TEACHING SENTENCE WRITING TO STUDENTS WITH AUTISM AND COMPLEX COMMUNICATION NEEDS USING MATRIX TRAINING, RESPONSE PROMPTING, SENTENCE FRAMES, AND SPEECH-GENERATING DEVICES

by

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ABSTRACT

MONIQUE PINCZYNSKI. Teaching sentence writing to students with autism and complex communication needs using matrix training, response prompting, sentence frames, and speech-generating devices. (Under the direction of DR. CHARLES L. WOOD)

Approximately 30% of individuals with autism have complex communication needs (CCN). These individuals are unable to use vocal speech as their primary form of language and typically require support across several areas of communication such as comprehension, pragmatics, phonology, semantics, and syntax (Ganz et al., 2022; Reichle, 2019). Researchers have found that communication skills can greatly impact academic, behavioral, social, and postsecondary outcomes (Carter et al., 2012; Chiang, 2008; Matson et al., 2013; Park et al., 2012; Pillay & Bronlow, 2017). Fortunately, augmentative and alternative communication (AAC) has been effectively used to increase communication for individuals with intellectual and developmental disabilities (IDD; Crowe et al., 2022). Most often, individuals with autism are only taught to request using single words or short phrases using AAC devices (Ganz et al., 2017; Muharib et al., 2018; Tincani et al., 2020). Another way to expand communication through AAC is to teach sentence structure. Researchers have used an intervention package consisting of response prompting, sentence frames, and technology like AAC to teach students with autism and CCN to construct sentences (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). Additionally, matrix training has been used as a generative framework to increase language for individuals with autism who use vocal speech (Frampton et al., 2016, 2019; Jimenez-Gomez et al., 2019; Kohler & Malott, 2014) and AAC (Marya et al., 2021; Naoi et al., 2006; Nigam et al., 2006; Tönsing et al., 2014). This researchers examined the effects of matrix training, response prompting, and sentence frames on sentence writing of four students, ages 10–18 years, with ASD and CCN in a specialized private school located in the southeastern United States. Three teachers, ages 23–46 years, served as the interventionists in the study. A series of A-B designs with modifications were used to examine the effects of the intervention package on the percentage of trained and untrained correct sentences, percentage of subject-verb combinations, and the percentage of correct word selections. Teachers presented photos of subject-verb combinations for students to write about using pre-programmed arrays with words and symbol supports on speech-generating devices. Overall, results indicated that across all interventions, there were no effects on the percentage of trained and untrained correct sentences and subject-verb combinations for all participants. Two students, however, increased their percentage of correct word selections. Overall, teachers found the intervention acceptable and beneficial for students in the classroom. Furthermore, three of four students preferred this writing intervention over their typical writing instruction in the classroom. Implications of this study provide several considerations for practitioners to use matrix training to teach subject-verb combinations and/or sentence writing with students who have autism and CCN.

DEDICATION

I dedicate this dissertation to my previous students who had complex communication needs and their families. This work is a testament of the profound impact you've had on my life. Thank you for your openness, your courage, and sharing your lives with me.

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CHAPTER 1: INTRODUCTION

Statement of the Problem

Communication skills can greatly impact one's quality of life, as they are used to get basic wants and needs met, foster relationships, promote self-advocacy, and participate meaningfully in educational, employment, and community settings. These skills emerge early in a child's development, through crying at around 9 months of age to using sentences in back-and-forth exchanges by age 4. Over time, these skills progress and are used for multiple purposes across a variety of settings in everyday life. Unfortunately, individuals with complex communication needs (CCN) who are unable to use speech as their primary mode of communication, including many with autism spectrum disorder (ASD) face barriers in acquiring these crucial skills.

Although barriers exist, having access to communication supports and using those supports to communicate is a human right. In 2016, The National Joint Committee for the Communication Needs of Persons with Severe Disabilities (NJC) outlined a Communication Bill of Rights (Brady et al., 2016). This bill of rights outlined 15 fundamental communication rights for people with severe disabilities. Some of these rights included the right to social relationships; to request and refuse things, events, or people; to share feelings, preferences, and opinions; to ask for and receive information; to improve communication; to access all settings to engage in communication with others; and be treated with dignity and respect. Thus, practitioners need evidence-based practices (EBPs) to ensure the communication rights of individuals with CCN are upheld.

Students with ASD who have Complex Communication Needs

ASD is a developmental disability characterized by persistent challenges in social communication, restricted interests, and repetitive behavior (American Psychiatric Association, 2013). Individuals with ASD may have difficulty acquiring a range of social communication skills including using verbal and nonverbal communication, initiating conversations, responding to social interactions, to developing and maintaining relationships. In fact, approximately 30% of individuals with ASD have CCN (Hughes et al., 2023; Rose et al. 2016; Tager-Flusberg & Kasari 2013). CCN is a term used to describe “people with severe disabilities who are not able to use speech as their primary communicative means and may have significant communication comprehension and production delays in multiple areas of communication (i.e., pragmatics, phonology, semantics, and syntax)” (Reichle, 2019, pp. 842–843).

Children who do not develop effective communication skills may be impacted across academic, behavioral, social, and postsecondary outcomes (Carter et al., 2012; Chiang, 2008; Matson et al., 2013; Park et al., 2012; Pillay & Bronlow, 2017). Researchers have found that students who have difficulty with communication and social skills are more likely to be placed in separate educational settings away from peers without disabilities (Eaves & Ho, 1997; Lauderdale-Littin et al., 2013; White et al., 2007). Recent data suggest that these segregated settings may not provide specialized and intensive instruction but may be characterized by passive student engagement and few opportunities to respond (Kurth et al., 2016; Pennington & Courtade, 2015). Additionally, communication has been correlated with higher levels of reading and math skills (Kleinert et al., 2015).

Difficulty with communication skills also has been associated with higher levels of challenging behavior (Chiang, 2008; Matson et al., 2009; Park et al., 2012) as learners acquire challenging behavior in lieu of conventional communication skills to access powerful reinforcers. Furthermore, restrictive interventions, such as restraint and seclusion are more likely to be used with individuals with communication support needs (Richardson et al., 2020). As students grow into adulthood, these early communication skills also predict challenging behavior into adulthood, including self-injurious behavior (Rattaz et al., 2018).

Furthermore, communication skills are related to developing friendships and accessing employment opportunities. Children with ASD have been found to have fewer friendships than their peers without disabilities (Kasari et al., 2011) and are more likely to be bullied or victimized (Matthias et al., 2022). This may be due to a link between communication skills and social relationships (Friedman et al., 2019). Finally, communication has been associated with higher rates of employment for individuals with disabilities (Carter et al., 2012; Pillay & Bronlow, 2017).

Evidence-based Practices (EBPs) for Students with ASD and CCN

Numerous EBPs have been identified to improve communication for individuals with ASD such as discrete trial training, social skills training, functional communication training, and naturalistic interventions (National Autism Center, 2015; Steinbrenner et al., 2020). A majority of these EBPs are rooted in the science of Applied Behavior Analysis (ABA) using strategies such as environmental arrangement, prompting, and reinforcement. For young children with ASD, these EBPs are often used to increase vocal communication skills. However, for individuals with ASD who do not acquire spoken language, augmentative and alternative communication (AAC) can effectively support communication.

AAC includes aids or techniques that supplement or replace vocal communication. These systems can be unaided requiring no additional equipment (e.g., sign language, gestures, body language) or aided, requiring additional equipment (e.g., tablets, computers, electronic eye gaze). Aided systems can range in technological complexity from low-tech options using non-electronic systems like printed picture communication symbols to mid- and high-tech options that use electronic devices to supplement speech like BIGmack (AbleNet, Inc., 2023) or an iPad with Proloquo2Go (AssistiveWare B.V., 2023). For students with ASD and CCN, studies have shown that AAC is effective in increasing communication skills (Andzik & Chung, 2022; Clarke et al., 2011) and speech production (White et al., 2021). Additionally, researchers have found that for students with intellectual and developmental disabilities, aided AAC has produced larger increases in communication than unaided AAC (Crowe et al., 2022).

One type of high-tech aided AAC frequently used with students with autism is speech-generating devices (SGDs). A SGD is an electronic device that emits human-recorded digitized speech or synthesized speech to supplement or replace spoken speech (Reichle et al., 2016). Researchers have shown that SGDs are effective in increasing communication skills for individuals with ASD (Ganz et al., 2017; Muharib & Alzrayer, 2018) and decreasing challenging behavior (Walker & Snell, 2013); there also is some evidence that they are preferred over other types of AAC (McLay et al., 2015).

A majority of the research on using SGDs to increase communication skills for students with ASD has focused on teaching students with ASD to request, using single words or short phrases (Ganz et al., 2017; Muharib et al., 2018; Tincani et al., 2020). To fully support students with ASD and CCN to communicate across a wide range of functions and forms, researchers have urged that future research should address more complex communication skills beyond making single word requests (Ganz et al., 2017; Logan et al., 2017). One way to expand the complexity of communication skills targeted for students with CCN who use AAC is to teach sentence writing.

Expanding Communication Through Writing Instruction

Writing is a powerful form of communication that can be used to support individuals with ASD. Researchers have studied teaching a variety of writing skills to students with ASD and CCN such as spelling (Schlosser et al., 1998; Schlosser & Blischak, 2004), sentence construction (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018), and story writing (Bedrosian et al., 2003; Pennington et al., 2011, 2014). Researchers have frequently used software applications like SGDs in that they displayed words and graphic symbols from which students made selections and upon selection, emitted synthesized speech. Software applications were primarily used on mobile tablets and included Clicker Sentences (Crick Software Inc., n.d.), Clicker 5 (Crick Software Inc., 2005), GoWrite (Attainment Company, Inc., n.d.), or Pixwriter (Slater & Slater, 1994).

Researchers also commonly employed response prompting procedures as a component of their intervention packages. Response prompting procedures consist of presenting a prompt after presenting the direction or some instructional stimulus to increase the likeliness of the student responding correctly (Collins, 2021). The literature on teaching writing to students with ASD and CCN indicates that researchers have used constant time delay and simultaneous prompting most often.

Several research teams have combined response prompting procedures and technology-aided intervention to teach students with ASD and CCN to use sentence frames in their writing (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). Researchers have used different types of sentence frames ranging from three-word requests (e.g., I want car.), subject-verb relations (e.g., The boy is running.), subject-adjective relation (e.g., The ball is red.), to subject-verb-object relations (e.g., The monkey is eating banana.). These frames were used to write about a variety of stimuli including physical reinforcers (e.g., toys, snacks) and photos depicting subject-verb relations and noun-adjective relations. For example, Pennington, Flick, et al. (2018) taught students to write sentences about reinforcers and photos of animals using the sentence frames, I want a (noun), I see a (noun), and The (subject) (verb). To date, most studies have involved teaching students to write about printed photos of animals (Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018) and digital photographs (Pennington et al., 2021).

Throughout these studies, it is important to analyze the strategies used to promote and/or assess generalization of outcomes across time, settings, and behaviors. Researchers most often have programmed for generalization by using multiple stimuli to write about and teaching a variety of sentence frames. For example, researchers used between 3 and 10 different stimuli for students to write about during intervention (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). Additionally, after teaching sentence frames researchers have assessed generalization by presenting novel stimuli or contexts. For example, after teaching students to write three different types of sentences about photos of animals, Pennington, Foreman, et al. (2018) asked students to write about a topic of their choice. In another study, Pennington and Rockhold (2018) presented novel photos of animals after intervention and used a trained photo in a book to assess response generalization.

One type of generalization that researchers have not explored with sentence writing is recombinative generalization. Recombinative generalization involves students responding to novel combinations of learned skills (Goldstein, 1983). For example, if a student is taught to write the subject-verb phrases “dog jumping,” “cat sitting,” and “bird drinking,” then they may acquire novel combinations of these skills without training such as “dog sitting,” “cat drinking,” and “bird jumping.” Programming for recombinative generalization can support practitioners who face many barriers to implementing effective communication instruction including time, staff training, and staff turnover (Pennington et al., 2021) by leveraging these resources to teach a smaller number of skills that can be recombined to produce novel skills.

