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Using a Concept Map With RECALL to Increase the Comprehension of Science Texts for Children With Autism

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Abstract

Learning science is important for students with autism spectrum disorder (ASD), as knowledge of science allows students to understand their natural world, and science, technology, engineering, and mathematics (STEM) education is increasingly emphasized in schools. Reading to learn science is, therefore, a vital skill in today's schools for all students. Using a single-case reversal design, this study evaluated the effectiveness of Reading to Engage Children with Autism in Language and Literacy (RECALL; a shared reading intervention) combined with a concept map on the ability of young children with ASD to answer comprehension questions from science text. Two 5-year-old boys with ASD participated in this study. Results indicated that RECALL combined with a concept map was effective in increasing participants' correct responding to comprehension questions from science text. Implications for intervention and research are discussed.

Keywords

autism spectrum disorder, elementary, science, storybook, reading, literacy, educational, evidence-based practices, prompts

Reading comprehension is one of the most important skills learned in school. It is a process that requires the reader to combine information from text and integrate this information with prior knowledge to understand the meaning of what is being read. Although reading instruction in the early grades emphasizes learning to read, as students move into intermediate grades, reading comprehension becomes more critical because the emphasis shifts from learning to read to reading to learn academic content (Alexander & Jetton, 2000). Reading to learn is a vital skill in today's schools with the growing emphasis on science, technology, engineering, and mathematics (STEM) education (Brown et al., 2011). Science is a component of STEM education, and reading comprehension is key to accessing science knowledge. That is, students must be able to comprehend science texts to understand concepts and vocabulary, draw inferences, and formulate hypotheses.

Learning science is important for students with autism spectrum disorder (ASD), as science knowledge provides an opportunity for students to understand their natural world (Spooner et al., 2011). Furthermore, individuals with ASD who major in a STEM field are more likely to persist in their college education (Wei et al., 2013). The importance of students with ASD learning science is further underscored by the Elementary and Secondary Education Act, requiring states to report achievement for all students in the content area of science. As children progress through school, the ability to learn science through reading becomes increasingly important. However, approximately 65% to 73% of school-age children with ASD have reading comprehension difficulties (McIntyre et al., 2017; Randi et al., 2010; Ricketts, 2011), making learning science through reading difficult.

Teaching Reading Comprehension Skills to Learners With ASD

The theory of Weak Central Coherence (WCC; Frith, 1989) may explain why individuals with ASD have difficulty with reading comprehension. According to WCC, individuals with ASD lack the cognitive skills needed to understand comprehensive concepts (Randi et al., 2010), as they may have a processing style (i.e., WCC) that results in a focus on details or individual words when reading. This processing style influences the ability to comprehend text (Williamson et al., 2012). However, WCC does not preclude learners with ASD from comprehending text, including science text, with appropriate supports (Happé & Frith, 2006).

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Several studies have focused on improving reading comprehension for students with ASD. In three of these studies, peers were included in the intervention as tutors (Kamps et al., 1989, 1994; Whalon & Hanline, 2008). When paired with a peer, elementary-aged students with ASD increased their ability to answer comprehension questions, decreased the number of errors made while reading, and increased reading fluency. Further research has shown that cloze, anaphoric cuing, and prereading strategies were equally effective (O'Connor & Klein, 2004); cooperative learning groups were as effective or more effective than teacher instruction (Kamps et al., 1995); and computer-assisted and book-based instruction reading strategies (Williams et al., 2002) were equally effective in supporting the development of reading comprehension for learners with ASD.

Teaching Science to Students With ASD

In addition to research focused on increasing general reading comprehension, studies to teach science content by increasing comprehension of science text to learners with ASD also have been conducted. High school students with ASD have increased their ability to verbally answer questions related to science text when taught to use text structure organization (Carnahan et al., 2016). Middle school learners with ASD have increased their ability to answer science text comprehension questions when using a Venn diagram (Carnahan & Williamson, 2013) and electronic etext (*Book Builder*) to hear science text read to them (Knight et al., 2015). Other studies have used specific forms of systematic and/or explicit instruction such as the *Model-Lead-Test* approach (Knight et al., 2012), scripted lessons in combination with guided notes (Jimenez, Lo, & Saunders, 2014), computer-assisted instruction (Smith et al., 2013), and systematic instruction paired with graphic organizers (GOs; Knight et al., 2013) to increase students' knowledge of science. In addition, Knight and Sartini (2015) concluded in a comprehensive literature review that response-prompting procedures and visual supports can increase comprehension skills in content areas including science for learners with ASD.

