotypical thoughts and emotions, including sarcasm or figurative language (Boutot, 2017). These characteristics can impact the way texts are heard, seen, read, and interpreted. A strong understanding of neurotypical social behaviors and norms for thinking and interacting is also needed, but often still developing, in young readers with ASD. Thus, texts can become challenging to access for readers with ASD.

Learning Characteristics in ASD

Core symptoms and associated features of ASD present benefits and challenges to students’ learning. In the classroom, students with ASD have strengths in the areas of rote memory and processing visual information (Fleury et al., 2014). They are routine-oriented and
often have a strong attention to details or selected areas of interest (Frith & Happe, 1994). However, students with ASD may need support in to plan and initiate complex tasks, set and monitor goals, and summarize (Fleury et al., 2014).

Three cognitive theories are often utilized to explain the learning characteristics of ASD: theory of mind (ToM), executive dysfunction, and weak central coherence (Rajendran & Mitchell, 2007). Theory of mind (ToM) refers to one’s ability to interpret and understand the beliefs and emotions of oneself and others (Wimmer & Perner, 1983). Past research has suggested individuals with ASD have an impaired theory of mind (Baron-Cohen et al., 1989). However, this viewpoint is often contested in the autistic community, who note that there is an equal lack of understanding by neurotypical individuals of the autistic experience – known as the double-empathy problem (Milton, 2012). Instead, the current perspective highlights neurological differences occurring in areas of the brain responsible for socio-cognitive ability (Schaafsma et al., 2015). This can impact the development of social-emotional skills and competencies that underlie communication and interaction, such as self-awareness and perspective-taking (Bang et al., 2013; Begeer et al., 2010; Loth et al., 2008). Research indicates ToM can affect a student’s academic performance, particularly in the area of literacy (Carnahan et al., 2011).

These same neurological differences are also explored in research on indicators of executive functioning (O’Hearn et al., 2008). Executive functioning skills include an individual’s ability to plan, anticipate, organize, predict, and regulate (Diamond, 2013). Autistic individuals present difficulties in areas of executive functioning, but can retain abilities in response inhibition and working memory (O’Hearn et al., 2008). Research suggests executive functions improve in autistic individuals from childhood through adolescence, but plateau in early adulthood (Rosenthal et al., 2013). In ASD, executive functioning skills are related to
performance on measures of language ability, specifically comprehension (Weismer et al., 2018). Executive functioning skills are also related to performance on measures of language ability and comprehension (Weismer et al., 2018). Recent research highlights the relationship between executive functioning and the development of reading comprehension skills in ASD, but indicates more studies are needed in this area (Davidson, 2021).

Last, the central coherence theory frames characteristics of autistic individuals as a cognitive style (Happe & Frith, 2006, p.5). Local and global processing abilities vary across typically developing and autistic children and no “single processing style unites individual patterns of performance” (Pellicano et al., 2006, p. 95). Theories of weak central coherence (WCC) suggest autistic individuals excel on tasks that require local processing, focusing on details rather than integrating details to form an understanding of a global theme (Frith & Happe, 1994).

These core, cognitive characteristics affect the development of reading comprehension skills in ASD (Lucas & Norbury, 2014). This is supported by prior research that cognitive functions such as working memory, executive function, retrieval, motivation, and coherence are essential to understanding texts for students with disabilities (Watson et al., 2012).

**Reading Ability in ASD**

Students with ASD perform below their same-age peers in the area of reading, facing difficulty with a range of tasks and skills (Brown et al., 2013). In a national study, researchers found children and youth (ages 3-17) with ASD typically score lower on standardized measures of reading, particularly in the areas of comprehension and phonemic awareness (Nally et al., 2018). Despite these general conclusions, reading skills vary considerably among children with ASD (Nation et al., 2006). Some young readers with ASD display age-appropriate skills in letter
naming and decoding, but struggle in comprehension (Huemer & Mann, 2010; Wei et al., 2014). Others may show difficulty decoding with non-words (Nation et al., 2006). Certain students with ASD may be able to retrieve information from the text if given the exact language or wording used but need support to interpret underlying meaning (e.g. figurative language and thematic elements) (Gately, 2008). Strengths in visual processing in ASD are beneficial in the early stages of literacy when the reader is focused on decoding the text. However, as students age, they move from learning to read to reading to learn. Difficulties with comprehension may be attributed to socio-cognitive differences in ASD, in that texts require the reader to interpret characters’ actions, understand author’s purpose, and take a perspective. Central coherence, which includes an emphasis on details in lieu of the bigger picture—may also play a key role in the development of reading skills. The thinking style of ASD may impact a student’s ability to interpret the larger meaning or “gist” of a text, draw connections across texts and to life experience, and interpret symbolic elements or allegory in a narrative (Carnahan et al., 2011).

A variety of developmental factors can contribute to reading comprehension ability in ASD, including oral language and word recognition (Ricketts et al., 2013). When controlling for these factors, measures of social behavior and social cognition may predict reading comprehension (Ricketts et al., 2013). Differences in reading ability are also associated with the severity of ASD symptoms (McIntyre et al., 2017). Individuals with more severe symptoms had lower language scores than typically-developing peers, specifically in the areas of vocabulary and word reading (Nally et al., 2018).

Previous research suggests decoding ability and semantic knowledge are the most significant predictors of a child with ASD’s ability to understand a text (Brown et al., 2013). In individuals who are labeled “high functioning,” fluency is also a predictor of reading
comprehension (Solari et al., 2017). Altogether, it appears that both the child’s fluency with letters and sounds, as well as experiences and prior knowledge, contribute to success in reading.

**Approaches to Addressing Reading Comprehension in Youth with ASD**

Several prior reviews were conducted on approaches to improving reading comprehension skills in students with ASD (Chiang & Lin, 2007; El Zein et al., 2014; Finnegan & Mazin, 2016; Senokosoff, 2015; Singh et al., 2020; Whalon et al., 2009). Research in this area has seen significant developments in the last decade. Although studies on this topic date back to 1980, the majority were published after 2010. Findings from this body of research are summarized in the paragraphs that follow.

Chiang and Lin (2007) reviewed 11 studies focusing on reading comprehension instruction for students with ASD and found they could acquire reading skills with the support of classroom interventions. Studies were included if they included at least one participant with autism and presented an experimental design examining the effect of an intervention targeting sight word or text comprehension for a functional and/or academic purpose. Visual aids and computer-based instruction demonstrate preliminary effectiveness to develop comprehension in ASD. Authors noted the relevance and importance of the National Reading Panel and research with other disability groups on the types of interventions investigated in ASD. However, in future research, it is the characteristics and thinking style of ASD that should inform the selection and implementation of interventions for autistic students, in addition to strategies that can facilitate inclusion in the general education environment (Chiang and Lin, 2007).