Promoting Generative Responding Through Matrix Training

Matrix training is a procedure that can be used to program for recombinative generalization. It involves organizing two or more skill components (e.g., subjects and verbs) in a table (i.e., matrix) so that when they are combined, multiple combinations are formed. Individual skill components are placed on the vertical and horizontal axes, and the combinations are within each cell (see Figure 1). Then a teaching procedure is selected to plan for which combinations will be directly taught and which combinations will be assessed for recombinative generalization.

There are two general teaching procedures used within the context of matrix training: diagonal training and stepwise training (Frampton & Axe, 2022). Diagonal training involves teaching responses along the diagonal of the matrix first, then assessing nondiagonal combinations for generative responding. Stepwise training involves teaching the diagonal combinations and the cell to the right of each diagonal, creating a stair-step pattern. Researchers have used diagonal training when the individual components across the axes are known (e.g., Axe & Sainato, 2010; Frampton et al., 2016) and stepwise training when some or all the individual components are unknown (e.g., Curiel et al., 2018; Kinney et al., 2003; Pauwels et al., 2015).

Figure 1

Matrix (Diagonal Training)			
	girl	boy	mouse
cooking	girl cooking	*boy cooking	mouse cooking
reading	girl reading	boy reading	*mouse reading
hiding	*girl hiding	boy hiding	mouse hiding

Example of Matrix Training Diagonal and Stepwise Training

Note. Grey cells represent trained cells in diagonal training and * notes additional cells trained in stepwise training.

In a recent systematic review, Kemmerer, and colleagues (2021) found that matrix training has been used with a wide range of individuals including those with ASD, intellectual disability, and speech and language disorders. Researchers have predominately used matrix training to target language skills such as listener discrimination (e.g., Axe & Sainato, 2010; Curiel et al., 2016, 2018; Ezell & Goldstein, 1989) and labeling or tacting (e.g., Frampton et al., 2016, 2019; Jimenez-Gomez et al., 2019; Kohler & Malott, 2014). It also has been used to target academic skills such as telling time (Curiel et al., 2020), spelling (Tanji & Noro, 2011), and play skills (Dauphin et al., 2004; MacManus et al., 2015; Wilson et al., 2017).

For students with ASD, matrix training has primarily been used to increase expressive labeling, also known as tacting (Curiel et al., 2020). Tacting involves a presentation of a stimulus (e.g., teacher presents a book) and then producing a name or label (e.g., student says “book”). Most of the literature on matrix training for tacting skills has involved participants who use vocal speech as their primary communication mode. For example, Frampton et al. (2016) used matrix training to teach animal-verb tacts to students with ASD. The researchers presented an animal figurine completing an action and asked, “What’s happening?” Students responded vocally (e.g., “dog jumping”).

Only five research teams have used matrix training to teach responding using AAC. Three teams taught combining picture communication symbols (Naoi et al., 2006; Nigam et al., 2006; Tönsing et al., 2014). One research team taught combinations using picture and text icons on speech-generating devices (Marya et al., 2021). Finally, Yamamoto and Miya (1999) used a computer program that displayed a photo and Japanese words with which to construct a sentence.

To date, only one team has used matrix training to teach sentence construction to students with ASD (Yamamoto & Miya, 1999). The remaining matrix training literature on tacting has used one-to-three-word responses such as “boy drinking” or “boy drinking milk” without using a sentence frame such as “The boy is drinking milk.” There is a need for more research to examine the effects of matrix training on sentence writing using alternative modes of communication to fully support students with ASD and CCN to communicate for a wide range of purposes and across different audiences.

Purpose Statement and Research Questions

The purpose of this study was to extend the current knowledge on the effectiveness of matrix training to teach sentence writing skills using subject-verb combinations to students with ASD and CCN. In this study, I evaluated the effects of an intervention package consisting of matrix training, sentence frames, and response prompting on sentence writing for students with ASD and CCN.

Research Questions

1. Is there a functional relation between matrix training, response prompting, and sentence frames and the percentage of trained and untrained sentences written for students with ASD and CCN?
2. Is there a functional relation between matrix training, response prompting, and sentence frames and the percentage of trained and untrained subject-verb combinations for students with ASD and CCN?
3. How do teacher and student participants perceive the feasibility and overall effects of the intervention package?

Significance of the Study

This study contributed to the literature in several ways. First, it added to research on teaching writing to students with CCN by using generative instruction through matrix training. This will provide future practitioners with a technology to teach generative sentence writing to students with CCN. Next, it added to the literature on matrix training as this represents the first study where researchers taught subject-verb combinations using sentence frames with students who use SGDs. Only one study has used matrix training with students who used SGDs (Marya et al., 2021). Expanding the matrix training literature to additional students with CCN who use SGDs is important due to the large population of individuals with ASD who use AAC. Additionally, only one research team has investigated the use of matrix training to teach sentence writing (Yamamoto & Miya, 1999). The contributions from this study provided implications for providing communication and writing interventions to students with CCN.

Delimitations

Several delimitations should be discussed to situate future findings. First, the use of a single-case design with a limited number of participants limits the generalizability of the results of this study. Second, it is possible that covariation may occur within the multiple probe across behaviors design. For example, a student may learn to recombine subject-verb combination after intervention in Matrix 1 and then may not need intervention in Matrix 2 or 3. To control for this, I used a multiple probe across participants design. Last, the setting of the study was highly controlled in that teachers worked with students in a one-on-one, limiting external validity to group settings.

Definition of Terms

Aided Communication Mode: A mode of communication that uses additional equipment ranging from low-tech systems (e.g., picture communication boards) to high-tech systems (e.g., SGDs; Johnston et al., 2012).

Antecedent: "An environmental condition or stimulus change existing or occurring prior to a behavior of interest" (Cooper et al., 2020, p.786).

Augmentative and Alternative Communication: Aids or techniques used to supplement or replace an individual's vocal or verbal communication skills (Mustonen et al., 1991).

Autism Spectrum Disorder: A neurological disorder that is characterized by challenges in social communication, restricted interests, and repetitive behaviors (American Psychiatric Association, 2013).

Behavior: "That portion of an organism's interaction with its environment that involves movement of some part of the organism" (Cooper et al., 2020, p. 787).

Complex Communication Needs: A term referring to individuals with severe disabilities who do not use speech and have difficulty in other areas of communication (Reichle et al., 2019)**.**

Consequence: A stimulus change that follows a behavior of interest (Cooper et al., 2020).

Discriminative Stimulus: "A stimulus in the presence of which a given behavior has been reinforced and in the absence of which that behavior has not been reinforced; as a result of this history, a discriminative stimulus evokes operant behavior because its presence signals the availability of reinforcement" (Cooper et al., 2020, p. 790).

Generalized Conditioned Reinforcer: "A conditioned reinforcer that as a result of having been paired with many other reinforcers does not depend on an establishing operation for any particular form of reinforcement for its effectiveness" (Cooper et al., 2020, p. 793).

Graphic Symbol: **"**Two- or three-dimensional representations of objects and concepts" (Johnston et al., 2012, p. 26).

Intraverbal: **"**An elementary verbal operant involving a response that is evoked by a verbal discriminative stimulus that does not have point-to-point correspondence with that verbal stimulus" (Cooper et al., 2020, p. 794).

Mand: **"**An elementary verbal operant involving a response of any form that is evoked by an MO and followed by specific reinforcement" (Cooper et al., 2020, p. 794).

Matrix Training: A procedure, that programs for generative instruction, which involves teaching a set of skills so that other skills emerge without direct training (Axe & Sainato, 2010).

Minimally Verbal: Describing an individual using fewer words than expected relative to age (Koegel et al., 2020).

Nonverbal: Describing an individual who has no consistent words or approximations of words (Koegel et al., 2020).

Nonverbal Stimulus: Physical aspects of the environment that are not the products of a speaker's verbal behavior (Sundberg, 2016).

Recombinative Generalization: "…differential responding to novel combinations of stimulus components that have been included previously in other stimulus contexts" (Goldstein et al., 1983, p. 281).

Reinforcement: "A basic principle of behavior describing a response-consequence functional relation in which a response is followed immediately by a stimulus change that result in a similar responses occurring more often" (Cooper et al., 2020, p. 798).

Response: "A single instance or occurrence of a specific class or type of behavior" (Cooper et al., 2020, p. 798).

Speech Generating Device: "… are electronic devices that rely on the speaker's pressing of a picture, word, or other symbol depicting an item, activity, response, or statement on an electronic screen with enough force to evoke a synthetic speech output" (Lorah et al., 2015, p. 3793).

Stimulus: "An energy change that affects an organism through its receptor cells" (Michael, 2004, p. 7).

Tact: "An elementary verbal operant involving a response that is evoked by a nonverbal discriminative stimulus and followed by generalized conditioned reinforcement. Tacting allows a speaker to identify or describe the features of the physical environment" (Cooper et al., 2020, p. 801).

Unaided Communication Mode: "Refer to methods of communication that do not involve additional equipment (e.g., speech, facial expressions, body language, gestures, sign language, sign systems) (Johnston et al., 2012, p. 26).

Verbal Behavior: Any behavior that is reinforced through the mediation of another person (Skinner, 1957, pp. 1-2).

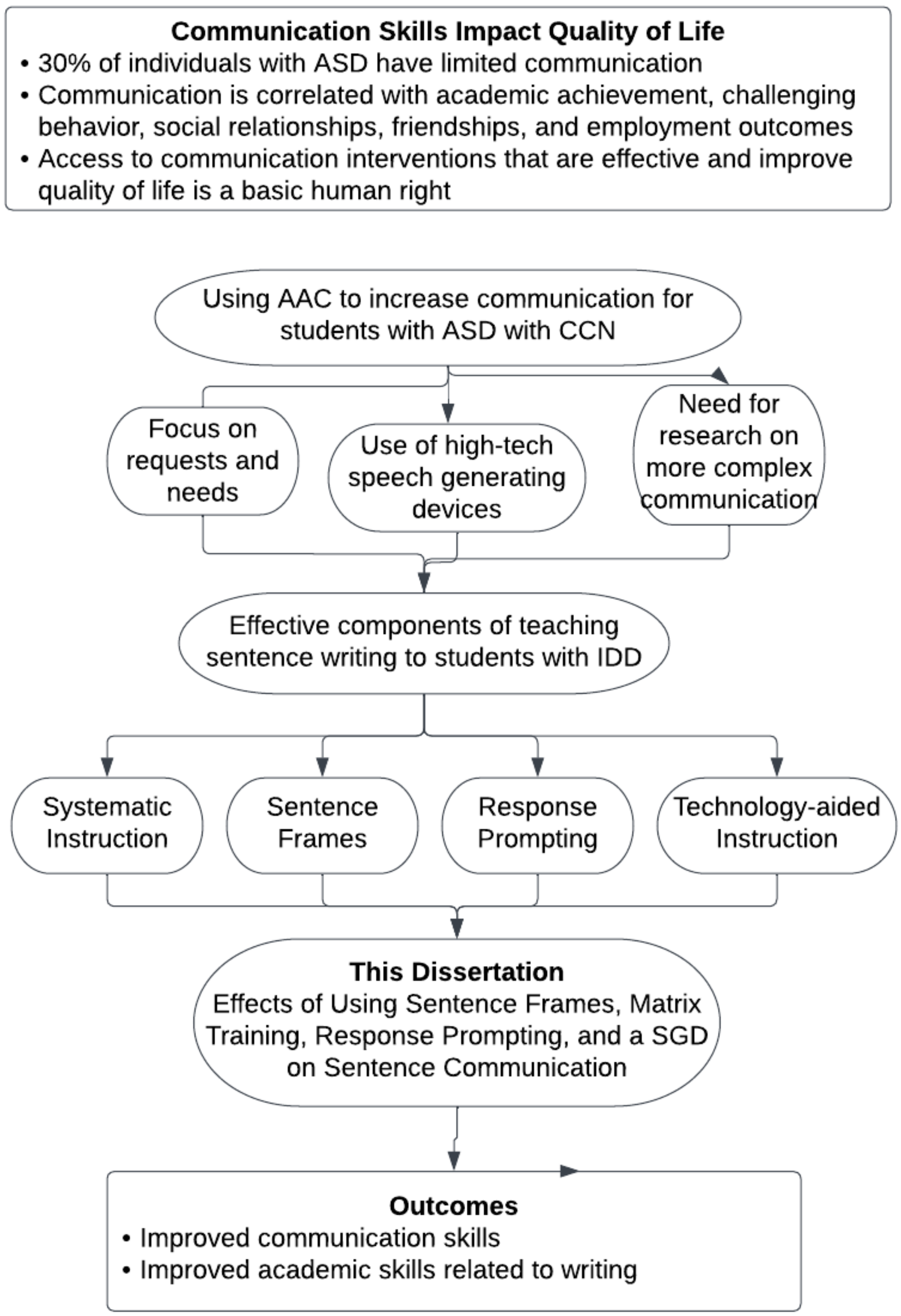
Verbal Operant: The fundamental unit of verbal behavior defined by sources of antecedent and consequent control (Tincani et al., 2020).