Concept Maps as Visual Supports

The Knight et al. (2013) and the Carnahan and Williamson (2013) studies suggest that GOs may be an effective support for students with ASD to learn science content through reading. GOs are a visual representation of concepts organized within a framework that allows readers to connect their existing knowledge to text information (Barron, 1969; Mayer, 1984). GOs have been recommended as a teaching tool to teach reading comprehension skills (Gately, 2008) and social studies content (Schenning et al., 2013) to children with ASD, as GOs include visual supports assisting individuals with ASD to organize and focus on key concepts in the text. A concept map is a specific type of GO and usually begins with a main idea and then provides visual linkages to show how other concepts relate to the main idea (Novak & Gowin, 1984).

Only one study has researched the use of concept maps to teach science to learners with ASD. Roberts and Joiner (2007) conducted a study of the effectiveness of teaching ten 14-year-old students with ASD to construct their own concept maps. Participants in the control group were taught using conventional instruction. Participants in the experimental group collaborated to develop concept maps on science topics based on a list of words or labeled pictures. Results indicated that, with the concept map, students could retain and recall nearly twice as much information as that of participants in the control condition based on a pre–post measure of questions related to the science content being learned. Furthermore, the improvement in the students' retention of science-related information resulted in a significant positive impact on their performance on traditional question/answer tests.

Shared Reading as an Instructional Context to Teach Science to Learners With ASD

Shared reading may be a developmentally appropriate context in which young children with ASD can learn science by increasing their reading comprehension, as shared reading has been shown to positively affect oral language and vocabulary of young children (e.g., Mol et al., 2009). Reading to Engage Children with Autism in Language and Literacy (RECALL) is an approach to shared reading designed specifically for children with ASD (Whalon, Delano, & Hanline, 2013). RECALL combines the prompts and instructional sequence found in dialogic reading (Whitehurst et al., 1994) with two strategies shown to be effective for young children with ASD, that is, prompting hierarchy and visual supports (Wong et al., 2015).

During RECALL, the adult asks completion, recall, open-ended, wh-, and distancing questions based on dialogic reading. RECALL adds wh-inference and emotion identification questions, as these questions are difficult for children with ASD (Hundert & van Delft, 2009) but are critical for reading comprehension (Tager-Flusberg et al., 2005). Often, children with ASD are only taught how to answer simple wh-questions that have literal answers (Krantz et al., 1981; Secan et al., 1989), but learning how to answer inferential questions is an important component of elementary education (Hundert & van Delft, 2009).

To help children answer questions during RECALL, when the child is asked a question they are not able to answer, a least-to-most prompting hierarchy using visual supports is used. The visual supports include pictures of

three response options, one of which is the correct answer. The adult verbally labels the response options and uses a prompting hierarchy involving removing one visual option at a time in a step-by-step fashion and ending in a physical prompt when necessary to help the child select the correct response by pointing to or picking up the correct visual response option.

In addition, RECALL embeds secure attention prompts to establish joint attention on the book between the adult and child. These prompts were included because research has suggested that verbal prompts to gain or direct the child's attention to the text helps establish joint attention (Patten & Watson, 2011) and joint attention is a skill with which children with ASD often have difficulty (Ezell & Justice, 2005). RECALL also includes intentional pause prompts before or after turning a page to encourage social initiations. These pauses are included because young children with ASD often lack the ability to initiate conversations and/or questions (American Speech-Language-Hearing Association [ASHA], 2006), and the intentional pause prompts may provide a subtle cue for the child to socially initiate.

RECALL has been shown to be effective in improving the ability of preschool children with ASD to correctly and spontaneously answer fact- and inference-based questions and increase their social initiations during shared reading in a small group with peers in a preschool setting (Whalon, Martinez, Shannon, Butcher, & Hanline, 2015). In another single-case design study, Whalon, Hanline, and Davis (2016) found that a 4-year-old boy with ASD improved his ability to answer comprehension questions during 6 weeks of RECALL implemented by his mother in the home.

Study Purpose

The research suggests that appropriate supports may be effective in teaching learners with ASD science content. Therefore, this study explored combining the systematic instruction in RECALL with a concept map to enhance the learning of science by young children with ASD. Although research documents the effectiveness of RECALL in improving the ability of young children with ASD to answer questions about the content of fictional storybooks, RECALL has not been used to teach children academic content, such as science. Furthermore, although the effectiveness of using GOs in teaching science vocabulary and concepts to students who have ASD has been shown, these studies have included middle and high school students and are few in number. There has been no research using shared reading and concept maps together to provide an intensive intervention to teach young children with ASD to answer questions related to science text. RECALL was used to help participants understand vocabulary and concepts in the science text, and the concept map, to assist participants to relate the concepts and vocabulary, thereby promoting comprehension of the overall content. Intervention/instructional packages have been used frequently in past research to teach science to learners with disabilities (Carnahan & Williamson, 2013; Carnahan et al., 2016; Jimenez et al., 2014; Knight et al., 2012, 2013; Smith et al., 2013).

Therefore, this study combined RECALL with a concept map to determine the outcomes of this intervention package on the ability of 5-year-old children with ASD to answer fact-based and inference questions related to science content. Specific research questions were as follows:

Research Question 1: What is the effectiveness of RECALL combined with a concept map on the ability of young children with ASD to answer comprehension questions from science text?