A later review by Whalon et al. (2009) also investigated reading instruction for students with ASD. Studies in this review were peer-reviewed, included at least one student with ASD, and tested the effectiveness an intervention on important literacy skills. Unlike Chiang and Lin
(2007), this review did not include sight word comprehension. Eleven studies were categorized as code-focused, meaning-focused, or multicomponent interventions. Whalon and colleagues concluded that students with ASD can improve their performance with interventions that target the five components of evidence-based reading instruction (e.g. phonemic awareness, phonics, fluency, vocabulary, and comprehension). The authors noted the heterogeneity of autism and the importance of providing detailed participant characteristics to allow practitioners and researchers to understand for whom the intervention is most effective. Suggestions for future research include ongoing examination of the impact of comprehensive reading instruction and also investigate the effect of the intervention(s) on language, social communication, and engagement (Whalon et al., 2009).

El Zein et al. (2014) conducted a review of 12 studies on the topic of reading comprehension in K-12 students with ASD. Like previous reviews, authors included studies of all methodological designs from peer-reviewed journals. Unlike previous reviews, this inclusion criteria stated papers must incorporate a dependent measure of reading comprehension; studies exploring listening comprehension, word meaning, or behavioral outcomes were not included. Treatments were organized in the following categories: Strategy Instruction, Anaphoric Cueing, Explicit Instruction, and Student Grouping Practices. El Zein et al. (2014) confirmed the findings from previous reviews: with support, students with ASD demonstrate improvements in reading comprehension. At this time, there was an increased focus on the quality, rigor, and consistency of research designs. As research on the topic began to accumulate, the limits of using researcher-developed measures in the interpretation and generalization of findings became clear. In addition, emerging practices including strategy development and technology began to appear in the literature. El Zein and colleagues encouraged the combined use of instructional techniques
(e.g. explicit instruction) with other practices, such as behavioral strategies. Researchers continued to highlight a critical issue on this topic: more evidence is needed on the theoretical explanations of reading comprehension difficulties in ASD to guide the design and implementation of interventions.

A broader review was conducted in Senokosoff (2015), focusing on both reading difficulties and strategies for addressing reading comprehension in ASD. Thirty-eight studies were included in the review representing literature published from 1999-2012 with students with high-functioning autism (HFA), Asperger’s syndrome, or ASD. Results pointed to specific strategies for students with HFA, indicating that strategic approaches to questioning and inference were effective (Senokosoff, 2015). This review captured the complexity of reading comprehension and the importance of addressing cognitive components and multiple skill areas. Further, the implications of the article highlighted the growing need for research in this area, in addition to high-quality professional development for teachers in how to implement the practices in their classrooms (Senokosoff, 2015).

Finnegan and Mazin (2016) reviewed 15 studies on reading comprehension strategies in ASD. Consistent with more recent papers, studies that focused on listening comprehension, social skills, vocabulary, or early literacy skills (e.g. oral reading fluency, sight words, decoding) were again excluded. Results indicated the effectiveness of interventions varies across studies (Finnegan & Mazin, 2016). Direct Instruction (DI) and graphic organizers showed more significant effects, with mixed effects from cooperative learning, and more research needed on anaphoric cueing and questioning strategies. The authors also noted the use of e-Texts was not effective without teacher-led instruction. Several unique implications were highlighted for future research and practitioners. Interventions must be readily available, low cost, and practical for the
classroom context and demonstrated need of the student(s). Researchers should address generalization of skills or strategies, conduct studies in languages other than English, include measures of social validity, and consider evaluating the impact on social and behavioral outcomes (Finnegan & Mazin, 2016).

The most recent review was completed by Singh et al. (2020). Unlike prior reviews, the paper focused solely on studies utilizing single-case research designs. Further, in addition to exploring the specific practices that have been utilized to address reading comprehension in ASD, Singh and colleagues also evaluated methodological quality and rigor using the What Works Clearinghouse (WWC) guidelines. The authors examined the treatment effect (Percentage of Data Points Exceeding the Median, or PEM) across all studies, concluding that the most effective practices were visually-cued instruction and strategic interventions. Moderate effect sizes were noted for grouping strategies and technology-assisted instruction and more research is needed on adapted texts and behavioral approaches (Singh et al., 2020). Similar concerns were noted regarding the use of researcher-created, non-standardized measures of reading comprehension. Task elements (i.e. materials and procedures) were also highlighted as important considerations for practitioners and researchers, demonstrating an increased emphasis in this body of research on the ability to interpret and generalize findings across studies.

Overall, prior syntheses of this research have varied in content and focus. Authors examined research-based methods for teaching (Chiang & Lin, 2007; Senokossoff, 2016; Whalon et al., 2009) and interventions implemented to improve (Finnegan & Mazin, 2016; Singh et al., 2020; El Zein et al., 2014) reading comprehension in students with ASD. The inclusion of sight word and listening comprehension was not consistent across reviews, nor the categorical structures that differentiate between code-focused, meaning-focused, and multicomponent
studies (Whalon et al., 2009). While some papers included sight word comprehension, listening comprehension, or fluency, other papers focused solely on reading comprehension (Finnegan & Mazin, 2016; Singh et al., 2020; El Zein et al., 2014). Increased emphasis has been placed on outcomes of reading comprehension (i.e. extracting meaning from a text) and less on early literacy skills. Broad inclusion criteria in regard to methodological design was utilized across almost all reviews, with the exception of Singh et al. (2020).

The following intervention strategies are highlighted by this research: Direct Instruction (DI), peer learning (e.g. Cooperative Learning, peer tutoring), technology-based instruction or intervention, behavioral training, use of a graphic organizer, shared reading, strategic interventions (e.g. Question-Answer Relationships, question generation), and anaphoric cueing. In sum, studies indicate learners with ASD may improve their reading comprehension skills as a result of instruction or intervention using these methods; however, the overall effectiveness of the practices across studies is unclear (Chiang & Lin, 2007; El Zein et al., 2014; Finnegan & Mazin, 2016; Senokosoff, 2015; Whalon et al., 2009; Singh et al., 2020).

**Moderators of Interventions Addressing Reading Comprehension in Youth with ASD**

**Age.** Age is a predictor of performance in reading for students with ASD, specifically in the area of comprehension (Davidson et al., 2018). For students with high-functioning ASD, reading comprehension skills continue to develop into the teenage years (Grimm et al., 2017). Individuals with ASD can demonstrate deficits in linguistic processing and inferencing into adulthood (Joliffe & Baron-Cohen, 2000). Although it is not clear whether autistic individuals present a delay or deficit in this area, this may depend on severity of autism symptoms (Nally et al., 2018). Age was included as a moderator in the analysis to determine if variability in intervention effectiveness is due to the age of the student.
**Single- vs. Multi-Component.** The core symptoms and associated features of ASD indicate the need for a specially-designed classroom environment. Effective learning environments for students with ASD are characterized by structure, a well-defined scope and sequence of curricula, systematic and specially-designed instruction, social/behavioral supports, and opportunities for practice and generalization (Iovannone et al., 2003; Spencer et al, 2014). To support the development of reading comprehension skills, the use of multiple instructional techniques, behavioral approaches, and the use of technology is recommended in past research (Cravalho et al., 2020). Various instructional or management techniques and classroom supports may be needed to model, teach, and reinforce the intervention. Prior reviews identified the prospect of layering methods or practices within an intervention (Whalon et al., 2009). A multicomponent approach, referring to the presence of one or more practices in a single study, may be appropriate for the treatment and population. Therefore, intervention type (Single or Multi-Component) may provide insight to suggest whether or not intervention packages with layered techniques have an increased effect on student outcomes.