Verbal Stimulus: "The product of earlier verbal behavior" (Skinner, 1957, p. 65).

CHAPTER 2: LITERATURE REVIEW

This chapter will begin by introducing the theory of Verbal Behavior (Skinner, 1978) followed by a literature review of three strategies used to increase communication for individuals with CCN. The first section will review literature on using AAC to increase verbal behavior for individuals with ASD. Next, I will review literature on writing instruction for students with CCN. Last, I will review the literature on matrix training to increase communication for students with ASD. Below, Figure 2 presents a graphic model of the literature review for this study.

Figure 2



Logic Model

Behavioral Strategies to Increase Communication

Traditional approaches to language intervention for individuals with ASD have focused on receptive (understanding others) and expressive language (communicating with others), targeting skills such as labeling, requesting, answering questions (Sundberg & Michael, 2001). Since the early 2000's, however, there has been a significant increase in the use of language interventions that are rooted in B.F. Skinner's theory of Verbal Behavior. This theory focuses on the function of language compared to traditional linguist theories that focus on the structure or meaning of words (Sundberg & Michael, 2001).

In his seminal text, Verbal Behavior (1957), Skinner defined verbal behavior as any behavior that is reinforced through the mediation of another person (p. 1-2). Like nonverbal behavior, he analyzed verbal behavior through the functional relation between responses and the environment. He classified verbal behavior into verbal operants that were distinguished by the types of antecedent stimuli that evoked them and the consequences that followed and strengthened them. Next, I will describe the basic unit of analysis of behavior to further understand how verbal behavior is acquired.

In the field of behavior analysis, the three-term contingency is known as the basic unit of analysis (Glen et al., 1992). It examines the relation between antecedent stimuli, behavior, and consequences to understand nonverbal and verbal behavior. A stimulus is "an energy change that affects an organism through their receptor cells," thus it can be detected through a range of senses (e.g., sight, smell, sound, touch; Michael, 2004, p.7). Stimuli can be categorized as verbal, by being products of prior verbal behavior (e.g., the written word "dog," a spoken word, a text message) or nonverbal, being physical aspects of the environment that are not usually a product of a speaker's verbal behavior (e.g., seeing a dog; Sundberg, 2016).

In the three-term contingency, the antecedent is an environmental condition, or a stimulus change that immediately precedes a specific response. Verbal behavior is evoked by three types of antecedent conditions including motivating operations, non-verbal discriminative stimuli, and verbal discriminative stimuli. Motivating operations are environmental variables that increase or decrease the reinforcing effect of stimuli, objects, or events (Cooper et al., 2019). These include unconditioned motivating operations that have no prior learning history (e.g., hunger, sleep deprivation, becoming too cold or hot) and conditioned motivating operations that are a result of a person's learning history (e.g., the value of money increases after being paired with other reinforcers). For example, a learner who is hungry (unconditioned motivating operation) may see a snack drawer for the first time (nonverbal stimulus) and ask, "Can I have a snack?" (response). If over time the teacher reinforces this response by letting the student chose a snack from the drawer, the snack drawer becomes a discriminative stimulus. A discriminative stimulus is "a stimulus in the presence of which a given behavior has been reinforced and in the absence of which that behavior has not been reinforced; as a result of this history, a discriminative stimulus evokes operant behavior because its presence signals the availability of reinforcement" (Cooper et al., 2019, p. 790). In the prior example, the snack drawer functioned as a nonverbal discriminative stimulus. Verbal stimuli can also evoke verbal behavior. For example, a teacher might ask "What's your name?" (verbal stimulus), the student responds "Charlie" (behavior), and the teacher responds with, "Thank you" and a high five (consequence).

The behavior or response in the three-term contingency refers to a single instance of behavior. Behavior can be analyzed by its form or topography and its function. In terms of verbal behavior, understanding the different types of response forms that can be used to communicate can help support diverse learners. In the previous example, the learner emitted vocal responses

("Can I have a snack?"). However, any response that is mediated by another person is considered verbal behavior including gestures, using picture communication symbols, sign language, text messaging, and etc. For example, a teacher might ask "What's your favorite food?" (verbal stimulus), a student responds by handing a picture communication symbol of pizza to the teacher (behavior), and the teacher responds with, "Yum, I love pizza" (consequence).

Lastly, consequences delivered in the form of reinforcement or punishment affect the future frequency of behavior. For example, when a student is learning to request items, the teacher may present a goldfish and say "goldfish" (antecedent), the student mimics the teacher's behavior by saying "goldfish" (response), and then the teacher delivers a goldfish to the student to consume (consequence). In this example, the goldfish is now a discriminative stimulus in that it signals the availability of reinforcement. Now the student is more likely to request goldfish when the snack is presented. This describes the process of stimulus control, where the behavior of saying "goldfish" is more likely to happen in the presence of the discriminative stimulus (Cooper et al., 2019).

Using these basic principles, Skinner classified verbal behavior by the antecedent conditions that evoked verbal behavior and the consequences that strengthen it. In the next section, I will briefly describe the basic verbal operants including (a) mands, (b) tacts, (c) echoics, and (d) intraverbals. One of the most essential verbal operants, the mand, permits speakers to control their environment through requesting access to preferred stimuli and escape from unpleasant situations. The mand is controlled by a motivating operation of either being in a state of deprivation or the presentation of an aversive situation and is reinforced by a specific corresponding consequence. For example, if a child has been running around the playground on a hot day, after some time they have become deprived of water so they ask their teacher, "Can I have some water please?” This results in access to water, which is the specific reinforcer. Mands are important for early learners to acquire because they allow them to control the delivery of reinforcers and establish beginning speaker and listener roles (Sundberg & Michael, 2001).

As learners become proficient in requesting stimuli in their environment, they also begin to name or tact stimuli. A tact is a verbal operant controlled by a nonverbal discriminative stimulus and is reinforced by generalized conditioned reinforcers (e.g., social praise). For example, a tact can be observed when a child sees a dog on their walk (nonverbal discriminative stimulus) and says “dog” to their mom (tact), resulting in the mom saying “Yes, that’s a dog!” (generalized conditioned reinforcement). Tacts are often considered building blocks to more complex verbal operants because once learners can name a variety of stimuli, they can engage in more complex social interactions.

The third type of verbal operant is echoics. Researchers have used echoics extensively to teach other verbal operants (DeSouza et al., 2017). An echoic is a response evoked by a verbal discriminative stimulus that has point-to-point correspondence with the stimulus (i.e., the stimulus and response match) and produces generalized conditioned reinforcement. For example, while holding a toy car a teacher says, “car” (verbal discriminative stimulus), the student responds by saying “car” (echoic), and the teacher reinforces this response by saying “That’s right this is a car!” (generalized conditioned reinforcement).

The last verbal operant Skinner described was the intraverbal. An intraverbal is evoked by a verbal discriminative stimulus whose response does not have point to point correspondence (i.e., the stimulus and response do not match) and results in generalized conditioned reinforcement. This type of verbal behavior comprises most conversational skills such as answering questions, making statements, and commenting on a topic of interest. For example, if a learner says “10:30 am,” in response to “What time does class start?” the verbal behavior of stating “10:30 am” would be considered an intraverbal. Developing a strong intraverbal repertoire is important for engaging in everyday conversational acts. However, some students with ASD have difficulty acquiring these skills even when they have robust mand and tact repertoires (Sundberg & Michael, 2001).

Over the last several decades, researchers have successfully taught different verbal operants to individuals with ASD and/or developmental disabilities using behavioral interventions (DeSouza et al., 2017; Oah & Dickinson, 1989; Sautter & LeBlanc, 2006; Sundberg & Michael, 2001). For young learners receiving early intervention, there is typically a focus on increasing these verbal operants using a vocal response mode. However, given that about 30% of the autistic population does not acquire vocal speech (Tager-Flusberg & Kasari, 2013), it is important to consider how these verbal operants can be targeted using augmentative and alternative communication (AAC) for individuals with CCN.

Augmentative and Alternative Communication (AAC)

AAC includes a variety of communication modes that support individuals with CCN to communicate. These communication modes can be aided, requiring external equipment (e.g., pictures, high-tech devices) or unaided, requiring no other equipment (e.g., sign language, gestures). Although both modes can be effective for learners, researchers have found that aided modes generally result in more communication skills (Crowe et al., 2022). Additionally, some AAC users have indicated a preference for aided AAC over unaided AAC (Couper et al., 2014; Lorah, 2016; Lorah et al., 2013; McLay et al., 2015, 2017; van der Meer et al., 2012a).

Aided AAC ranges from low-tech systems using printed photos or icons to high-tech systems using electronic devices. High-tech devices range from single switches that emit a recorded message to applications on iPads such as Proloquo2Go (AssistiveWare B.V., 2023) that generate speech. These high-tech speech generating devices (SGD), also known as voice-output communication aids (VOCA), allow users to communicate using natural or synthesized speech through a variety of electronic devices. SGDs have evolved over time with early technology using battery-operated switches, to static electronic communication boards, and most recently, the use of software applications on mobile devices.

High-tech SGDs have emerged as an evidence-based practice to increase communication skills for individuals with ASD or intellectual disability that have CCN (Morin et al., 2018). Several researchers have analyzed the different types of communicative functions or verbal operants targeted using SGDs, with much of the literature targeting requests or mands (Ganz et al., 2017; Muharib et al., 2018; Tincani et al., 2020). Researchers have suggested this may be due to the communication needs of many individuals with ASD that focuses on supporting basic communication skills such as requests (Tincani et al., 2020) or because of the ease of programming compared to teaching more complex verbal behavior (Ganz et al. 2022). However, to support learners in developing comprehensive functional communication it is important to teach all the verbal operants.

In addition to teaching all the verbal operants, practitioners must focus on the formal properties of student responses. For example, after acquiring one-word mands, learners need to be able to combine words into phrases and/or sentences to better control listener behavior. For example, an early learner might first use the single word “car” to ask for a toy car. Then they might learn to use “two blue cars” to ensure they receive a specific quantity and type of car from a listener. Finally, they use the sentence “Can I have two blue cars please?” to ensure his request is effective across a range of speakers. These expanded responses are essential in conversation for speakers across the lifespan. For example, a speaker might respond to the question "What did you do this weekend?" with, "I went to a movie and swam with some friends."

Teaching learners to combine words into phrases or sentences enables them to be effective communicators and engage in conversation with others around them. There have been three literature reviews that have examined the use of high-tech SGDs to teach communication skills to individuals with ASD (Ganz et al., 2017; Muharib et al., 2018; Tincani et al., 2020). To date, researchers have not analyzed the extant literature to determine the formal properties of intervention targets across the SGD literature. Upon examination of the studies from the following reviews that included individuals with ASD using a high-tech SGD, most researchers taught learners to select a single icon or graphic symbol on their SGD. Below I reviewed studies that incorporated the use of high-tech SGDs to teach verbal operants.

Teaching Manding using High-tech SGDs

The use of high-tech SGDs to teach manding has been heavily explored (Ganz et al., 2017; Muharib et al., 2018; Tincani et al., 2022). Teaching procedures generally involve arranging the environment to motivate the learner to emit a mand (i.e., motivating operation), using response prompting strategies to facilitate student responding (e.g., time delay or system of least prompts), and then providing reinforcement that corresponds with the request. When considering the learner's trained response, most often a single selection on a SGD is trained, which upon selection produces speech output of a single word (e.g., "water") or a full sentence (e.g., "I want water"). For example, Achmadi et al. (2014) taught students to select a single icon that illustrated "MORE" that upon selection emitted "I want more" on the SGD during toy play.