Research Question 2: What are the perceptions of the participants and the mothers of the participants of using RECALL combined with a concept map?

Method

Participants

After informed consent was obtained from the Institutional Human Subjects Committee, two 5-year-old boys with ASD were recruited and participated in the study. One was recruited from a local therapy center. The other was the child of a friend of a colleague of the interventionist, the first author. Prior to the start of the study, the interventionist screened the participants to be sure they met the inclusion criteria of (a) diagnosis of ASD, (b) adequate vision and hearing to interact with the materials, (c) ability to respond to questions orally, and (d) availability for the study.

In addition, the participants were individually administered a preassessment developed by the interventionist. The preassessment consisted of five questions based on the text of the book being read aloud to the participant, a DK Level 1 book (part of Penguin Random House) titled *Learning to Read Dinosaur*. DK is a publishing company that specializes in illustrative reference books for children. While reading, the interventionist stopped to ask the five preassessment questions. The fact-based questions were as follows: "What is the book about?"; "What is a triceratops?"; and "What protects the dinosaur?" The inference questions were as follows: "Why do you think the other dinosaurs fear the tyrannosaurs?" and "Why do you think they are hooting?" The participants must have met the criterion of not being able to answer orally more than one fact-based and more than one inference question.

Si was 5 years old at the onset of the study. He is a Caucasian male with ASD. An intellectual disability was not identified by his cumulative folder or by his mother. A licensed clinical social worker diagnosed Si with ASD by the criteria established in the *Diagnostic and Statistical*

Manual of Mental Disorders (5th ed.; *DSM-5*; American Psychiatric Association, 2013). Si received occupational, speech, and behavioral health therapy services 1 hr each per day at the therapy center he attended 5 days a week. His current reading curriculum was individualized using teacher-developed materials provided by the center. Si is able to use complete sentences when having conversations and verbally express his needs and wants.

The second participant in the study, Carter, was a 5-year-old Caucasian male with ASD and a sensory processing disorder. An intellectual disability was not identified by his individual education plan or by his mother. Carter was diagnosed with ASD by a psychologist using the *Autism Diagnostic Observation Schedule* (ADOS-2) Module 3 (Lord et al., 2012). Carter attended a special education public school preschool and received services in occupational therapy in school for 1 hr every other week and outside of school every other week for 45 min. While in preschool, Carter used SRA's *Read-Aloud Library* as his reading curriculum. Carter is able to verbally communicate using three- to four-word sentences and is able to ask questions. He has a lisp, making some of his speech difficult to understand.

Setting

Sessions for both participants were conducted in a one-to-one format in a Southeastern suburban community. Si's sessions took place either in a classroom at his therapy center or in his mother's school classroom. Carter's sessions were conducted in his mother's living room.

Study Design

A reversal (ABAB) single-case research design (Ledford & Gast, 2018) was used to determine the impact of the intervention on the participant's number of independent correct responses to oral comprehension questions of science text. Baseline phases and intervention phases were alternated and then repeated to complete four phases in the study with each participant engaging in four phase changes for a total of eight phase changes. This meets the Institute of Education Sciences (IES) requirements of a reversal design.

Dependent Variable

The dependent variable (referred to as the oral comprehension assessment) was the number of independent correct verbal responses answered within 5 s to five questions about the book. These questions were the same type and number of questions asked when reading each book during baseline and intervention sessions, and included two inference questions, two fact-based questions, and a question about the main topic of the book ("What is the book about?"). These questions were different in baseline and intervention sessions as different books were used in the two experimental conditions. Questions were presented orally to the participant by the interventionist. RECALL visuals and the concept map were not used during the oral comprehension assessment.

Data Collection

All sessions were video recorded for data collection and coding purposes. Event recording was used to code the dependent variable data from baseline and intervention sessions immediately following each session.

Data Analysis

Visual analysis was used to determine whether a functional relation existed between the independent and dependent variables. Visual analysis included analyzing changes in the level, trend, immediacy of effects, and variability between baseline and intervention; overlap of data among phases; and consistency across the same phases.

Procedure

The first author, who has 5 years of experience teaching children with ASD, served as the interventionist. Prior to the start of the study, the interventionist explained to both mothers the procedures of the study.

The books were randomly assigned for all sessions using the online randomization sequencing tool, Random.org. Each book was read only once to each participant. Si's sessions were 5 days a week for 12 weeks. Carter's sessions were 4 days a week for 8 weeks. Each baseline session lasted approximately 8 min, and intervention sessions lasted 20 min.

Oral comprehension questions. Ten questions for each book were written by the interventionist. The second author verified that the questions were developmentally appropriate and could be answered by information provided in the text of the books being read. Fact-based questions began with who, what, where, when, or how many. They were asked when the page was being read that contained information the participant could use to answer the question. The mean length of all fact-based questions was 5.54 words (range = 3–10). Inference questions all began with why or how and were asked when reading the pages that contained information from which the participant could infer the answer from the text. The mean length of all inference questions was 7.91 words (range = 4–15).