**Study Quality.** The What Works Clearinghouse has established standards to evaluate the quality and rigor of studies using single case designs. The What Works Clearinghouse Standards Handbook (Version 4.1) identifies key features of single case designs and a process for determining a study rating. Ratings provided in this framework are:

1. Meets WWC SCD Standards Without Reservations
2. Meets WWC SCD Standards with Reservations
3. Does Not Meet WWC SCD Standards

Prior reviews on reading comprehension interventions for students with ASD have highlighted methodological rigor as a limitation of the current body of research. Studies vary considerably in
their measurement design, treatment fidelity measures, context of reading activities, and experimental control (Whalon et al., 2009; El Zein et al., 2014). Assessing the quality and rigor of single case designs is important to the synthesis of research on reading comprehension in ASD (Singh et al., 2020).

**Study Design.** The use of different study designs may introduce variability and influence comparisons of results across single-case studies. Study design can impact the context of the treatment delivery, specifically for students with ASD. For example, alternating treatment designs utilizing different intervention approaches simultaneously may produce a blended or combined effect of multiple interventions and may have a unique impact as compared to designs exploring a single intervention. Reversal/withdrawal designs where the treatment is introduced and then removed may have a different impact on students who thrive in consistency and predictability, such as in ASD. Previous reviews on reading comprehension in ASD have noted that effect sizes from different designs should be interpreted with caution (Finnegan & Mazin, 2016). However, more rigorous quantitative methods may be useful to understand and synthesize findings across studies.

**Rationale for the Study**

Special education is an ever-growing and evolving field. Continued analysis of existing practices is necessary to confirm previous findings, as well as identify promising and best practices for practitioners to utilize in the classroom. Prior reviews suggest the effectiveness of approaches targeting reading comprehension in ASD varies across studies. However, additional research on new and existing practices has not been reflected in prior and recent reviews. Further, no meta-analysis has been conducted to date on single-case studies targeting reading comprehension in ASD. Therefore, a more in-depth analysis of this research is needed. Results
will not only clarify the overall effectiveness of these interventions, but indicate the variability in effect based on participant and study variables.

The purpose of this study is to evaluate the effectiveness of interventions targeting reading comprehension in ASD using single case designs, identify factors that contribute to the effectiveness of these treatments, and evaluate the quality of the research to determine areas of improvement for methodology. This meta-analysis will utilize the What Works Clearinghouse Standards Handbook 4.1 procedure for applying SCD standards to evaluate the design and evidence for the included studies (What Works Clearinghouse, 2020). The current study builds on prior research by including updates to the literature through the year 2020, encompassing new studies and approaches to be considered. Using this information, the range and scope of practices will be used to determine implications and next steps for future research.

**Research Questions**

This study aims to address the following research questions:

1. Is there an overall statistically significant effect of interventions addressing reading comprehension in students with ASD?

2. Is the effectiveness of the intervention consistent across studies and participants?

3. If there is variability, can this be explained by moderators such as participant age, intervention approach (single- or multi-component), study design, or study quality?
Methodology

Search Procedure

This paper investigated single-case data within studies targeting outcomes of reading comprehension for students with ASD. The search was completed using the following databases: Academic Search Complete, Education Source, Education Resource Information Center (ERIC), and Psychology and Behavioral Sciences Collection. Databases selected were consistent with prior reviews, widely used in the field of education, and represent major journals impacting autism research, such as the Journal of Autism and Developmental Disorders, Research in Autism Spectrum Disorders, or Teaching Exceptional Children. The primary aim of the search was to locate single-case studies exploring the effect of a school-based intervention on reading comprehension in students with ASD. Key terms used to complete the search were selected to represent the target population (“autism,” “Asperger,” or “PDD-NOS”) and the relevant skill and content area (“reading comprehension” or “reading intervention”). All combinations of terms were searched. An ancestry search was also conducted to locate articles not generated by the key search terms, including examining articles from previous meta-analyses and reviews.

Inclusion and Exclusion Criteria

Two independent researchers examined the articles using the established inclusion and exclusion criteria. Studies were included if they were published in peer-reviewed journals from 1985 - present (2021), consistent with previous reviews. Selected studies must have included at least one participant diagnosed with ASD. Individuals with Asperger Syndrome and PDD-NOS were included to reflect recent changes to the DSM-5, including all of these diagnoses under “Autism.” Studies must have included participants that are school-age (Grades K-12) and a measure of reading comprehension. Studies that focused on listening comprehension were
excluded, consistent with prior reviews on this topic (Finnegan and Mazin, 2016; Singh et al., 2020). Articles utilizing group designs or randomized controlled trials or designs other than single-case methodologies were excluded from the meta-analysis. Studies utilizing multiple probe designs were included if the experiment had at least three observations in each phase. Only studies from peer-reviewed journal articles were selected. Dissertations were not included to focus solely on interventions that were published in peer-reviewed journal articles, as educators often rely on this evidence-base to make decisions about what practices to use in their classrooms.

**Coding of Study Variables**

When the final list of included articles was determined, the author trained an independent researcher (a doctoral student at the same university) in the coding protocol for extracting important information from the studies. The two researchers coded several variables. First, basic information about the article were retrieved, including the authors’ names, year published, and total n. Then, the following independent variables were recorded. Participant demographic information was coded, including age (years), Grade, Gender (M/F), and diagnosis (ASD, PDD-NOS). The treatment was specified, as well as if it were single- or multi-component (see definitions below). In addition, the single-case methodology, interventionist, and outcome measure(s) of reading comprehension were coded. The variables were selected in consistency with prior reviews and for their importance to understanding the conditions and context of the treatment delivery. Last, the number of baseline observations, treatment sessions, and maintenance sessions were recorded. What Works Clearinghouse standards were applied to determine the quality of the included studies (What Works Clearinghouse, 2020).
Dependent Variables

Outcome measures of reading comprehension were the dependent variable of interest in the meta-analysis. Measures vary between a curriculum-based measure (CBM), standardized assessment (i.e. Woodcock Johnston-III), or set of tasks (e.g. retelling, comprehension questions). Measures of decoding accuracy, fluency, or phonological/morphological awareness were not analyzed in this study. Although related, they do not target students’ interpretation or understanding of the text. This is consistent with recent, prior reviews on this topic (Finnegan & Mazin, 2016; Singh et al., 2020).