Several other researchers have taught learners to request using "I want" in a sentence however, the sentence frame "I want _____" was not taught as two separate selections (e.g., Achmadi et al., 2012; Agius et al., 2016; Kagohara et al., 2010; van der Meer et al., 2013). This removes the possibility for the learner to construct the sentence word by word. If sentence construction was taught by selecting each word, then the learner may be able to recombine these words into new sentences.

In one of the first studies using a mobile device to teach manding to learners with ASD, Kagohara et al. (2010) conducted a case study to examine the effects of differential reinforcement and delayed prompting on the acquisition of mands by a 17-year-old learner. The learner had previous experience with the iPod Touch and Proloquo2Go application and was able to select preferred items, but often applied insufficient force to activate the voice output. The iPod Touch was programmed with one page containing three graphic symbols: “I want a cookie,” “I want a lolly,” and “I want chips.” During baseline sessions, the research team presented the three items (i.e., cookies, lolly, chips) on a tray out of reach for the learner and said, “Let me know if you want something.” The learner manded for the preferred items, but only activated the voice output for 0 to 30% of sessions. During intervention sessions, the researchers used constant time delay with 0-s and 10-s delay sessions to teach selection activation, which resulted in an increase in responding. Next, the researchers withdrew the intervention and reinforced all responses regardless of device activation which resulted in a rapid decrease in correct responding. Finally, they implemented a 10 s delay condition with differential reinforcement of correct responses which resulted in an immediate increasing level change and stable responding.

In another application using the iPod Touch with Proloquo2Go (Sennott & Bowker, 2009), van der Meer et al., (2011) used a multiple probe across participants design to examine the effects of a SGD with graduated guidance, time delay, and differential reinforcement on requests. Participants included three individuals ages 13, 14, and 23 with intellectual and developmental disabilities and CCN. The researchers designed a single page of icons on the device including, “Can I play with a toy?” “I want a snack please?” and “What’s new with you?” During baseline sessions, the researchers held an iPod in an upright position and in front of the participant, presented preferred items and the directive, “Let me know if you want snacks or toys.” Participants were then given access to toys regardless of requests made on the SGD. Participants emitted 0 responses per minute. During intervention, the researchers used a discrete trial teaching format. First, they presented three errorless trials using a second trainer to deliver physical prompts which resulted in making the correct selection on the iPod. Starting with the fourth discrete trial, they used 10-s time delay trials until each student made three consecutive independent requests. Following training, the researchers implemented procedures identical to those in baseline sessions with the addition of differential reinforcement for independent responses on the iPod. Results indicated that the intervention was effective in increasing requests on the SGD for two of the three participants, and that high levels of responding maintained over time. Like Kagohara et al. (2010), participants often self-corrected when initial responses were of insufficient force to activate voice output. The third participant did not acquire targeted mands and engaged in avoidance behaviors during sessions, so assent was withdrawn following training. Researchers suggested that this may have been since she was previously given access to preferred items freely, and that she found physical prompting aversive.

Next, Achmadi and colleagues (2012) investigated teaching more advanced manding skills to SGD users. They used a multiple baseline across participants design with two male participants with ASD, ages 17 and 13, who had previously learned single step requests on the iPod. The researchers used an iPod Touch with Proloquo2Go (Sennott & Bowker, 2009) that included one main page with the icons “SNACKS” and “TOYS.” Upon selection of “SNACKS” or “TOYS” another page was presented that had either three snacks or three toys displayed which upon selection emitted a full sentence “I want a cookie.” During baseline sessions, researchers presented a tray of snacks and toys along with the iPod touch and presented the directive “Let me know if you want something.” Participants were provided free access to the snacks and toys every 30 s regardless of participants selecting the correct selection on the iPod. During intervention, they used the same procedures as in baseline with the addition of gestural prompts for errors. Upon students selecting the correct response, they were provided with the specific reinforcer. Both participants increased the number of multistep requests after intervention and maintained these skills over time.

As technology has advanced, researchers have used other mobile devices such as the iPad to teach communication skills. For example, Wendt et al., (2019) used a multiple baseline design across participants to examine the effects of a modified Picture Exchange Communication System (PECS; Bondy & Frost, 1994) protocol using an iPad with the application SPEAKall! (Wendt, 2017) for three participants with ASD ages 14–23. None of the participants had experienced previous communication intervention using a SGD. During baseline sessions, researchers presented one edible at a time that was out of reach to the participant with the corresponding graphic symbol on the iPad in front of the participant. After 5 to 10 s, the edible was delivered to the participant whether they requested it or not. Then, participants were taught Phases I through V of the PECS protocol using the SGD application following the prompting methods in the PECS protocol. All three participants showed an increase in the number of independent requests across PECS Phases I through II; however, only one participant met mastery criteria to move to Phases III through V. This participant was able to use a “I want” graphic symbol to build a complete sentence when edibles were presented with the question "What do you want?" being asked. Generalization probes indicated that this participant also requested across novel items.

Teaching Tacts using High-tech SGDs

Like the literature on teaching mands with SGD for students with ASD, tacts have typically been trained using only one-word or one-symbol selections on SGDs. Generally, training procedures include presenting a stimulus (e.g., a book) and then a directive such as "What is it?", delivering an echoic prompt "book," which results in the student responding "book." Expanding these responses to include multistep selections on SGD to create sentences is important to develop more complex verbal behavior.

In the first study to explore the use of mobile devices to teach tacts to students with CCN, Kagohara and colleagues (2012) used an iPod Touch and an iPad with the application Proloquo2Go (Sennott & Bowker, 2009). The researchers used a multiple probe across participants design to examine the effects of an intervention in this two-part study with two students with ASD ages 13 and 17 years old. In study one, they presented four photographs of places, animals, or community items per page and asked, "What is this?" while pointing to a specific photo. The iPad was programmed with corresponding graphic symbols that were non-identical to the presented stimuli. During intervention sessions, researchers used a system of least to most prompts to teach correct naming of the stimuli. In study two, researchers used an iPad and a picture word book for stimuli. Training procedures remained the same as in study one. Results indicated that both participants learned how to name or tact 12 different photos in study one using the iPod Touch with Proloquo2Go and 18 drawings in study two using the iPad with Proloquo2Go (Sennott & Bowker, 2009).

Similarly, van der Meer et al. (2015) used a multiple probe across behaviors design to examine the effects of an intervention using iPad with Proloquo2Go (Sennott & Bowker, 2009) on the tacting skills of a 10-year-old student with ASD and CCN. During intervention, the researchers presented a photo and asked, "What do you see on this card?" Students responded by selecting the corresponding word on the iPad out of a field of four items. Researchers used constant time delay to prompt correct responses during intervention. Results indicated that tact relation (i.e., picture to word) emerged without training following the earlier conditions (matching picture to picture and word to picture skills). A limitation of the study was that they did not assess for generalization across novel pictures and words.

In the first study to target multi-step tacts, Lorah et al. (2014) used a multiple baseline design across participants to examine the effects of an intervention using an iPad with Proloquo2Go (AssistiveWare, n.d.) to teach tacting using sentence frames with three students with CCN ages 4–6. During baseline sessions, researchers presented four physical items to the participants with the iPad and asked, "What do you see?" During intervention for the "I see" sentence frame, the researcher presented an item with the iPad and asked, "What do you see?" If the participant did not respond or responded incorrectly, the researcher emitted a full physical prompt to assist the learner to make the correct selection on the SGD and access social praise.

Next, participants were trained on the "I have" sentence frame which included presenting the iPad, then placing an item in the non-dominant hand of the participant and asking, "What do you have?" Prompting procedures were identical to the "I see" condition. Lastly, participants were taught to discriminate between the two sentence frames by randomly presenting either the "I have" condition or "I see" condition. Both participants successfully acquired tacting skills using the sentence frames and were able to discriminate between the frames when presented in random order.

Teaching Intraverbal Behavior using High-tech SGDs

Many of individuals' daily interactions involve intraverbal behavior. There has been an increase in research in this area, particularly for students with vocal verbal behavior (DeSouza et al., 2017); yet there is a large gap in teaching intraverbal behavior for students with CCN (Ganz et al., 2017; Muharib et al., 2018; Tincani et al., 2020). When training vocal intraverbals, an antecedent is presented with an echoic prompt such as, "What is your name? Matt," which results in the learner echoing, "Matt." Learners with CCN who do not have strong echoic repertoires but use AAC also can acquire intraverbals using response prompting (e.g., system of least prompts, constant time delay). Currently, there are only two studies that have targeted teaching intraverbal behavior to students who use a SGD.

In the first study to target intraverbal behavior, Strasberger and colleagues (2014) used a multiple baseline design across participants to examine the effects of a peer training intervention using a SGD on intraverbal responses with four students with ASD. Materials included an iPod Touch with Proloquo2Go (Sennott & Bowker, 2009) application that was programmed with four graphic symbols. During intervention, the researchers used time delay to teach students to respond to the question asked by the peer, "What is your name?" Students engaged in a multi-step response by selecting more than one graphic symbol in a communicative act. For example, a student would make two selections on the SGD to say, "My name is Jacob." Two students successfully learned intraverbal responses and maintained effects over time. The remaining participants did not meet mastery criteria of previous conditions, so intervention was not provided on intraverbal responding.

In the other study, Lorah et al. (2015) used an iPad II with Proloquo2Go (AssistiveWare B.V., n.d.) to teach intraverbal responses to the following questions “How old are you?” “What is your favorite toy?” and “Where do you live?” The researchers used a multiple baseline across behaviors design with two children with ASD, ages 8 and 12 who had CCN. During intervention, researchers presented one question at a time and in response to errors implemented a full physical prompt to select the correct response. Both participants increased their level of intraverbal responses on the SGD and maintained effects over time. The authors provided examples of student responses using sentence frames (e.g., “I live in…”) however, it is unclear how the device was programmed to determine how steps or selections students had to engage in to create the sentence.

Summary

SGDs have been effective tools to support learners with CCN to develop verbal behavior. Researchers have investigated teaching mands most often; however, there is emerging evidence that SGDs can be used to teach all the verbal operants. In addition to teaching all the operants, researchers have begun to investigate teaching more complex verbal behavior using sentence frames on SGDs. A variety of sentence frames can be used to teach more complex verbal behavior. Researchers have used “I want” with mands, “I see” or “I have” with tacts, and a variety of sentence frames with intraverbals including “My name is”, “I am _ years old”, “I live in”, and “My favorite toy is.”

However, when researchers target sentence construction for communication it does not always include complete sentence construction that involves students selecting one word at a time. For example, researchers most often use an “I want” icon instead of creating two separate icons “I” and “want.” Teaching learners to construct sentences word by word could promote generalization of recombined words to make new sentences. For example, if the teaching focuses on "I want the red iPad," then "I see a car", and "I have a backpack" and students must select single words, they can later recombine these words to make new sentences. Like, "I have a iPad," "I see a backpack," and "I want a car."

Writing Instruction for Students with ASD and CCN

Writing is an essential skill that is used in numerous contexts of everyday life. In school, students are expected to write arguments, informative/explanatory texts, and real or imagined narratives for a variety of audiences and lengths beginning in kindergarten and continuing through 12th grade (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). At work, employees frequently engage in writing to complete job tasks. Writing also provides a way to connect with others through text messaging, social media, and email. In 2021, 72% of Americans used social media to connect with each other, engage with content, or share information (Pew Research Center).

As mentioned previously, verbal behavior can be defined by its formal properties or what it looks like as well as its function. Writing is one form of verbal behavior that can be used to serve many functions. People write to request things (mand), label things in their environment (tact), or engage in conversation (intraverbal). Given that there is a large population of non-speaking individuals with ASD, writing provides a powerful way to communicate that can affect the quality of their lives. Unfortunately, researchers have shown that students with ASD have difficulty with written expression (Finnegan & Accardo, 2018). Findings suggest that students with ASD write less than their typical peers (Finnegan & Accardo, 2018; Hilvert et al., 2019) and produce more grammatical errors (Hilvert et al., 2019, 2020). Additionally, they often experience difficulties in handwriting (Kushki et al., 2011; Verma & Lahiri, 2022), which can make writing arduous for the writer and illegible to the reader.