The interventionist used the randomization tool, Random.org, to select two inference- and two fact-based questions to be asked during each baseline and intervention session. The first question remained the same throughout each book ("What is the book about?").

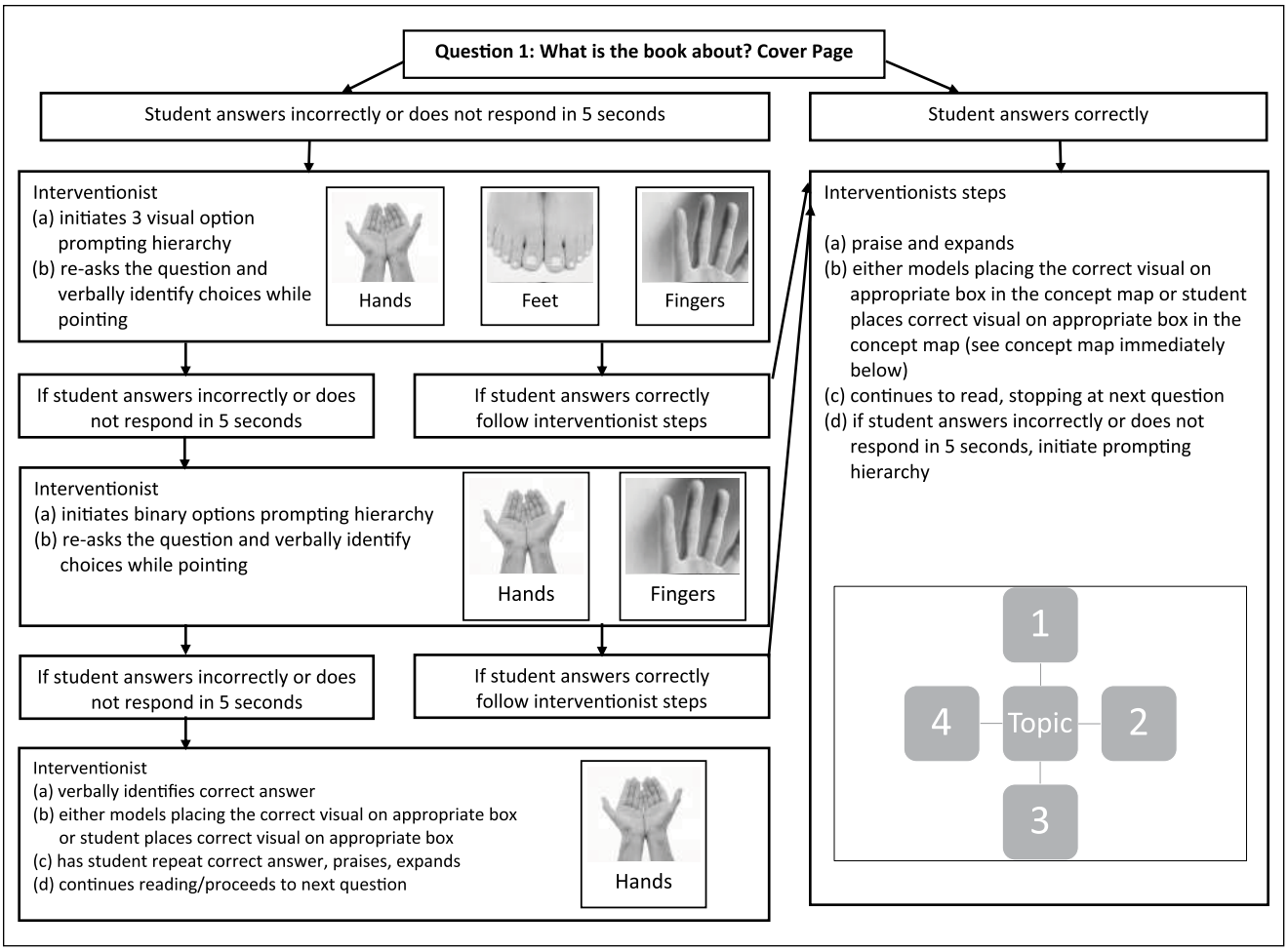

Figure 1. Flow chart of the prompting procedures.

Materials. The books used for this study were selected from the *Let's Read-and-Find-Out Science Books* series published by HarperCollins©. A total of 30 books were used. Topics covered in the books were plants and animals, the world around us, and the human body. The books had Lexile® levels that ranged from AD370L to AD660L. Books measured with an adult directed (AD) are "better when read aloud to a student rather than having the student read independently" (https://lexile.com/educators/find-books-at-the-right-level/about-lexile-codes/).