Moderators

Age of participant. Continuous predictor

Single-case design. The design utilized in the study was coded as a nominal variable, as follows: (0) Multiple baseline design, (1) Multiple probe design, (2) Alternating treatment, and (3) Reversal/Withdrawal.

Study quality. Ratings according to WWC standards were also coded as a nominal variable: (0) Meets WWC Standards without Reservations, (1) Meets WWC Standards with Reservations, and (2) Does Not Meet WWC Standards.

Treatment Approach. Treatment approach, or Type, was coded as (0) Single-component or (1) Multi-component. Single component interventions were those that employed a single treatment approach (e.g. Direct Instruction). Multi-component interventions utilized an array of practices within a treatment package. For example, studies may have investigated a treatment package that included Direct Instruction as well as a graphic organizer and behavioral supports, which was considered separate treatments and studied individually.
Data Extraction

WebPlotDigitizer was used to extract the single-case data on all outcomes of reading comprehension from the studies (Rohatgi, 2011). WebPlotDigitizer is a data retrieval program that is free for use and reliable in obtaining needed data from graphs and visuals (Moeyart, Maggin, & Verkuilen, 2016). Using WebPlotDigitizer, each data point in the graph is selected and program identifies the coordinate values (x,y), where x is the independent variable (time) and y is the dependent variable (e.g. CBM score). Extracted raw data was exported to an Excel file to be used for data-analysis. To ensure that the data was appropriately extracted, a second and separate rater utilized WebPlotDigitizer to extract 20% of data from included studies. Data from first- and second raters was compared to evaluate inter-rater reliability. Using Lin’s Concordance coefficient, a calculation of percentages of agreement was made. Lin’s Concordance coefficient is appropriate when coding a continuous variable (Lin, 1989). Inter-rater reliability was high according to this measure ($\rho_c = .99$).

Data Analysis

In single-case studies, measurement occasions are nested within participants, nested within studies in a hierarchical nature. Therefore, a multi-level model is appropriate to analyze data across studies included in this meta-analysis (Kratochwill et al., 2010; Moeyaert et al., 2013; Van den Noortgate & Onghena, 2003a, 2003b). A multi-level model can provide an estimate of the treatment effect and trend over time. Multi-level modeling can also be utilized to determine between-case and between-study variability and if this variability in effect can be explained by moderating variables. In this study, the average treatment effect and average effect over time on outcomes of reading comprehension was explored. The moderators Age, Design, Type, and
Quality were added to the model to explain variability between cases and studies. An introduction to the basic model and interpretation of parameters is provided below.

**First-Level.** Equation (1) demonstrates the estimate of the treatment effect for one participant in a single-case design. At the first level, outcome $\gamma_i$ for observation $i$ is regressed on $\beta_1 \text{Phase}_i$, a dummy coded variable that is a “0” during baseline and “1” during treatment. In the equation, $\beta_0$ represents the baseline level and the treatment effect is captured by $\beta_1$.

$$\gamma_i = \beta_0 + \beta_1 \text{Phase}_i + e_i \sim N(0, \sigma_e^2) \ (1)$$

To estimate the change in effectiveness over time, another coefficient is added to the equation to capture the time trend. This is represented in Equation (2) below, where $\text{Phase}_i \text{Time}_i$ represents an interaction between $\text{Phase}_i$ and $\text{Time}_i$. Therefore, $\beta_2$ reflects the linear time trend during the intervention phase.

$$\gamma_i = \beta_0 + \beta_1 \text{Phase}_i + \beta_2 \text{Phase}_i \text{Time}_i + e_i \sim N(0, \sigma_e^2) \ (2)$$

The time variable is typically centered on the first point in the intervention phase and increases one unit for each measurement occasion. When using this type of centering $\beta_1$ reflects the immediate effect of the intervention on the outcome. Other design matrices, including those that center at the last point in the intervention are possible. For instance, if a delayed intervention effect is anticipated, or the research interest is in estimating the effect of the intervention at the end of the experiment, centering at the last point of the intervention might more appropriate. Because this is the case in current study, centering around the last intervention point is chosen. For a full description of design matrices, see Moeyaert et al. (2014).

**Two-Level.** At the second level, we can estimate the baseline, treatment effect, and time trend during treatment across cases *within a study*. A similar regression approach is used, as
shown in Equation (3) below, where observation $i$ is nested within participant $j$. In the equation, $\beta_{1j}$ continues to represent the treatment effect and $\beta_{2j}$ the time trend in the intervention phase.

$$\gamma_{ij} = \beta_{0j} + \beta_{1j} \text{Phase}_{ij} + \beta_{2j} \text{Phase}_{ij} \text{Time}_{ij} + e_{ij} \sim N(0, \sigma^2_e) \quad (3)$$

Coefficients can vary at the second level, allowing an estimation of between-case variability, as shown in Equation (4).

$$\begin{cases}
\beta_{0j} = \theta_{00} + u_{0j} \\
\beta_{1j} = \theta_{10} + u_{1j} \\
\beta_{2j} = \theta_{20} + u_{2j} \\
\text{with} \quad \begin{bmatrix} u_{0j} \\ u_{1j} \\ u_{2j} \end{bmatrix} \sim \mathcal{N}(0, \Sigma_u) \\
\gamma_{ij} = \theta_{00} + u_{0j} + (\theta_{10} + u_{1j}) \text{Phase}_{ij} + (\theta_{20} + \theta_{2j}) \text{Phase}_{ij} \text{Time}_{ij} + e_{ij} \sim N(0, \sigma^2_e) \quad (4)
\end{cases}$$

Here, participant-specific deviations (i.e. $u_{0j}$) from the overall average baseline, treatment effect, and time trend are indicated. Assumptions of this model indicate that all deviations and errors are normally distributed. However, even if normality is violated, estimates of fixed effects are still unbiased, according to empirical research validating the use of multi-level modeling for single-case data (Moeyaert et al., 2014).

**Three-Level.** The average treatment effect across all participants and studies can also be estimated using a regression approach. At the third level, outcome $\gamma_{ijk}$ for observation $i$, nested within participant $j$, is now nested in study $k$. The average baseline level for case $j$ of study $k$ is indicated by $\beta_{0jk}$ in Equation 5 below. The average treatment effect across individual cases $j$ and study $k$ are shown as $\beta_{1jk}$ and the time trend by $\beta_{2jk}$.

$$\gamma_{ijk} = \beta_{0jk} + \beta_{1jk} \text{Phase}_{ijk} + \beta_{2jk} \text{Phase}_{ijk} \text{Time}_{ijk} + e_{ijk} \sim N(0, \sigma^2_e) \quad (5)$$

Each coefficient in the model can now vary at the second and third levels, thus producing an estimate of between-case and between-study variability (refer to previous section for Level 2 equations). Now, participant- and study-specific deviations from the overall average baseline,
treatment effect, or time trend are shown. The full, combined three-level model is shown in Equation (6).

\[
\begin{align*}
    \theta_{00k} &= \gamma_{000} + v_{0jk} \\
    \theta_{10k} &= \gamma_{100} + v_{1jk} \\
    \theta_{20k} &= \gamma_{200} + v_{2jk}
\end{align*}
\]

\(\gamma_{ijk} = \gamma_{000} + v_{0jk} + u_{0jk} + (\gamma_{100} + v_{10k} + u_{1jk}) phase_{ijk} + (\gamma_{200} + v_{20k} + u_{2jk}) phase_{ijk} Time_{ijk} + e_{ijk} \sim N(0, \sigma_e^2)\) (6)

In this model, the outcome across cases and studies is derived by adding the average baseline level (\(\gamma_{000}\)), average treatment effect (\(\gamma_{100}\)), or average time trend (\(\gamma_{200}\)) plus additional variation around the means (i.e. \(v_{0jk}\)).