To support these learners, researchers have begun to investigate interventions to improve written expression for students with ASD. Two literature reviews on writing interventions for students with ASD have been previously conducted. First, Pennington and Delano (2012) reviewed the literature on writing interventions for students with ASD including Asperger's and pervasive developmental disorder-not otherwise specified (PDD-NOS) from 1994 to 2011. They identified 15 articles that met their search criteria. Skills targeted included spelling, sentence construction, increasing adjective use, narrative writing skills, and persuasive writing skills. Participants were mostly male (n=27) with two females and ranged from ages 4 to 21 years, with majority being diagnosed with ASD.

Many of the included studies examined the effects of using technology to teach writing skills, such as the use of researcher developed programs (Stromer et al., 1996; Sugasawara & Yamamoto, 2007) and VOCAs (Schlosser & Blischak, 2004; Schlosser et al., 1998) to teach spelling. Additionally, researchers used video models that were displayed on Microsoft PowerPoint to teach spelling (Kinney et al., 2003) and computer software to teach sentence construction (Basil & Reyes, 2003; Yamamoto & Miya, 1999). One study involved the use of sentence combing to increase adjective use in students' written responses (Rosseau et al., 1994). Lastly, five studies investigated the use of self-regulated strategy development (SRSD) to increase persuasive writing or story writing skills (Asaro & Saddler, 2009; Asaro-Saddler & Saddler, 2010; Delano, 2007a; Delano, 2007b; Mason et al., 2010).

Recently, Accardo et al., (2020) conducted a literature review on writing interventions for students with ASD including Asperger's and PDD-NOS up to 2018. They found 24 studies that included a variety of skills including persuasive writing, story writing, spelling, informational writing, sentence construction, handwriting, and adjective use. Like Pennington and Delano (2012), most participants were male (92%), and ages ranged from 4–20 years old. Researchers cited nine common interventions that were used throughout the studies including SRSD, simultaneous prompting and computer assisted technology, AAC devices, constant time delay and sentence frames, graphic organizers, Handwriting Without Tears, and video modeling. They also coded the studies for quality indicators using single-case research design criteria from Kratochwill et al. (2013), Reichow et al. (2008), and Horner et al. (2008). The overall quality of the studies resulted in a mean of seven out of 10 points. Findings revealed that researchers rarely included a description of how interventionists were trained, and social validity and generalization were only measured in about 50% of the studies. Additionally, researchers coded the percent of non-overlapping data (PND) and found the following interventions to have a PND score higher than 70%: SRSD, constant time delay, response prompting and sentence frames, video modeling, Handwriting Without Tears, sentence combining and reinforcement, and task analytic instruction using systematic prompting and graphic organizers.

Accardo and colleagues (2020) identified 15 additional studies conducted after Pennington and Delano's review. Interestingly, there were seven studies that were included in the Pennington and Delano (2012) review but were not included in the Accardo et al., (2020) review. These were Stromer et al. (1996), Yamamoto (1996), Basil and Reyes (2003), Bedrosian et al. (2003), Kinney et al. (2003), Sugasawara and Yamamoto (2007), Asaro and Saddler (2009). Similarly, Pennington and colleagues did not include one earlier study (Carlson et al., 2009) which was included by Accardo and colleagues. From both literature reviews, after removing duplicates, a total of 31 studies on writing interventions for students with ASD have been published between 1994 and 2018. Although both reviews indicated an increased interest in writing interventions for students with ASD, neither addressed differences between learners with and without CCN. This is important due to the wide range of language individuals with ASD may have. For example, a student with CCN who uses gestures to communicate, and one-word utterances will require different supports than a student who uses vocal communication and is able to engage in multiple conversational exchanges. In the following section, I will review articles from these reviews that provided participant demographics to identify participants as having CCN across different writing interventions.

Foundational Skills

Foundational writing skills include handwriting, spelling, typing, and sentence construction (Graham, 2019). As students become more fluent in these skills, they are to acquire more advanced concepts in writing. Thus, developing research-based interventions for students with ASD and CCN on these foundational skills is essential to enable learners to engage in more complex writing skills.

Spelling

Spelling is an important skill for reading and writing. When reading, misspelled words can make a text difficult to read (Graham et al., 2008). When writing, if a student has difficulty with spelling it can tax their working memory which can lead to them forgetting ideas (Graham et al., 2002) and over time this can lead to students avoiding writing (Beringer et al., 1991). Researchers have found that students with ASD have difficulties in spelling (Finnegan & Accardo, 2018); however, only two studies have investigated teaching spelling to students with ASD and CCN.

In the first study to teach spelling to a student with CCN, Schlosser et al. (1998) used an adapted alternating treatments design to examine the effects of speech output and orthographic feedback using a VOCA on spelling acquisition. One 10-year-old male with ASD and CCN, participated in the study. He communicated with word approximations, modified sign language, finger spelling, gestures, graphic symbols, and printed words. The special education teacher and teacher's aide were the interventionists, holding sessions in the library or classroom. The three conditions included (a) an auditory visual condition where the VOCA was turned on and the student could see the LCD screen, (b) a visual condition where the speech output was turned off, and (c) an auditory condition where the visual feedback was covered. Twelve words were chosen to train after receiving feedback from the teacher and mother. During intervention, the interventionist used the copy-cover-compare method (Murphy et al., 1990) by presenting the word on an index card, reading it out loud, finger spelling it, reading it again, and then asking the student to spell it twice. Then, the teacher removed the index card and asked the student to spell the word again. Last, the teacher had the student compare their spelling to the index card. Results indicated that the participant was able to effectively spell across all three conditions, with little difference between conditions. This suggests that not all VOCA components are needed (e.g., speech output, visual feedback) when teaching spelling to students with ASD and CCN.

Later in 2004, Schlosser and colleagues, replicated their previous study with four participants with ASD who were described as having no functional speech. Like, Schlosser et al. (1998), they used an adapted alternating treatments design across three VOCA conditions speech, speech–print, and print. In the speech condition, the students only received the speech output on the VOCA for the selected words. Next, in the speech–print condition the students received auditory and visual feedback on the VOCA. Last, in the print condition, the students received only visual feedback on the VOCA, and the speakers were turned off. Intervention procedures were identical to Schlosser et al. (1998), using the cover-copy-compare method. Findings were like those made by Schlosser and colleagues (1998) in that participants increased spelling across conditions, suggesting that not all features of a VOCA need to be used to teach spelling.

Sentence Construction

For students with CCN who use AAC, teaching sentence writing using AAC devices is important to increase not only written expression, but also communication. Due to the interconnectedness of writing and language, many researchers have taught writing using a verbal behavior framework. Teaching sentence structure to individuals with CCN is important because it allows them to be effective speakers across a wide range of listeners. The following studies targeted sentence construction skills with students with ASD and CCN.

In an early study, Basil and Reyes (2003) taught sentence writing skills to six students with extensive support needs ages 8–16, four of whom had CCN. The researchers used Delta Messages (Nelson & Heimann, 1995), a computer software that displayed animations of animals with a word bank for students to construct sentences. Ten lessons were programmed in Spanish and Catalan using 70 words that could be combined to make 200 different sentences. Teachers provided intervention in 30-min sessions, twice a week for 3 months, resulting in a total of 24 sessions. During intervention sessions, the teachers presented a word bank with no image and let students independently select words to construct a sentence using a mouse. The word bank was organized in the order of the correct sentence with multiple options below each phrase that made a correct sentence. The first six lessons focused on noun-verb-noun sentences such as "The carrot chases the vulture," lessons 7–8 included prepositions like "The gorilla puts the hat on the panda's table" and lessons 9–10 included conjunctions and adjectives such as "The crying dragon sails over the sea and helps the penguin." Once the student composed a sentence, the computer read the sentence aloud using digitized speech, and an animation matching the sentence appeared. At the end of each intervention session, the teacher presented a test task which displayed an animation with a word bank. Students then constructed a sentence to match the animation. Results indicated that all students increased in their sentence writing skills and sentence writing lengths/components. However, due to the design of the study a functional relation could not be established.

Later, Pennington, Flick, et al. (2018) used a multiple probe across sentence types design to examine the effects of response prompting and sentence frames on sentence writing for three males with ASD ages 12–13 who had CCN. The special education teacher conducted all the sessions in their classroom, using six photos of animals and 36 sentences written on index cars. Three sentence frames were taught in random order (i.e., The subject is adjective, The subject verb, and The subject feels adverb). During intervention, the teacher first presented a sentence writing rule, "A sentence names a character and tells more." Then, they used constant time delay to teach the different sentence frames by presenting a photo and randomly selecting a sentence frame with a corresponding directive (e.g., "Write a sentence telling me what the ____is doing"). Students responded using paper and pencil materials. The students increased their sentence writing across the three sentence frames; however, maintenance probe data showed that some participants had difficulty discriminating between the sentence frames depending on the antecedent condition. Additionally, participants started to use more sentences in their journal writing outside of the intervention context.

Pennington and Rockhold (2018) replicated the study by Pennington, Flick, et al. (2018) and used a multiple probe design across participants to examine the effects of constant time delay, computer-assisted instruction, and multiple exemplar training. Participants included four males with ASD ages 6–9 years old who all spoke in one-to-two-word utterances, except for one participant who was non-vocal. The classroom teacher conducted all sessions in her classroom using printed photos of animals doing actions, printed sentence exemplars, and an iPad with the application Clicker Sentences (Crick Software Inc., n.d.). During intervention, the teacher presented the iPad with the word bank, a picture, and presented the directive "Write a sentence about the picture." Then, the teacher randomly selected a sentence model using one of the three sentence frames (a) The subject is adjective, (b) The subject verb, or (c) The subject verb object. The teacher conducted three days of 0-s delay trials, pointing to the words on the index card as the controlling prompt and providing vocal praise after the student completed the sentence. Then, the teacher moved to 5-s delay trials. Two participants acquired the sentence frames without modifications to the intervention. The last participant required intervention modifications including vocal praise after every word selection, pictures with only one animal, training on only one sentence frame (i.e., The subject verb), and embedding a picture on the iPad that matched the photo stimulus. After these modifications were made, the participant met criteria for the single sentence frame.

Next, Pennington, Foreman, et al. (2018) taught the sentence frames "I want," "I see," and "The ___ is ____" to three students with CCN ages 7–12 using a multiple probe across behaviors design. All participants communicated in one-to-three-word phrases and had moderate intellectual disability, with two participants having ASD. Materials included an iPad with Clicker Sentences (Crick Software Inc., n.d.) for two students and paper and pencil for one student, as well as preferred items for the “I want” frame, and pictures for the “I see” and “The ____ is ____” frame. During intervention, the teacher used simultaneous prompting for two participants and constant time delay for the third participant to teach the sentence frames. The teacher conducted generalization probes following mastery of the last sentence frame for each participant. Generalization probes included novel stimuli and the addition of new words to the word bank. Results indicated that all three participants acquired the three sentence frames and maintained skills over time. Additionally, all participants generalized the “I want” frame across novel stimuli.

In the most recent sentence writing investigation, Pennington, and colleagues (2021) examined the use of an instructional package on the percent of correct sentences for eight students with intellectual and/or developmental disabilities, five of whom had CCN. Researchers developed an iPad application, GoWrite (Attainment Company, n.d.), that embedded teaching procedures within the application. These included a pictured stimulus about which to write, a nine-item word bank, and a token system within the app that students could use to purchase items for their avatars in the application. They used a multiple probe design across participants to teach the sentence frames “I see” and “The [noun] is [adjective].” During intervention sessions, the application delivered 0-s delay trials by displaying the stimulus, the target sentence, and then highlighting the word in the sentence and word bank while blocking access to the other words in the bank. Next, during prompt delay trials, the application displayed the stimulus and word bank. If the student chose the correct word the application sounded a “ping,” and the student received a digital token. If the student did not respond within 8 s or made an error, the application highlighted the correct word for the student to select while the other words were inaccessible. At the end of each trial, the application read the complete sentence aloud. Seven of the eight participants increased the percent of correct sentences written. One participant was successful in acquiring a portion of the frame “I see the” but did not select the last word after intervention. Furthermore, one participant showed gains during baseline, suggesting maybe the presentation of assistive technology with the word bank was enough to support sentence writing skills.