During intervention phases, a colorful and laminated concept map with Velcro© was used to secure responses (see Figure 1). In these phases, each of the five questions to be asked during shared reading was printed on a laminated page with three Google images secured to the bottom of the page with Velcro© in a horizontal row. One image represented the correct response, and two images represented incorrect responses. The placement of the correct response was varied. The images provided visual support in the form of response choice options.

Baseline. The interventionist read aloud the science book, stopping to ask each of the five predetermined questions at appropriate times based on the content of each page. The first question was asked when the interventionist was reading the cover of the book. The interventionist did not respond to the correctness or incorrectness of the responses, but provided praise for appropriate behaviors (e.g., sitting and listening). If the participant was off-task, the interventionist redirected the participant to the reading activity. If the participant asked questions or made comments, the interventionist responded simply ("Yes, that is a bear" or "Oh, okay") and redirected the participant. Immediately after the book reading was completed, the interventionist administered the oral comprehension assessment.

Intervention. Before reading, the interventionist explained the purpose of the concept map, describing the concept map as being a picture of what the participant would use to answer questions about the book. The interventionist then explained the different parts of the concept map.

Participants had access to the concept map throughout the intervention sessions either in their lap or in front of them on a table.

During reading, the interventionist asked the predetermined questions, beginning with the first question when reading the cover of the book. If the participant responded correctly, the interventionist reinforced the correct answer and modeled putting the visual on the appropriate number of the concept map. When asking subsequent questions, Si and Carter were taught to put the correct response option on the concept map by verbally prompting them to do so and using physical assistance when needed.

If the participant did not respond to the question within 5 s or responded incorrectly, the interventionist initiated the prompting hierarchy. A flowchart of the prompting procedures is provided in Figure 1. That is, the interventionist showed the laminated card with the questions and three visual choice options to the participant, and repeated the question and verbally identified the response choice options while pointing to each in succession. The visual response options included the correct response, and one plausible and one nonplausible distractor. If the participant did not answer within 5 s or selected the wrong visual choice, the interventionist removed one response option (leaving two response choices) and repeated the question. If the participant responded incorrectly or did not respond within 5 s, the interventionist verbally answered the question and assisted the participant to place the correct response card on the concept map. She then repeated the question and encouraged the participant to verbally answer the question and point to the correct visual response option on the concept map. This process was followed until all five predetermined questions were answered.

While reading the book, after Question 3 was answered, the interventionist reviewed the questions and answers. All five questions and answers were reviewed when the book reading was completed.

The interventionist provided RECALL shared attention and intentional pause prompts during intervention phases. The number of secure attention and intentional pause prompts was not consistent in each intervention session. The interventionist provided an average of 6.94 (range = 4–18) secure attention prompts and an average of 3.89 (range = 1–7) intentional pauses during the two intervention phases.

If Si or Carter made a comment during the intervention phases that was off-task, the interventionist responded as in baseline. If a participant made a comment or asked a question related to the book, the interventionist provided an expansion ("Yes, the green dinosaur is way up high on the mountain."). When finished reading the book, the interventionist administered the oral comprehension assessment.

Social Validity

Multiple methods to access social validity were utilized, each method measuring a different aspect of social validity. Interviews were conducted with mothers and participants. In addition, a measurement less subject to bias was used (i.e., blind ratings of participants' behavior in different phases were conducted by mothers; Barton, Meadan-Kaplansky, & Ledford, 2018, p. 145).

The mothers of the participants participated in social validity measures, as they were present during the study. The interventionist asked the participants' mothers questions regarding the importance of the intervention (i.e., "Do you feel the intervention was important for your child? Why or Why not?"), their child's interests in reading science text (i.e., "Since the intervention, does your child show more interest in science?"), and their child's ability to answer questions correctly during shared reading (i.e., "What have you noticed about your child's ability to comprehend what he reads?"). Mothers were also asked, "If trained, do you feel you could implement this intervention?"

The mothers were also shown one randomly selected video clip of their child from the first baseline phase and the last intervention phase. They were unaware of the experimental phase in the videos. The interventionist asked the mothers to note any differences in their child's ability to answer questions and in their child's attention and behavior between the two videos and to describe the differences.

Si and Carter also were interviewed and were asked the following questions: (a) "Did you like reading with me? Why or why not?"; (b) "What part of reading did you enjoy the most? Why?"; (c) "Is there anything about reading that you did not like?" The participants were provided visuals to help answer the second and third questions, that is, a picture of a book, a picture of three visual response options, and a picture of the concept map were provided.

Fidelity of Implementation

All sessions were coded using two author-developed fidelity of intervention checklists, one for baseline and one for intervention. The interventionist trained two coders, special education doctoral students (Coders 1 and 2), to use the checklists by watching two author-made training videos. The coders then independently coded three additional training videotapes, achieving 100% reliability.