To have sufficient power for the analysis, the recommended number of studies for a meta-analysis is 30 (Moeyaert et al., 2020). Given the low incidence of ASD and lack of research in the area of reading comprehension, the total number of participants across studies was considered in lieu of the total number of studies.

Outcome data from the various studies was not on a uniform scale. Therefore, the data was standardized to allow for comparison across studies. For further description of standardization procedures, see Van den Noortgate et al. (2003a, 2003b). Last, Hedge’s bias correction was applied to account for the small sample size in the included studies (Hedges, 1981; Ugille et al., 2014).

**Publication Bias**

Research with null results is seldom published; thus, the possibility of publication bias influencing this meta-analysis is important to consider. While dissertations were found through the search process in this study, they were excluded from the analysis. The focus of the current study was to evaluate the evidence-base that is utilized to make practitioner recommendations, which is more often peer-reviewed literature and not grey literature or dissertation papers.
Results

Study Selection

Database searching identified 481 records, with 6 studies identified through an ancestry search of references from prior systematic reviews, as shown in Figure 1. After duplicates were removed, 237 articles remained. Results were reviewed by title and abstract to determine if the article met preliminary criteria for inclusion. Twenty-seven articles were downloaded and then assessed for eligibility. Two papers were excluded because they did not meet inclusion criteria upon further review. A total of 25 studies were included in the quantitative analysis, with publication dates ranging from 1989-2020 as shown in Table 1.

Figure 1. Selection process for the meta-analysis (n = number of studies)
Descriptive Statistics

Participant and Setting Characteristics. There were 67 participants within the 25 studies. The number of participants within each study ranged from 1-5 with an average $n$ of 3. The majority (87%) of participants were male and 13% were female. Student grade level varied between Grades 2-11. However, it is important to note that some (36%) studies did not specify the grade level of participants in the study demographics. The average age of participants was 11 years ($min = 5$, $max = 17$, $mdn = 11$). Only participants diagnosed with ASD or high-functioning autism were included in the meta-analysis.

Multiple settings and academic placements are represented in the included studies. 16% of interventions were implemented in a special education or self-contained classroom, while 12% took place in the general education setting. 40% of studies described the setting simply as “classroom,” 12% took place in a private school classroom, 4% in a non-public classroom, and 16% in a clinic or home setting. One study took place in the school counselor’s office (El Zein et al., 2016).

Dependent Variable. The dependent variable of interest in this meta-analysis was reading comprehension. Studies utilized measures of reading comprehension such as researcher-created comprehension probes (76%), curriculum-based measures (8%), reading inventory (8%), or classroom assessments (4%). Some studies also utilized retelling tasks as an additional measure of reading comprehension (16%). Retelling was included in this study as an outcome measure of reading comprehension because it evaluates the accuracy of ideas recalled from the text. Outcome measures of sight word comprehension, decoding ability, fluency, and/or listening comprehension were not included; while relevant, they measure skills that are not the focus of
this analysis. Further, while some studies also measured social behaviors and engagement, these were also not explored by this analysis.

**Implementation and Design Characteristics.** Studies varied in implementation approach and design characteristics. About half (56%) of studies employed the researcher as the interventionist, while the remaining 11 (44%) included studies where the intervention was delivered by the participant’s classroom teacher. The average number of measurement occasions per participant was 6 for the baseline phase \((\min = 3, \max = 24, \mdn = 5)\) and 8 for the treatment phase \((\min = 3, \max = 29, \mdn = 6)\). More than half (60%) of studies included maintenance or generalization phases. The average number of measurement occasions in the maintenance phase was 2.5 \((\min = 1, \max = 9, \mdn = 6)\).

Coding structures used to identify the treatments were consistent with approaches utilized in previous reviews. Interventions were organized into the following categories (% of studies including this as a treatment component): Direct Instruction (16%), shared reading (20%), behavioral approaches (16%), strategy instruction and intervention (16%), forms of peer learning (20%), use of technology (i.e. graphic organizer, eTexts, software or online program (40%). Of all intervention components, technology was utilized most often across studies included in the analysis. While the other components are generally equal across categories, it is important to note that the majority of studies were multi-component.

**Moderating Variables.** The first moderator of interest was participant age. The average age of participants within included studies was 11 years old \((\min = 5, \max = 17, \mdn = 11)\). Next, the second moderator study quality was examined. Although twenty-four percent (24%) of included studies met the criteria for Meets Without Reservations, the majority did not meet the full set of standards outlined by the WWC. Sixty percent (68%) met criteria With Reservations.
and 8% Did Not Meet the standards. Intervention type was also included as a moderator, categorized as single- or multi-component. Thirty-six percent (36%) of studies were coded as applying a single intervention, while the remainder (64%) layered intervention strategies and were considered multi-treatment approaches. Last, study design was explored as the final moderators. All single-case design types were represented in the data set. Thirty-two percent (32%) utilized a multiple probe design, 40% multiple baseline, 20% reversal/withdrawal, and 8% studied alternating treatments.

**Inferential Statistics**

The parameter estimates for each of the three models can be found in Table 2. Results from each model are explained in detail in the following sections.