Narrative Writing

Researchers also have begun to teach more complex writing repertoires including narrative or story writing to students with CCN (e.g., Bedrosian et al., 2003; Pennington et al., 2011, 2014). Narrative writing is a focus throughout Common Core State Standards (CCSS) in Writing for K–12 students (National Governors Association & Council of Chief School Officers, 2010). Beginning in kindergarten students are expected to either draw, dictate, or write about a single event, the order in which it happened, and provide a reaction. Then by fifth grade students should be able to write narratives about real or imagined events using narrative techniques such as dialogue and description, with descriptive details, and sequence of events. Furthermore, story writing provides students with the power to communicate what is happening around them and engage in creative writing by writing about imagined stories. In the following paragraphs, I reviewed studies that have investigated teaching narrative writing to students with ASD with CCN will be reviewed.

Bedrosian and colleagues (2003) first explored teaching story writing to students with CCN using a single case, A-B-A design to teach story planning, writing, revising, and publishing. Participants included a 14-year-old male with ASD who was nonverbal but fluent in using an AAC device, and a typical peer who was a 13-year-old male with difficulty with writing. During baseline sessions, researchers instructed students to write a story together given a computer with word processing software. Intervention was then provided for planning, writing, revising, and publishing of the story using explicit instruction, modeling, and prompting. For the planning phase, researchers taught students to complete a story map using an AAC device. Then, students completed the storyboard using symbols that included different people, places, and things related to the story map. Next, during the story writing phase, researchers modeled and then prompted students to write a story using My Words (Hartley-Jostens Software, n.d.) software that allowed students to type words, use sound effects, use a dictionary to check spelling, hear the story read aloud, and print the story. Last, researchers instructed students on how to edit their writing by printing a hard copy of their completed story and prompting them to look for certain errors (e.g., capitalization). Students marked the errors on their hard copies and the revised stories were reprinted. Results indicated that both students increased their story writing skills including incorporating story elements with minimal punctuation and capitalization errors.

Pennington et al. (2011) used a multiple probe across participants design to examine the effects of computer aided instruction and simultaneous prompting on story writing for three males with ASD, ages 7–10 who had difficulty with vocal communication. Researchers trained the classroom teachers to conduct all baseline and intervention sessions in a one-to-one format using a touch screen computer with Clicker 5 (Crick Software Inc., 2005) software. During intervention, teachers used simultaneous prompting to teach students to write a four-sentence story from the word bank provided on the screen which was organized by subjects, verbs, articles, and objects with color line drawings for the subjects. The teacher presented three different story templates throughout intervention in a random order. Following intervention, generalization was assessed on a fourth story template for two of the three students. All three participants increased in the percentage of story steps completed; however, only two of three met criteria (i.e., three days at 100%). Both students who met criterion, only required nine sessions of intervention and both increased the number of vocalizations when asked to vocally tell a story compared to pre intervention. The third participant showed slower progress, requiring 31 sessions to reach 75% accuracy.

In a similar study, Pennington, and colleagues (2014) used the computer software Pixwriter with simultaneous prompting to teach story writing to five male students ages 7–10 years old with ASD who had moderate to severe language delays. The research team trained the teacher and paraprofessional to conduct one-on-one sessions in the self-contained classroom. During intervention, teachers presented the Pixwriter (Slater & Slater, 1994) software with a 3x6 word bank and delivered a controlling prompt by pointing to the correct words on the screen to write the story. Researchers scored the number of correct sentences and story elements used. Teachers conducted a generalization probe using a novel template as well as a vocal probe post intervention. Results indicated that all participants acquired story writing skills and maintained skills over time. However, when presented with a novel template post-intervention, only three students were able to construct one to two sentences. Additionally, participants increased vocal responses when asked to tell a story after intervention as well as sight word reading of the words within each story template.

Summary

Writing is a powerful form of communication, and for many learners with CCN may be their primary communication mode. Researchers have successfully taught students with ASD and CCN to spell using different types of feedback on a VOCA (Schlosser et al., 1998; Schlosser et al., 2004), acquire multiple types of sentence frames (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018), and write fictional narratives (Bedrosian et al., 2003; Pennington et al., 2011; 2014). Across these studies, interventions frequently involved the use of response prompting techniques such as constant time delay or simultaneous prompting to teach writing skills.

Researchers used a variety of technology including a keyboard-based text to speech device, LightWRITER (Zygo-USA, n.d.), word processing software My Words (Hartley-Jostens Learning, n.d.), and tablet-based applications that present graphic symbols in a word bank such as Clicker 5™ (Crick Software Inc., 2005), Pixwriter (Slater & Slater, 1994), and GoWrite (Attainment Company, n.d.). Although these technologies were effective in increasing writing skills for students with ASD and CCN, future research should consider using AAC applications that are commonly used for students' communication like Proloquo2Go (AssistiveWare B.V., 2023) or GoTalkNow (Attainment Company, 2023). Using AAC technology to support writing could support students in increasing natural speech. For example, White et al., (2021) reviewed the literature on using AAC to support individuals with ASD to communicate and found that AAC resulted in participants increasing natural speech in several investigations. Using these technologies may promote generalization of communication skills in natural contexts. For example, if a writing intervention targeting sentence construction is taught using the sentence frame "I want ____" or "I see ____" using a student's AAC device, this skill may more readily transfer to natural settings instead of teaching it using a different device and software.

Generalization of writing skills has been explored in multiple ways across the studies reviewed. Researchers have assessed generalization of writing skills across novel stimuli (Pennington et al., 2011; Pennington, Foreman, et al., 2018; Pennington & Rockhold, 2018) and across different response topographies (i.e., vocal response and handwriting; Pennington et al., 2011; 2014). Future research should incorporate generative instruction which involves teaching a set of skills so that other skills emerge without direct training (Axe & Sainato, 2010). This type of instruction can be beneficial to students in that it results in generative responding, requiring less time in intervention and teaching generalization across different stimuli/contexts.

Matrix Training

One strategy that can be used to program for generative instruction is matrix training. Matrix training involves organizing learning targets in a table with component skills across each axis that can be combined within the cells of the table or matrix (an example is in Figure 1). For example, a student could be taught to tact or name color-object combinations such as yellow cup, blue car, red ball, and then be probed on new combinations such as yellow car, blue ball, and red cup. Goldstein (1983) called this type of generative responding, recombinative generalization. Recombinative generalization is defined as "…differential responding to novel combinations of stimulus components that have been included previously in other stimulus contexts" (Goldstein, 1983, p. 281).

Frampton et al. (2016) taught learners with ASD to tact or label noun-verb combinations using animal figurines by organizing the learning targets in a 3x3 matrix. The matrix, shown in Figure 3, was comprised of mastered verbs across the horizontal axis (e.g., drinking, jumping, eating) and mastered nouns across the vertical axis (e.g., dog, bear, alligator). Participants were trained on the diagonal combinations (e.g., dog drinking, bear jumping, alligator eating) and then assessed on the combinations of the other targets that were not trained (e.g., dog eating, bear drinking, alligator jumping).

Figure 3

	Dog	Bear	Alligator
Drinking	Dog Drinking	Bear Drinking	Alligator Drinking
Jumping	Dog Jumping	Bear Jumping	Alligator Jumping
Eating	Dog Eating	Bear Eating	Alligator Eating

Matrix from Frampton et al., (2016).
Note. Shaded cells represent trained targets.

Two research teams have reviewed the literature on matrix training, one examining the literature specifically for individuals with ASD (Curiel et al., 2020) and the other examining the matrix training literature in its entirety regardless of participant demographics (Kemmerer et al., 2021). Curiel et al., (2020) found 12 studies from 1999 to 2017 that used matrix training to teach a wide variety of skills to individuals with autism. The skills targeted included receptive identification (Axe & Sainato, 2010; Curiel et al., 2016), tacting or labeling (Frampton et al., 2016; Kohler & Malott, 2014; Pauwels et al., 2015), play skills (Dauphin et al., 2004; MacManus et al., 2015; Wilson et al., 2017), sentence construction (Yamamoto & Miya, 1999), and spelling (Kinney et al., 2003; Tanji & Noro, 2011). Most importantly, Curiel et al. found that across the 12 studies found, more than half of the skills learned were acquired without any direct teaching.

In a later review, Kemmerer, and colleagues (2021) found 35 studies from 1982 to 2020 that used matrix training for a wide range of individuals and skills. Matrix training had been used to teach individuals with intellectual disability sign language (Remington et al., 1990; Romski & Ruder 1984; Rudd et al., 2007), with typical students to teach consonant-vowel-consonant reading combinations (Mueller et al., 2000), with individuals who have a language delay to teach receptive and expressive language (Mineo & Goldstein, 1990), with an adult with aphasia to teach vocal sentence production (Schneider et al., 1996), and with individuals with cerebral palsy to teach graphic symbol communication (Tonsing et al., 2014). Both reviews found that most often matrix training was used to target language.

Matrix Training Components

To implement matrix training, Frampton and Axe (2022) outlined several steps and considerations practitioners should take in selecting curricular areas, designing the matrices, selecting training, and testing arrangements, and evaluating results. They suggested the first step is to identify a curricular area and terminal skill, comprising of two or more response components, to target. Examples of two component skills are tacting noun-verb combinations (e.g., dog run), color-shape combinations (yellow star), or even preposition-object combinations (under bed). In these examples each component skill is controlled by its own unique stimuli, whereas tacting a stimulus like cupcake after learning to tact cup and cake would not match the unique stimulus of a cupcake.

When selecting curricula, learning targets should be able to be combined in an effective manner. Some curricula may pose a challenge, for example when teaching word reading combinations using ending sounds such as -ow and -et when combined with initial sounds such as will not always produce the desired response (Frampton & Axe, 2022). Practitioners also will want to consider what materials will be used. Researchers have used a variety of materials including printed photos to represent color shape combinations (Frampton et al., 2019), videos to represent subject-verb-object combinations (Kohler & Mallot, 2014), and physical items such as toy figurines to represent object-action combinations (Marya et al., 2021).

Researchers have used a variety of matrix sizes ranging from 2x3 to 12x12 (Kemmerer et al., 2021). Most often a 3x3 matrix has been used as seen in Figure 1. Additionally, majority of the literature on matrix training with individuals with ASD has used known components across each axis of the matrix (Curiel et al., 2020). However, unknown components also have been used and acquired through direct teaching (e.g., Axe & Sainato, 2010; Curiel et al., 2016; Pauwels et al., 2015). Depending on the use of trained or untrained components in a matrix Frampton and Axe, (2022) recommend using different training procedures.

When using known components, diagonal training is suggested (Frampton & Axe, 2022). Diagonal training involves directly teaching the combinations across the diagonal of the matrix (see shaded cells in Figure 1) and then assessing for recombinative generalization for the other cells of the matrix. This procedure aligns with typical developmental trajectory when considering language interventions moving from acquiring single words to combinations of words (Frampton & Axe, 2022). Curiel et al. (2020) found that most researchers used diagonal training with known components for matrix training interventions for individuals with ASD.

When using unknown components, overlap or stepwise training may be required. This entails training the diagonal targets and each cell to the right of the diagonal following a stair-wise fashion. Several researchers have attempted to use diagonal training with unknown targets, but found it was not effective so then overlap training was added (Axe & Sainato, 2010; Curiel et al., 2016; Pauwels et al., 2015). Additionally, even when known stimuli are used, some participants may require overlap training (e.g., Frampton et al., 2016; Kohler & Malott, 2014).