Coder 1 coded all the videos from all phases for both participants and Coder 2 coded 30% of randomly selected videos from all sessions for both participants. Agreement for Si was 100% for baseline sessions and 95% (range = 90%–100%) for intervention sessions. Agreement for Carter was 96.43% (range = 85.71%–100%) for baseline and 95.46% (range = 85.48%–100%) for intervention. These outcomes provide evidence of acceptable adherence to specified procedures and differentiation of procedures in different phases (Ledford & Gast, 2018).

Interobserver Agreement

The interventionist was the primary coder of the dependent variable for all phases of the study. The interventionist trained

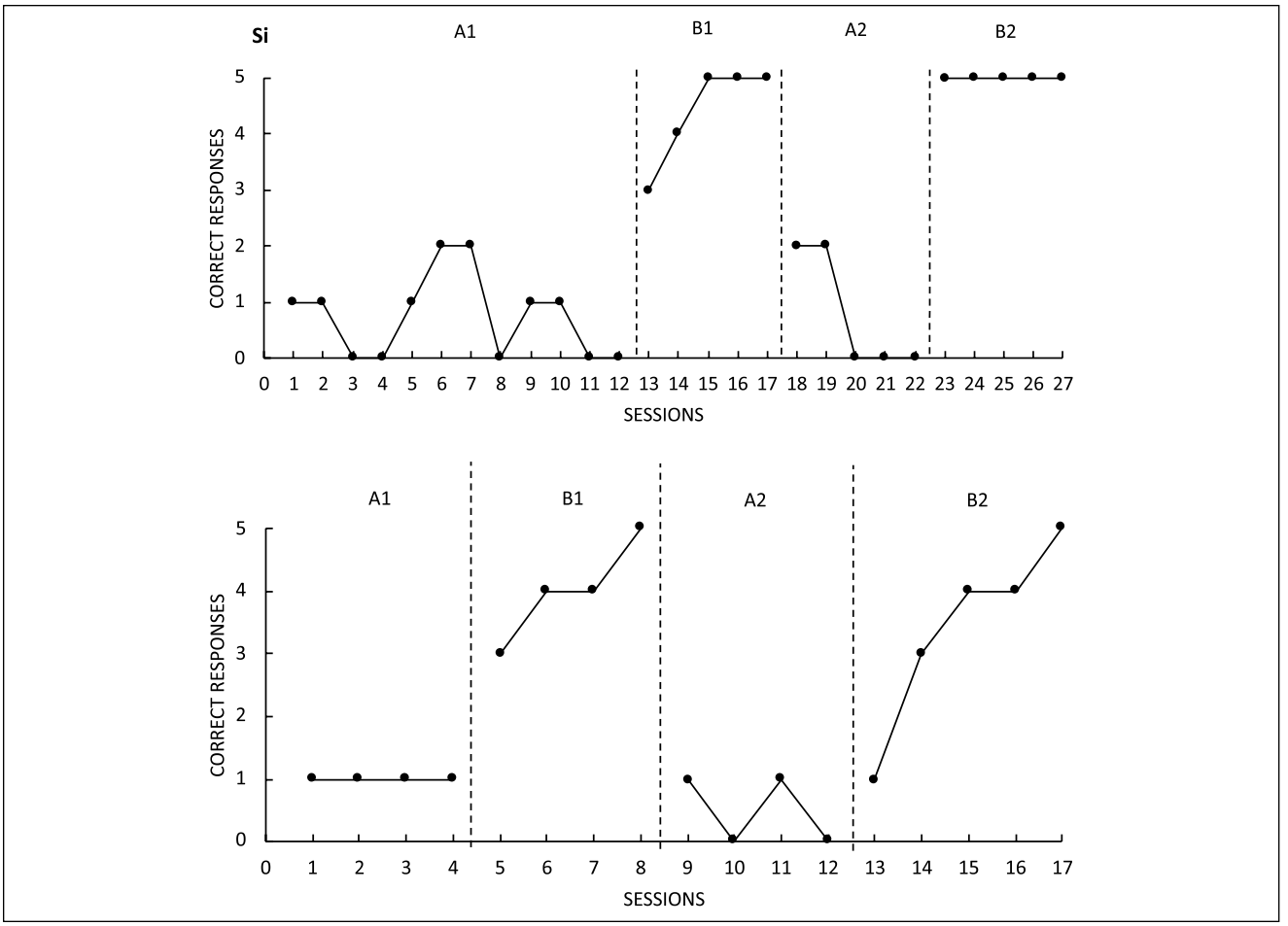

Figure 2. Correct responses to comprehension questions.

Coder 1 by watching author-made training videos until 80% agreement was reached with the interventionist on three consecutive videos. Once criteria were met, a randomly selected 30% of sessions from baseline and intervention for both participants were coded by Coder 1. Interobserver agreement was calculated by dividing the number of agreements observed by the number of agreements plus number of disagreements and multiplying by 100. Agreement was 100% in all sessions for both participants.