**Table 2**

Multi-level Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameters estimate (SE)</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed Effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average baseline level</td>
<td>2.74(0.50)*</td>
<td>2.75(0.50)*</td>
<td>2.75(0.50)*</td>
<td></td>
</tr>
<tr>
<td>Average treatment effect</td>
<td>6.90(3.78)</td>
<td>7.17(3.78)</td>
<td>13.01(9.18)</td>
<td></td>
</tr>
<tr>
<td>Average trend during treatment</td>
<td>0.06(0.01)*</td>
<td>0.06(0.01)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Moderators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age x Intervention Effect</td>
<td></td>
<td>0.35(0.05)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design x Intervention Effect</td>
<td></td>
<td>-1.20(3.41)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study Quality x Intervention Effect</td>
<td></td>
<td>0.34(6.52)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type x Intervention Effect</td>
<td></td>
<td>-8.20(7.74)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Random Effects

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Intervention</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Between-study variance</td>
<td>Between-case variance</td>
</tr>
<tr>
<td>Between-study variance</td>
<td>5.15</td>
<td>5.12</td>
<td>3.61</td>
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<tr>
<td>Between-case variance</td>
<td>3.59</td>
<td>3.60</td>
<td>5.14</td>
</tr>
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</table>

Note. *p < .05

**Model 1.** Model 1 examined the intervention effect as a change in level. The average baseline level was found to be significant ($\gamma_{000} = 2.74, t(24) = 5.48, p < .05$). No significant change in level was observed from baseline to intervention phase. Although there was no overall significant intervention effect on reading comprehension performance, the effect of the intervention approached significance ($\gamma_{100} = 6.90, t(32) = 1.83, p = .08$). Some variability was observed at the baseline of the case and study levels ($\sigma_{u0}^2 = 3.59; \sigma_{v0}^2 = 5.15$) There was significant variability in the treatment effect, with the highest variability at the case and level and moderate variability at the study level ($\sigma_{u1}^2 = 1396.55; \sigma_{v1}^2 = 7.54$).

**Model 2.** Model 2 estimates a treatment effect as change in level and trend. In contrast to the first model, Model 2 includes a time variable centered around the last point in the treatment. Although it was not statistically significant, there was a large average treatment effect at the end of the intervention phase ($\gamma_{100} = 7.17, t(32) = 1.90, p = .07$). The slope during the intervention phase was statistically significant in Model 2 ($\gamma_{200} = 0.06, t(1347) = 7.87, p < 0.001$). This indicates a significant, increasing effect of the treatment over time in improving
reading comprehension performance. Again, some variability was observed at the baseline of the case and study levels ($\sigma_{u_0}^2 = 3.60; \sigma_{v_0}^2 = 5.12$) As in Model 1, significant variability was found in the treatment effect at the case and study levels ($\sigma_{u_1}^2 = 1396.11; \sigma_{v_1}^2 = 6.92$).

**Model 3.** To explain variability, the following moderators were added to the model: Age (mean-centered), Type, Design, and Quality. In Table 2, Model 3 estimates of intervention effect are provided for the reference group indicated by the coding method: students at the average age ($M = 11$) in a study of a single-component intervention that utilizes a multiple baseline design and is rated Meets Without Reservations on the WWC Standards. The average baseline level remains significant ($\gamma_{000} = 2.75, t(24) = 5.49, p < .05$). The average treatment effect at the last point in the intervention phase is still not statistically significant ($\gamma_{100} = 13.01, t(28) = 1.42, p > .05$). As in Model 2, results of Model 3 indicate a significant, increasing effect of the treatment over time ($\gamma_{200} = 0.06, t(1346) = 8.39, p < .05$). Age was found to be a significant moderator in the analysis. Results suggest that older students were associated with larger intervention effects ($p < .001$). The remaining moderators – Design, Quality, and Type – did not have a statistically significant impact on the variability across studies and participants. When controlling for the other moderators, studies rated “Meets Without Reservations” on the WWC standards were associated with larger effects ($\gamma_{Quality} = 0.34, t(33) = 0.05, p < .05$). A negative effect was found for the moderator Type in the analysis, which could indicate that single-component studies were found to be more effective, on average, than multi-component interventions ($\gamma_{Type} = -8.20, t(27) = -1.06, p < .05$). Last, a small, negative effect was observed for Design ($\gamma_{Design} = -1.20, t(28) = -0.35, p < .05$). Although it was not significant, when controlling for the other moderators, studies utilizing multiple probe, alternating treatment, or reversal withdrawal had, on average, a smaller intervention effect.
Discussion

Results of this study indicate there are a variety of single case studies addressing the development of reading comprehension skills in autistic students. Over time, interventions can gain momentum and increase their effectiveness, leading to a significant change in student performance. There are several contextual considerations for understanding these results.

Reading comprehension is a complex skill that involves many different cognitive capacities (e.g. memory, executive function, language ability, and social-emotional development) (Tracey & Morrow, 2017). ASD is a developmental disability impacting areas of socio-cognitive function and the development of language and communication (American Psychiatric Association, 2013). In autism, oral language underlies both decoding and comprehension abilities (Nation et al., 2005). The meta-cognitive ability of the student – their ability to monitor their own understanding while reading, make inferences and connections – may also impact the development of reading comprehension skills (Turner et al., 2017). For these reasons, we may not expect a significant change in level. Further, the significant change in trend may indicate that longer interventions may be necessary to make gains in reading comprehension. The additional significance of age as a moderator is important to consider. Variability in reading comprehension in ASD can be attributed to differences in the development of oral language (Norbury & Nation, 2011). As children age, they may widen or close gaps in language ability and social cognition, leading to differences in intervention effects. This is supported by research on youth with ASD, which showed lower scores on measures of linguistic and reading comprehension than their peers, with differences in scores lasting over time.

Several reasons may explain the lack of significant change in level across studies. The majority of studies included in this analysis employed reading comprehension questions as a
measure of comprehension. Because these probes are scored on a scale of 0-100%, there is a limit of 100% accuracy of responses. Practically speaking, it's rare that a student scores a flat 0% on comprehension probes during baseline. For example, a student may score a 40%, 60%, and 80% on baseline probes, then “max out” at 100% during intervention. In addition, comprehension can vary based on the reader’s prior knowledge of the topic and vocabulary (Schwanenflugel & Knapp, 2016). Students with ASD in particular often have special interests and increased knowledge in a specific area, which can facilitate and motivate social interaction (Vismara & Lyons, 2007). In this way, performance may vary based on the familiarity with the topic(s). For example, if a student has a special interest in trains and one passage in baseline was about the history of trains, they may naturally perform better on comprehension probes. However, this does not necessarily mean the student has comprehended the text, improved reading skills, or can generalize knowledge to other tasks or texts.

The structure and content of the reading and assessment tasks are also important to highlight in the interpretation of results. Curriculum-based measures (CBMs) are widely used but lack a research basis for their use (Knight et al., 2018). Although they are useful to determine student need for reading interventions, they are typically norm-referenced to a Typically-Developing (TD) or non-autistic population. More research is needed to understand the validity and reliability of CBMs as an assessment for youth with ASD. Regarding the materials of the reading tasks, it is important to consider challenges in comprehending narrative texts common in ASD (Brown et al., 2013). Prior research suggests an inclination toward expository texts, which do not pose challenges of interpreting characters’ internal states (Randi et al., 2010). Studies included in this analysis included both narrative and expository texts. This may lead to variations
in intervention effects, particularly if the intervention is not designed to address socio-cognitive needs.

Due to the time needed by the student to acclimate to the task and demands of the intervention, there is a possibility of a delayed treatment effect. Prior research indicates that students with developmental disabilities may improve their performance with more time to practice the skill or strategy or understand the format of the task or assessment (Snyder et al., 2017). Results of this meta-analysis detected no change in level but a significant change in trend, supporting these assertions. Although there may not be a distinct improvement in performance, the student may reach and sustain a high level of performance with time.