Using Matrix Training to Increase Language

Matrix training has predominately been used to target language for individuals with and without disabilities (Curiel et al., 2020; Kemmerer et al., 2021). For students with ASD, tacting or labeling has been the predominant language target investigated by researchers. Researchers have evaluated using matrix training to teach subject-verb-object tacts (Kohler & Malott, 2014), object-preposition tacts (Pauwels et al., 2015), subject-verb tacts (Frampton et al., 2016;

Jimenez-Gomez et al., 2019), color-shape tacts (Frampton et al., 2019) and color-object tacts (Naoi et al., 2006). Additionally, researchers have targeted receptive language tasks such as following two-step directions to complete an academic action (e.g., circling, stamping, or highlighting) pictures of different stimuli (Axe & Sainato, 2010), complete two-step directions using animal figurines such as "point to cat" or "hide dog" (Curiel et al., 2018), and selecting two-component stimuli from an array when given a direction like "Give me the red car" (Naoi et al, 2006). Finally, Marya and colleagues, (2021) used matrix training to teach subject-verb tacts to students with ASD who use SGD as their primary form of communication.

Matrix Training for Listener Responding

Listener responding, more commonly known as receptive language, involves teaching learners to respond to verbal stimuli using a nonverbal response mode. Listener skills can range from simple discriminations such as a teacher asking a student to "sit down" and the student sits down, to more complex discriminations like presenting three items in front of a student, and asking them to "Touch car," to which the student responds by touching the car.

The first research team to use matrix training to teach receptive skills to students with ASD was Naoi and colleagues (2006). They used a multiple baseline across participants design to examine the effects of matrix training on receptive language skills of three children with ASD who had CCN, ages 6–8 years old. The researchers designed one training matrix and one generalization matrix to be used with all participants. The training matrix included nine adjective-object combinations using red, blue, yellow, trousers, cup, and car. The generalization matrix included the same colors but different objects including umbrella, balloon, and cap. For receptive identification tasks, researchers used printed picture cards of the adjective-object combinations (e.g., a photo of a red car). Students had mastered receptive identification of the individual colors and objects prior to the study.

During intervention sessions, Naoi et al. (2006) used diagonal training to directly teach three adjective-object receptive identification tasks. During each session, they presented three photo cards on the table and delivered an instruction such as "Give me the red car." Following an incorrect response or no response, they used a gestural prompt to support the student in selecting the correct card. After students acquired the three diagonal responses, researchers then probed the non-diagonal targets to assess for recombinative generalization. Additionally, the generalization matrix was probed after the session to assess responding to an untrained matrix. Results indicated that all students improved in their receptive identification of adjective-object labels; however, progress was variable. Participant one scored 0% in baseline, then following intervention 100% on the untrained combinations in the teaching matrix, and 100% on the generalization matrix. Participant two scored 11% in baseline, 50% on untrained combinations in the teaching matrix, and 44% on the generalization matrix. Participant three scored 78% in baseline, then following intervention 100% across untrained responses in the teaching and generalization matrix. All three participants maintained a high level of responding following 2 weeks of meeting criteria during intervention.

Next, Axe and Sainato (2010) used a multiple probe design across behaviors to examine the effects of matrix training on following two-step academic instructions for four preschoolers with ASD. The researchers developed four submatrices for each participant representing each tier of intervention. Matrices included two-step instructions including an action typically used during academic instruction such as underline, stamp, circle, and highlight for a variety of pictures that were familiar to the students. During intervention, researchers used diagonal training across each matrix to teach the action-object combinations. At the beginning of each session, researchers presented one to two mastered tasks and then had students select a reinforcer to earn at the end of the session. Next, a researcher presented an instruction such as "Get ready, underline pepper" with a cup of materials and a single photo, followed by modeling the correct response. Then, they modeled the action and physically guided the student to perform the correct response. Subsequent trials included adding distractors and fading prompts. Three of the four participants produced recombinative generalization across untrained targets in all matrices. Results from social validity assessments indicated that overall, the respondents found the procedures acceptable with a mean of 5.9 out of 7 and the outcomes socially valid with a mean of 6.1 out of 7. One noted concern was whether this procedure could be transferred from a one-on-one setting to the classroom.

Extending this research, Curiel et al. (2018) used known targets in the matrix with overlap training to reduce additional training for toddlers with language delays. They used a multiple probe across responses design with three participants who were 22–35 months old. The researchers designed a 5x5 matrix for two participants and a 4x5 matrix for the other to teach action-object combinations (e.g., push the dog) with animal figurines. During a preassessment, researchers assessed responding to a variety of actions and animals for the objects to design each participants matrix. From the results, each matrix included two known animals, three unknown animals, one to two known actions, and three unknown action words. During intervention, researchers first probed the combinations in the submatrix then provided discrete trial teaching using a five-phase sequence. In phase one the researcher presented only one animal with the corresponding action from the matrix (e.g., lift the cat) while using a most to least prompting. As phases increased, more animals were added, and targets were placed in random rotation to aide with discrimination. All three participants were directly trained on six cells of their matrix and the remaining cells were probed for recombinative generalization. Results indicated that each participant engaged in recombinative generalization at varying levels, ranging from 71–75% object–action combinations learned without training. The researchers noted that the participant with the least amount of recombinative generalization did not have any object-action combinations mastered prior to entering the study whereas the other participants had two mastered prior to intervention. This may have affected the participant's recombinative generalization.

Matrix Training for Tacting

Naoi and colleagues (2006) first investigated matrix training to increase tacting for three males with ASD, ages 6–8 years old with CCN. The researchers used a multiple baseline across participants design with a 3x3 matrix for each participant that contained adjective-object combinations (e.g., red cup). Prior to the study, participants were able to identify the individual adjectives and objects of the combinations receptively and expressively. During intervention, researchers taught the diagonal combinations of the matrix by holding up a photo of a colored object and asking, "What is this?" If the participant did not respond or made an error, an echoic prompt was delivered (e.g., "red cup"). Following acquisition of the three diagonal targets, researchers probed the non-diagonal targets in the matrix and a generalization matrix with novel objects. All participants engaged in recombinative generalization after being trained in the three diagonal targets.

Next, Kohler and Malott (2014) used a multiple probe across responses design to examine the effects of matrix training on subject-verb-object tacts with two 5-year-old children with ASD. Both children could emit one-to-three-word mands and tacts prior to the study;

however, they did not engage in generative responding. The researchers used eighteen, 3x3 matrices with one subject, three verbs, and three objects, making a total of 162 subject-verb-object combinations (e.g., Lisa hugs cat). Individual components placed on the horizontal and vertical axes were mastered as tacts prior to intervention. Researchers created a video for each subject-verb-object combination using familiar people and objects in the children's environment. During intervention, researchers taught the combinations along the diagonal of each matrix using constant time delay procedures. They started with 0-s delay trials by presenting a video with the directive "What?" and immediately provided an echoic model (e.g., "Chase drinks milk"), followed by reinforcement. Each session was consisted of five, three-trial blocks, resulting in 15 total trials. After the first session, researchers used 3-s delay trial with error correction.

Following mastery of the diagonal combinations, the nondiagonal combinations were probed by presenting each target once. The researchers' mastery criterion for generalization was 22 out of 24 correct responses to nondiagonal targets. If the students did not meet this, they received additional training until mastery was met. Once mastery criteria were met, the researchers probed the diagonal targets of the remaining matrices. If the participants scored lower than two of three correct responses, diagonal training was provided. If they scored two or three correct responses, the remaining nondiagonal targets were probed. The researchers provided additional training if the generalization criterion was not achieved. Data indicated that participant one mastered the 162 sentences within 24 sessions after being trained on only 14 sentences, indicating a high level of recombinative generalization occurred. The participant also maintained a high level of responding 8 months after the intervention. Participant two required more direct training on subject-verb-object combinations, across 78 sentences, which resulted in 32 training sessions. However, participant two did master all 162 sentences after intervention, also showing a high level of recombinative generalization. These findings suggest that matrix training with constant time delay can be effective in teaching generalized responding for three component tacts (e.g., Baby jumps table).

Pauwels et al. (2015) used both diagonal and nondiagonal training to promote generative responding. They used a multiple probe design across participants design to evaluate the use of matrix training on object-preposition tacts using kitchen objects. Participants include two females with ASD and one female with PDD-NOS, ranging in ages 13-20. Researchers created a 6x6 matrix with 36 object-preposition combinations (e.g., strainer above box). Combinations were modeled with real kitchen items (i.e., strainer, melon baller, tongs, whisk, grater, and peeler) being placed in different positions around a box. The researchers used a combination of diagonal and nondiagonal training. First, they provided diagonal training on the first four diagonal combinations, making a 4x4 matrix. During intervention, they presented the object-preposition combination using the corresponding kitchen utensil and box, and the directive "tell me about it" followed by an echoic prompt (e.g., "strainer above box"). As participants met mastery, prompts were faded using 2-s delay with partial prompts (e.g., "strainer above ____" then "strainer _____ ____") to eventually no prompting. Then, researchers probed the non-diagonal responses in the 4x4 matrix followed by providing nonoverlap training on the combinations to the right of the diagonal from the same section of the matrix. After participants mastered the nonoverlap targets, the untrained combinations were probed again to test for recombinative generalization. Last, the researchers provided diagonal training for the remaining portion of the 6x6 matrix, training two diagonal combinations, followed by nondiagonal probes.

For two participants, diagonal training was effective in producing high levels of recombinative generalization (71–96%) even when the isolated objects-preposition were not mastered. Researchers still provided these participants with overlap training, which resulted in 100% responding on untrained nondiagonal targets. Session lengths ranged from 53–78 sessions. The last participant exhibited low levels of responding to nondiagonal targets after diagonal and nondiagonal training. Thus, the researchers provided horizontal/vertical training where they trained one object with each preposition and one preposition with each object to aid in discrimination of the objects and the prepositions. Results indicated the training produced no change in responding. The remainder of the 4x4 matrix was trained along with the last two diagonal responses in the larger matrix. The last probe on the remaining nondiagonal targets indicated low responding. A total of 133 sessions were conducted for this participant.

In another study, Frampton et al., (2016) used a multiple probe design across participants design to examine the use of matrix training on noun-verb tacts with five children with ASD. The researchers developed a 3x3 training matrix and a 3x3 generalization matrix for each student, including known nouns and verbs on the horizontal and vertical axis. During baseline sessions, researchers began with one to two mastered skills and then presented the noun-verb combination using the animal figurine (e.g., the researcher showed a dog drinking using the figurine) asking, “What’s happening?” Following a 5-s response interval, researchers delivered neutral responses for correct and incorrect responses such as “okay.” The targets in the generalization matrix were assessed first, then the training matrix was assessed. During intervention sessions, the same antecedent condition as baseline sessions was presented and then if the participant answered incorrectly or did not respond within 2s, an echoic prompt was used (e.g., “dog drinking”). This was followed by a transfer trial where the instruction was provided again, and students responded independently. Next, researchers presented a mastered task and present the same target once more to mimic the probe condition more closely. Correct responding on this final trial resulted in access to highly preferred reinforcers.

After participants met the mastery criteria for the diagonal targets, researchers probed the nondiagonal responses in the training matrix and then the entire generalization matrix using baseline procedures. Results indicated that matrix training was effective in establishing generative responding in all participants. For four participants, training the three diagonal responses resulted in the emergence of 15 novel combinations. After teaching the initial three diagonal responses, the fifth participant was able to recombine the nondiagonal targets within the training matrix, however he did not produce correct responding to the generalization matrix. The researchers then created two additional matrices for this participant and after being trained on those diagonal responses, the participant acquired 27 novel combinations. As suggested by the authors, the participant may have had other barriers to learning since he was 9 to 10 years older than the other participants.

To extend this work, Frampton et al. (2019) used matrix training to teach color-shape tacts to six children with ASD using an additional generalization matrix and randomization of pre and posttests. The additional matrix was added to streamline remediation when recombinative generalization did not occur and pre/posttests were to minimize sequence effects. Researchers used a multiple baseline design across participants to examine the effects of matrix training on novel color-shape tacts. Three 3x3 matrices were created using mastered color and shape tacts. Baseline sessions and posttests were randomized using the targets in matrix 1, generalization matrix 1, and generalization matrix 2. The researchers' procedures were identical to those used in Frampton et al. (2016), using diagonal training in matrix 1 with an error correction procedure. After each student met the mastery criteria (two consecutive session at

89%) for the three diagonal targets in Matrix 1, posttests were conducted in a random order across all three matrices. If the mastery criteria of two sessions at 89% was not met, researchers delivered a booster training on the diagonals of Matrix 1. Three of six participants met the mastery criteria for posttests across all matrices after diagonal training on Matrix 1, suggesting matrix training with randomized probes was effective in teaching recombinative generalization. The remaining three participants showed varied levels of responding across posttests. However, after receiving booster training, two of the three participants increased recombinative generalization across novel targets to mastery levels. The last participant did increase responding to novel targets after booster training but not to mastery. The authors suggested if time were to permit, additional training across the nondiagonal targets in matrix 1 would have been beneficial.