Results

Results for both participants' correct responses for the oral comprehension assessment are displayed in Figure 2. Data documented a functional relation between the dependent and independent variables.

Si

During the first baseline (A1), Si's mean score was 0.75 (range = 0–2). During this phase, Si frequently replied "I don't know" or would ask the interventionist to repeat the question. At the start of the first intervention phase (B1), there was a clear level change from A1 to B1. With B1, Si made gains in his correct responding, achieving the highest possible score of five correct responses. His mean B1 score was 4.4 (range = 3–5). An abrupt decline in correct responses is visible from B1 phase to A2 phase. Si's correct responding continued to decline in A2, resulting in zero correct response rates for the last three sessions. Si's correct response rate in the second baseline (A2) was similar to that of the first baseline (A1) with a mean of 0.8 and a range of 0 to 2. The positive change in correct response rates from A2 to B2 is evident by Si's immediate achievement of the highest possible score. He remained at this rate of correct responses until the conclusion of the study.

During intervention sessions, Si responded to 30 (44.45%) out of 66 secure intentional prompts. He responded verbally to 12, gesturally to two, and combined a verbal and gestural response 16 times. Si responded to 21 (56.75%) of the 37 intentional pauses during intervention. He used a verbal response 13 times and a verbal–gestural response 8 times.

Carter

During the A1 phase, Carter's data demonstrated a stable pattern with no variability. His mean A1 score was 1. There was an immediacy of effect and a clear level change from A1 to B1. Within the B1 phase, Carter's data revealed an ascending trend resulting in the highest possible score of five correct responses for the last session in that phase. His mean B1 score was 4 (range = 3–5). Carter's data showed a negative level change from B1 to A2. His mean A2 score was 0.5 (range = 0–1). Although Carter's first data point of B2 overlapped with his first and third data point of A2, he continuously increased correct responses, resulting in achieving the highest possible score of five correct responses in the last session. His second intervention (B2) mean score was 3.4 (range = 1–5).

Out of 66 secure attention prompts during intervention, Carter responded to 20 of the prompts (30.30%). He responded verbally to 14 and gesturally to one. He used a verbal–gestural response 6 times. Carter responded to 21 of 37 (56.75%) intentional pauses. He used a verbal response 10 times, a gestural response 3 times, and verbal–gestural response 8 times.

Social Validity

Both mothers stated that the intervention was important for their child. They expressed that since the intervention, both Si and Carter have been eager to read at times in addition to bedtime. In addition, while participating in reading activities with their children, both mothers reported that Si and Carter were more involved in asking and answering questions about the books. When asked whether they felt they were able to implement the intervention, both mothers felt confident in their ability to do so. Carter's mother stated that she had begun to use RECALL secure attention prompts, as they seemed to gain Carter's attention. In addition, when viewing the video clips, both mothers stated that their children asked and answered questions and remembered more information about the book during intervention.

Both children said they enjoyed reading with the interventionist. They also said they liked all parts of the intervention materials—the books, visuals, and the concept map. Si and Carter's mothers were sitting with children when social validity data were gathered and they both agreed with the child's responses.

Discussion

This single-case reversal design study examined the effect of an intervention package that combined the use of a concept map as a visual support with RECALL on the ability of two 5-year-old children with ASD to answer comprehension questions from science textbooks. RECALL is a shared reading activity that combines systematic prompts and an instructional sequence found in dialogic reading. In addition, RECALL incorporates a prompting hierarchy and visual supports that help children with ASD answer reading comprehension questions. Results of the study indicated that the participants increased their ability to answer fact- and inference-based questions relating to science text.

The findings of this study support findings of other studies assessing the outcomes of instructional approaches to teach science to students with ASD. Research in science education has indicated learners with and without disabilities have benefited from the use of concept maps by learning, retaining, and understanding more when the concept maps are used in instruction (Anderson-Inman et al., 1998). With the use of a concept map, individuals with ASD have a visual support to connect new information to existing knowledge (Novak & Gowin, 1984). Visual supports as part of an intervention package have been shown to be effective in teaching learners with ASD science concepts and vocabulary (Carnahan & Williamson, 2013; Knight et al., 2013). In addition, several studies have documented that the use of systematic and/or explicit instruction included within an instructional package increased the ability of students with ASD to comprehend science text (Carnahan et al., 2016; Jimenez et al., 2014; Knight et al., 2012). The intervention package used in this study incorporated systematic instruction in the form of RECALL prompts and the use of visuals in the form of a concept map and RECALL visual response options to increase the ability of young children with ASD to answer comprehension questions related to science text.

The outcomes of this study expand our knowledge of effective interventions when teaching science to learners with ASD. The context in which instruction occurred (i.e., shared reading) in this study has not been an instructional context in other studies. RECALL has increased the reading comprehension and language skills of young children with ASD when reading fiction (Whalon et al., 2015; Whalon et al., 2016), but this study provides evidence that shared reading adapted to meet the needs of learners with ASD may provide a developmentally appropriate context in which academic content (such as science) may be learned by young children. In addition, the only other study using a concept map to teach science content (Roberts & Joiner, 2007) included middle school students. The results of this study indicate that concept maps may be effective in teaching younger student's science content.