**Supporting Reading Comprehension in ASD**

The results of this study raise questions about the nature of reading comprehension difficulties for young autistic readers. Studies included in this analysis investigated instructional procedures, strategic processes, and supplemental supports. It’s expected that interventions addressing social, semantic knowledge, or cognitive components of reading may demonstrate a large effect, given prior explanations of reading comprehension challenges in ASD. Results of the meta-analysis support findings from previous reviews and research on effective learning environments for students with ASD. Larger intervention effects were observed in studies exploring Direct Instruction techniques, forms of peer learning, and shared reading. This suggests talking about texts with peers or adults offers an authentic, meaningful opportunity to scaffold the application of social knowledge. Further, instruction that is systematic allows the student to see and practice a reading skill with gradual release or fading of support that can be individualized to their needs.
Findings are largely consistent with prior research that points to preliminary effectiveness but high variability in study, intervention, and participant characteristics. This was reflected in the present study by the significant change in trend and variability in between cases and studies. Nonetheless, aspects of the current study were inconsistent with previous reviews. Finnegan & Mazin (2016) suggested that the length of the intervention had no impact on the effectiveness. However, the significant change in trend found in this analysis may indicate intervention effectiveness can increase with time and, therefore, the length of intervention should not be discounted.

Implications and Future Directions

The conclusions from this meta-analytic review have various implications for practitioners teaching students with ASD. Prior research suggests students with ASD perform below grade-level in the area of reading comprehension (Grimm et al., 2017). Given the increasing effect of intervention over time, the continued use of these practices offers an opportunity to close these gaps. However, when implementing a practice, it may take time before significant increases in performance are apparent. Although short-term interventions are sometimes easier to implement, long-term interventions may gain effectiveness with time. Practitioners may consider selecting more complex, long-term interventions and monitor small changes in skills or behaviors to detect progress. In return, teachers need adequate access to training and resources to ensure readiness and capacity to implement these practices.

Generalizing knowledge, skills, and processes to new situation is challenging for some students with ASD (Brown & Bebko, 2012). Using similar strategies may be beneficial across settings to maintain consistency and support the transfer of skills. If students are able to continue to increase their scores and maintain them at a high level, the student may benefit from
generalizing the skill or strategy to other tasks. For example, if the use of a reading strategy keeps a student’s comprehension at a high level in English/Language Arts instruction, they may benefit from using TWA across texts, or in other subjects (i.e. Social Studies or Science). Having mastered the protocol and procedure, the directions and task demands will likely be clearer to the student, which may lead to improvements in performance.

Results of this study can also be utilized to inform future research in this area. Researchers should continue to investigate the interventions explored in this review to expand beyond a cohort of practices with preliminary effectiveness. Studies should consider variability introduced by participant age, the length of intervention, and the methodological design. Given the increasing effectiveness of the interventions over time, researchers may consider utilizing methodological designs with more measurement occasions in each phase. This may improve participant outcomes, but also increase the likelihood an intervention effect be captured in the timeframe of the treatment.

A careful selection of the content of study materials – particularly regarding outcome measures, text topic(s) and genre – are also important to consider. Prior research in this area emphasizes the presentation of materials and study activities, including the format of questions (e.g. Yes/No vs. multiple-choice) and text levels or types (e.g. narrative, expository, argumentative) (Snyder et al., 2017). The intervention design should define a clear rationale for the task components, such as: the ability to return to the text before responding to questions, responding orally vs. using a communication device, and how the student will be acclimated to the procedures and steps of completing the reading or assessment tasks (Snyder et al., 2017).

In addition to content, the setting and interventionist should also be considered in future research. High effect sizes were associated with studies that took place in several different
locations, including general and special education classrooms, as well as home/clinic environments. This suggests interventions in reading comprehension can be implemented flexibly in a variety of settings. Still, it is preemptive to say which setting(s) are most beneficial, as studies conducted at home, in clinics/centers, or non-classrooms are emerging. Future research can continue to explore alternative settings for intervention, as well as a multitude of school-based environments (i.e. Counselor’s office). There was no observable difference in studies based on the interventionist – whether the researcher or a teacher. As more research is published, future analyses can determine if the variability in effectiveness can be explained by where the treatment is implemented and by whom (i.e. teacher or researcher).

While this study included research that was rated Does Not Meet, several studies included did not achieve WWC Standards of Meets Without Reservations. This is important to consider, given that there are few randomized controlled trials and/or quasi-experimental research on reading comprehension in ASD. The field, particularly practitioner research, leans heavily on the strategies presented in the single case design studies. It’s important that these studies exhibit methodological rigor to strengthen conclusions and give practitioners a clear message about what is/is not effective in their classrooms, for whom, and steps to implementation that will lead to gains in the area of reading comprehension. Further, the current study focused solely on peer-reviewed research and did not include dissertations. Although grey literature is not published in peer-reviewed journals, that does not necessarily indicate that it is not high-quality according to the WWC Standards. Future research can expand on this study by including grey literature.

New directions in this line of research have suggested the use of novel approaches such as augmented reality (AR). Stemming from research on video modeling, research on AR shows promise and are available at free or low-cost on common technological devices such as smart
phones (Howorth et al., 2019). Given new advances and access to educational technology, future single subject research may explore these options for addressing reading comprehension in ASD. Future research should also explore interventions that address the unique challenges of reading comprehension in ASD, such as making inferences, drawing connections to texts or experiences, and synthesizing the larger meaning of the text (Nation & Norbury, 2005).

**Limitations**

The following limitations should be considered in the interpretation of study results. First, a relatively small number of studies were included in the meta-analysis with high variability found between cases and studies. As a result, the aggregation of this research must be understood in context. Studies ranged significantly in terms of their methodologies, participant characteristics, and treatment design. In addition, some studies utilized researcher-developed comprehension probes. As these are not standardized measures of reading comprehension, the average intervention effects across studies can be misleading if not interpreted properly. As more research is published, this can be repeated with a larger (or more focused) group of participants and studies to strengthen the analysis.

Next, the inclusion of only single case studies may be a limitation to understanding the full and complete literature on reading comprehension interventions in ASD. Studies using group designs, quasi-experimental or randomized controlled trials were not included, but may provide results for more participants than are seen in single-case methodologies or use more rigorous approaches with increased experimental control. This analysis also included studies of all ratings from the WWC Standards for Single Case Designs, including Does Not Meet Standards and Meets with Reservations. One characteristic of the studies that affected WWC ratings was the number of points within phases. Including studies with few measurement occasions may not capture a change in level or trend. Additionally, the manipulation of the independent variable,
alignment of probe points across participants, and use of consecutive probes prior to introducing the intervention also impacted ratings. The level of experimental control allows the researcher to accurately determine if a change in performance or behavior is functionally related to the introduction of the treatment. Additionally, not all studies in the meta-analysis included a maintenance measure. Maintenance measures can indicate if the effectiveness of the treatment can be sustained and are essential in special education research. If not included, it is difficult to conclude if intervention effects have the potential to be long-lasting. While these aspects are sometimes difficult to accomplish in a practical setting such as a classroom, it is important to understand how the data being analyzed in this meta-analysis was collected.

Last, several variables were not coded that may be of interest to the researcher and/or practitioner. Some participant demographics (e.g. language scores, autism diagnostic scores) were not considered in this analysis due to the inconsistencies in reporting this information across the included studies. Practitioners looking to utilize the practices described in this meta-analysis will need to consider potential variability in effectiveness based on student characteristics and needs. Further, this study did not code whether studies utilized an expository or narrative text. This information is important to understanding the context of delivery – where, when, and how interventions were found to be effective.

**Conclusion**

The current study presents meta-analytic findings from 25 single-case studies on reading comprehension outcomes in youth with ASD. Results indicate that intervention approaches had a significant effect on outcomes over time, with increased effectiveness associated with older students. Findings from this study can be utilized by practitioners to guide the selection, design, and delivery of interventions in their classrooms. Methods that support reading comprehension
included Direct Instruction, shared reading, forms of peer learning, the use of technology, strategy development, and behavioral approaches. Teachers may consider providing students with ample time to adjust to the intervention or strategy. Practitioners may also consider using a layered approach, where multiple techniques are implemented concurrently.

More research is needed on reading comprehension interventions in ASD. Although this topic has been explored for three decades, research is still limited on how to effectively support the development of reading comprehension skills in students with ASD. While there is significant research that attests to challenges in reading, this study shows that under certain conditions youth with ASD were able to demonstrate high performance on measures of reading comprehension. Understanding the contexts and practices that eliminate barriers impacting students’ ability to read and comprehend texts is key supporting the learning needs of students on the spectrum.
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* indicates study was included in meta-analysis


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capabilities/deficits in children with an autism spectrum disorder: “weak” central
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40, 890-902.

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development for high school students with autism spectrum disorder: stakeholder

a reading comprehension intervention for high school students with autism spectrum

spectrum disorders: the role of oral language and social functioning. *Journal of Autism
and Developmental Disorders, 43*, 807-816.

literacy in an inclusive English/Language Arts class: preliminary efficacy and ecological

promote text comprehension skills by students with ASD in core content areas. Focus on Autism and Other Developmental Disabilities, 33(3), 150-159.


learners with autism spectrum disorder. Intervention in School and Clinic, 46(4), 195-203.


Table 1. Studies included in the meta-analysis

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Intervention</th>
<th>n</th>
<th>Age range</th>
<th>Grade</th>
<th>Type</th>
<th>Outcome Measure</th>
<th>Setting</th>
<th>Interventionist</th>
<th>WWC Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alison et al. (2017)</td>
<td>Multiple probe</td>
<td>Shared reading with e-Text and prompting; Constant time delay</td>
<td>3</td>
<td>8-10</td>
<td>2-4</td>
<td>Multi</td>
<td>Researcher-Developed</td>
<td>Self-contained classroom</td>
<td>Researcher</td>
<td>Meets Without Reservations</td>
</tr>
<tr>
<td>Bethune &amp; Wood (2013)</td>
<td>Multiple baseline</td>
<td>Graphic organizer with wh-questions</td>
<td>3</td>
<td>8-10</td>
<td>n/a</td>
<td>Single</td>
<td>Researcher-Developed</td>
<td>Special education classroom</td>
<td>Researcher</td>
<td>Meets Without Reservations</td>
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<tr>
<td>Browder et al. (2017)</td>
<td>Multiple probe</td>
<td>Graphic organizer with iPad; System of least prompts</td>
<td>3</td>
<td>8-10</td>
<td>2-4</td>
<td>Multi</td>
<td>Researcher-Developed</td>
<td>Self-contained classroom</td>
<td>Researcher</td>
<td>Meet Without Reservations</td>
</tr>
<tr>
<td>Carnahan &amp; Williamson (2013)</td>
<td>Reversal ABAB design</td>
<td>Compare-Contrast Strategy; Graphic organizer</td>
<td>3</td>
<td>13</td>
<td>7-8</td>
<td>Multi</td>
<td>Researcher-Developed</td>
<td>Private school classroom</td>
<td>Teacher</td>
<td>Meet with Reservations</td>
</tr>
<tr>
<td>Carnahan et al. (2016)</td>
<td>Multiple baseline</td>
<td>Text Structure intervention package</td>
<td>3</td>
<td>15-16</td>
<td>n/a</td>
<td>Multi</td>
<td>Researcher-Developed</td>
<td>Classroom</td>
<td>Teacher</td>
<td>Meet with Reservations</td>
</tr>
<tr>
<td>El Zein et al. (2016)</td>
<td>Alternating</td>
<td>Embedding perseverative interest</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>Single</td>
<td>Curriculum-based measure</td>
<td>School Counselor office</td>
<td>Researcher</td>
<td>Does Not Meet</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Intervention</td>
<td>Sessions</td>
<td>Age</td>
<td>Setting</td>
<td>Researcher Developed</td>
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<td>Researcher</td>
<td>Meet With Reservations</td>
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<tr>
<td>Head et al. (2018)</td>
<td>Multiple probe</td>
<td>Direct Instruction <em>(Corrective Reading Thinking Basics: Comprehension Level B1)</em></td>
<td>2</td>
<td>10-16</td>
<td>5-10</td>
<td>Single</td>
<td>Researcher-Developed</td>
<td>General education classroom</td>
<td>Researcher</td>
<td>Does Not Meet</td>
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<tr>
<td>Howorth et al. (2016)</td>
<td>Multiple baseline design</td>
<td>Think Before, While, and After (TWA) Reading Strategy</td>
<td>4</td>
<td>10-11</td>
<td>5-6</td>
<td>Single</td>
<td>Qualitative Reading Inventory 5th ed. (QRI-5); ReadWorks</td>
<td>Classroom Teacher</td>
<td>Meet with Reservations</td>
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<tr>
<td>Howorth &amp; Raimondi (2019)</td>
<td>Concurrent multiple probe</td>
<td>TWA-Supported Digitally</td>
<td>3</td>
<td>11</td>
<td>n/a</td>
<td>Multi</td>
<td>Qualitative Reading Inventory 5th ed. (QRI-5)</td>
<td>Classroom Teacher</td>
<td>Meet with Reservations</td>
<td></td>
</tr>
<tr>
<td>Jackson &amp; Hanline (2020)</td>
<td>Reversal design</td>
<td>RECALL <em>(Shared Reading)</em></td>
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<td>5</td>
<td>n/a</td>
<td>Multi</td>
<td>Researcher-Developed</td>
<td>Therapy Center or classroom, home</td>
<td>Researcher</td>
<td>Meets with Reservations</td>
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