The concept map in this study served as a visual support that helped participants correctly answer comprehension questions. Participants were supported to discover correct answers to use when building the concept map by RECALL visual response options and systematic instruction to select the correct answer. The utilization of the concept map allowed the participants to focus on the detail of one

question at a time; however, by consistently adding another visual to the concept map and reviewing answers to questions, it helped them "see" the big picture by creating a schematic network that capitalized on the strengths of their visual processing skills and provided guidance to overcome the difficulty of seeing the comprehensive picture as a result of WCC. Similar to studies completed by Carnahan and Williamson (2013) and Knight et al. (2013), in which a Venn diagram was used, the concept map assisted in aiding the participants to correctly answer fact- and inference-based questions. In this study, however, the concept map helped participants answer questions without the use of the concept map in the assessment procedures. This may be an indication that the concept map not only supports the initial learning of science content but also helps students retain the information as evidenced by the participants' abilities to answer questions without the use of the concept map in the oral comprehension assessment. Roberts and Joiner (2007) also found that a concept map enhanced retention.

Social validity outcomes indicate that both children enjoyed participation. Both mothers noticed a positive change in their child's ability to attend to and answer comprehension questions during the shared reading. Furthermore, the interventionist and the participants' mothers had informal conversations about the children throughout the study. In one of these conversations, Si's mother reported that Si told her he was excited that science was on his new kindergarten schedule because he knew a lot about science since working with the interventionist. Carter's mother shared that Carter began wanting to check out science books from the library.

Implications for Intervention

Although persons with ASD can benefit from visual supports, individual considerations need to be made when constructing visuals. As example, some of the visuals used in this study were considered "scary" or "cute" to Carter. This resulted in Carter not selecting visuals considered "scary" even if the scary picture was the correct response. In addition, Carter would select a response he considered "cute" even when it was the wrong response. Also, organizing the concept map on an individualized basis may be needed. Carter did not like that the question number did not match the numbers on the concept map and that the Velcro© was not aligned to the boxes on the concept map.

Although the books used in this study were designed for preschool- and kindergarten-age children, the vocabulary in the books was occasionally too advanced for the participants. At times, the participants would ask the interventionist to further explain what words meant. Therefore, a preassessment prior to reading and, if necessary, a vocabulary lesson to enhance comprehension and promote language skills might be considered.

Limitations

Having a convenience sample of participants is a limitation that should be noted. Generalizability of results to other population of learners is also limited because of the small number of participants in this study. Furthermore, the generalization of intervention effects to other settings, persons, books, and academic subjects is unknown because generalization probes were not conducted in the study. In addition, similar to other studies to teach science to learners with disabilities that utilized an intervention package, it is not possible to discern if the concept map or RECALL alone would result in the same positive outcomes as the intervention package.

Implications for Future Research

Despite the importance of science in the education of children with ASD, few studies that focused on interventions to increase children's ability to comprehend science text have been conducted, particularly with young children. Because of the promise of the effectiveness of using a concept map and the context of shared reading for this purpose, additional research assessing the effectiveness of these interventions is needed. Furthermore, additional research needs to be conducted to determine whether children retain the content of what is learned during shared reading during RECALL using a concept map.

More research is needed to assess the effectiveness of the intervention strategies to teach science in natural environments and in other content areas. Future research should explore whether teachers and parents can implement the intervention with fidelity in classroom and home settings. Although RECALL has been implemented in preschool settings (Whalon et al., 2015), the intervention was conducted by a researcher, not the classroom teacher. Although parents of children with ASD often find it difficult to engage in shared book reading with their children, parents can be taught strategies to support their children's skills within the context of shared reading (Fleury, 2015; Tipton et al., 2017).

Because technology is increasingly utilized in education, incorporating the use of an iPad or other technology to create the concept map and RECALL visuals would be an alternative way to expand the findings from the current study. Research indicates technology instruction has many advantages for learners with ASD (Grynszpan et al., 2014). Therefore, used appropriately, technology may be a tool to assist individuals with ASD to help improve reading comprehension of science text.

Conclusion

Students with ASD benefit from learning science in many ways. On an everyday level, science helps students understand their natural world. STEM education, including

science, helps students develop problem-solving skills and critical analytical thinking abilities. Furthermore, learning science in preschool, elementary, and secondary education experiences may support future college and vocational training in a STEM-related field. For these reasons, along with the focus on access to the general education curriculum for students with ASD and other disabilities, finding effective instructional strategies to support learners with ASD to learn science is critical. This study provides evidence that adapted shared reading combined with a concept map may hold promise to be such an intervention for young children with ASD.

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