Finally, Jimenez-Gomez et al. (2019) used matrix training to teach noun-verb tact and listener responses to five children with ASD ages 25, 28, and 24 months old at a university-based clinic. Researchers used a multiple probe design across submatrices design with progressive time delay to teach noun-verb combinations using figurines and toys. Two 6x6 matrices were made for each participant including mastered nouns and unknown verbs. Each matrix was divided into a 3x3 submatrix. During baseline sessions, researchers assessed both listener and tact responses across the diagonal targets of the matrices. For listener responses, they presented the corresponding toys for the target such as a baby figurine and asked, “Show me baby walking.” For tact responses they performed the action with the toy and asked, “What is it doing?” During intervention, researchers taught the diagonal combinations using progressive time delay with vocal prompts for tacting and gestural or model prompts for listener responses. Then they probed the nondiagonal combinations to test for recombinative generalization. Researchers followed this procedure across the four submatrices for each participant using the multiple probe design across submatrices. Results indicated that all three participants engaged in recombinative generalization across tact and listener responses. Additionally, two participants increased spontaneous noun-verb tacts when observed outside of the intervention session. The authors suggested that this could have happened due to matrix training teaching a behavioral cusp leading to these spontaneous combinations.

Using Matrix Training with AAC Users

The previous studies provide evidence that matrix training is effective in increasing tact repertories for learners with ASD who use speech as their primary communication mode. However, expanding this research to include individuals who use aided modes of communication is important given the large population of learners who do not acquire functional speech. Fortunately, researchers have begun to investigate the use of matrix training with learners who use aided AAC, including picture communication symbols (Nigam et al., 2006; Tonsing et al., 2014) and SGDs (Marya et al., 2021).

Nigam et al. (2006) conducted the first study to investigate the use of matrix training on tact responses for individuals using aided communication. They used a multiple probe design across matrices with three participants with CCN. Tammy, age 11 had a diagnosis of ASD and intellectual disability and used a combination of gestures, sign language, and graphic symbols to communicate. Sally, age 13, had multiple disabilities including intellectual disability, orthopedic impartment, and communication disorder and communicated using vocalizations, facial expressions, and graphic symbols. Danny, age 7, had ASD and used vocalizations and graphic symbols to communicate. Researchers created a 6x6 action-object matrix (e.g., drop cup) with corresponding picture communication symbols in a communication book for both participants. Prior to intervention, participants had mastered the individual actions and objects. A communication board was made on construction paper with picture communication symbols displaying all the actions and objects on one page. Researchers divided the larger matrix into four submatrices to be targeted for intervention. Each submatrix included a total of three trained action-object combinations that included two diagonal targets and one additional, nondiagonal target. During intervention sessions, the researchers presented the action-object combination using physical items (e.g., dropping a cup for "cup drop") with the directive, "What am I doing?" If the participant responded incorrectly, they said "Tell me by pointing to the symbols," if the student did not respond within 4 s or respond incorrectly, researchers then provided a model by pointing to the correct symbol combinations.

Following mastery of a sub matrix (six out of nine trials over two consecutive sessions), researchers conducted generalization probes for the 24 action-object combinations that were not trained. Results indicated that matrix training was effective in teaching action-object combinations to Tammy and Sally. After training each submatrix, Tammy acquired 67% of the novel action-object combinations, and Sally 59%. Danny however did not make any progress across 13 intervention sessions and started to engage in challenging behavior, thus researchers terminated intervention. Researchers suggested that Danny's young age may have been a contributing factor to his progress as well as behavioral challenges with remaining on task and he had a smaller repertoire of picture communication symbols than the other participants at the beginning of the study.

Next, Tonsing et al. (2014) used a multiple probe across responses design to investigate the effects of matrix training on graphic symbol combinations with four children in South Africa with CCN ages 6–10. All participants attended English language schools where English was the predominant language used. Two participants were proficient in English. Researchers designed a

5x2 matrix for three different combinations including subject-action combinations, subject-object combinations, and attribute-object combinations. All participants had mastered naming the component parts of the matrix using picture communication boards. Five combinations of each matrix were selected for training and written into story-based lessons. Researchers created three stories, one for each type of combination, and a communication board for each participant with 21 graphic symbols. The communication board displayed all subjects, actions, objects, and attributes on one page. During intervention sessions, a researcher read the book aloud while the student had the communication book. When a target stimulus appeared, the researcher pointed to the picture and asked, "What is happening here?" followed by a least to most prompting hierarchy to support the student in correctly responding. Researchers conducted probes on the first, third, and fifth session of intervention which entailed presenting different pictures from the stories but still representing the combinations and asking, "What is this?" for all 30 possible combinations. Two of four participants acquired trained combinations and showed high levels of generative responding across untrained combinations. The remaining two participants exhibited varied levels of correct combinations during intervention and low levels of generative combinations. This may have been due to both participants having less proficiency in English compared to the other two participants.

To date, only one study has used SGDs during tact instruction with matrix training. Using the procedures from Frampton et al., (2016), Marya and colleagues (2021) used a nonconcurrent multiple probe design across participants to examine the effects of matrix training on noun-verb tacts. Participants were three males, ages 3, 6, and 16 years, with ASD who used a SGD as their primary communication mode. Prior to the study, all participants could mand and tact single responses but did not combine words together to make phrases on their SGD. Sessions were conducted in an intensive behavioral clinic for two participants and at home for the last participant. Researchers created two matrices, a training matrix, and a generalization matrix for each participant with mastered nouns and verbs. During baseline sessions, researchers presented an animal figurine to model the noun-verb combinations (e.g., elephant jumping) and asked, "What's happening?" Next, during intervention sessions, they presented the same antecedent condition and followed a multistep error correction procedure, outlined by Frampton et al. with the addition of physical prompts instead of echoic prompts. Once mastery criteria were met at 89% across two consecutive sessions, researchers delivered a posttest across the nondiagonal targets in matrix 1. If participants demonstrated recombinative generalization at 78% across three consecutive sessions, then the generalization matrix was probed. After meeting mastery criteria along the diagonal responses, two of three participants engaged in high levels of recombinative generalization across the nondiagonal targets in matrix 1 and across the targets in the generalization matrix. The third participant engaged in high levels of recombinative generalization in matrix 1, but not within the generalization matrix.

Marya and colleagues (2021) created a second matrix (matrix 2) with known nouns and verbs and then provided diagonal training. This led to high responding across nondiagonal targets, but not across the generalization matrix. An additional matrix was created (matrix 3) and the same procedures were followed. Similar results were obtained, thus the researchers conducted maintenance probes of matrices 1 and 2 to assess responding on previously mastered targets. Results indicated that the participant had decreased in responding to previously mastered combinations. The researchers then taught the diagonal responses across all three matrices which resulted in 100% responding on novel combinations. Last, they created a fourth matrix and provided diagonal training after low levels of responding were shown in baseline. After training this last matrix the participant successfully engaged in recombinative generalization across the nondiagonal targets in matrix 4 and all the targets in the generalization matrix.

Using Matrix Training to Teach Writing Skills

Researchers have used matrix training to teach different writing skills to individuals with intellectual and developmental disabilities including spelling (Kinney et al., 2003; Tanji & Noro, 2011) and sentence construction (Yamamoto & Miya, 1999). In 2003, Kinney and colleagues used a multiple baseline design across matrices to investigate the effects of matrix training using video models to teach generative spelling to an 8-year-old child with ASD. The authors did not describe the participant's communication profile. Researchers used three 3x3 matrices to teach spelling across nine-word endings and nine single letter word beginnings, making a total of 27 words. They used diagonal training across each matrix to teach the spelling of three words and then tested for recombinative generalization to the remaining words. Video models were created using PowerPoint by embedding videos, text, and sound files into slides. The video models began with one researcher providing the direction, "Write (target word)" and another researcher modeled spelling the word on an easel. Then a researcher played with toys or objects that incorporated the spelling word and said a sentence out loud using the word such as "Jump over the rock, not on the rock" with the target word being rock. This play segment of the video was used for reinforcement after the student responded correctly and still images from these segments were used for test conditions.

During intervention sessions, Kinney et al. (2003) began each session with a test segment by presenting a still image from the play segment of the video model with a fill-in-the-blank sentence. They read the sentence aloud, including the omitted target word. For example, if the target word was "Ana," the researchers provided a fill in the blank, "My name is_____" and the student filled in the blank. Then, the researchers played the video model, and the student copied the video model using paper and pencil. Last, the researchers presented the photo of the play segment again and instead of reading the target word in the sentence, the student inserted the target word and spelled it out on a worksheet. This procedure was used for all diagonal targets across each matrix. Results indicated that matrix training with video models was effective for increasing generative spelling skills.

Next, Tanji and Noro (2011) used a multi pre-post design to examine the effects of matrix training on generative spelling for two Japanese children with ASD who had CCN. The researchers created two matrices for each participant, a training matrix and a generalization matrix using word beginnings and endings with Japanese characters. Each matrix contained a total of 12 two-character words. During intervention sessions, researchers provided training on six words using a match to sample task. The computer displayed a sample of the word and the dictation and then students were provided multiple characters that could be selected to spell the word. Participants selected the characters by either touching the screen or using a mouse. If participants responded correctly by spelling the displayed word, the computer chimed, and a preferred avatar was presented. Incorrect responses were followed by a beep and the students were given another opportunity to complete the task. After directly teaching the spelling of six words, both participants engaged in high levels of recombinative generalization across novel combinations.

In the only study to use matrix training for sentence construction, Yamamoto and Miya (1999) used a pre-post design to teach students with ASD to construct sentences in Japanese with subjects, verbs, objects, and particles using computer-based training. Participants were three males with ASD and CCN, ages 6–10 years old. A matrix with three subjects and three objects was created and then replicated across three verbs, making a total of 27 possible subject-object-action combinations. During interventions sessions, researchers used a computer to present an image depicting the sentence with a word bank below. Students selected word choices using a mouse to make their selections. If students constructed a correct sentence corresponding to the image, a fanfare was displayed on the screen. If students made an error, the correct sentence was displayed on the screen for 5 s and the trial was represented. Researchers also conducted a vocal assessment prior to and after intervention that presented the image and asked students "What is she/he doing?" Results indicated that the computer-based training was effective in increasing sentence construction skills and generative responding. After training three combinations, all participants constructed 24 novel combinations.

Summary

Matrix training has been effective in increasing language skills in the areas of listener responding and tacting. Majority of the research on using matrix training for tacting skills was implemented with students who used speech. However, four studies used AAC including picture communication symbols printed in communication books (Nigam et al., 2006; Tonsing et al., 2014), computer software with word banks for writing (Yamamoto & Miya, 1999), and SGD (Marya et al., 2021). Across these studies only one research team examined the use of matrix training for sentence construction (Yamamoto & Miya, 1999).

In the matrix studies that targeted tacting usually only two-to-three-word tacts (e.g., boy eating or boy eating apple) were used without the use of articles or a sentence frame. A variety of tacts were selected for intervention including subject-verb, subject-verb-object, color-shape, adjective-object, object-preposition, action-object. Stimuli representing these combination ranged from photos, flashcards, animal figurines, pictures from a book, real life kitchen objects to show prepositions, and video clips. Within the antecedent condition researchers typically presented the stimulus and a question such as “What’s happening?” or “What is it?” to evoke the tact response. Like the research on using AAC to teach verbal behavior, future research should focus on more complex verbal behavior including the use of sentence frames.

Summary of the Review of Literature

To support students with ASD and CCN to effectively communicate across a wide range of contexts, people, and purposes researchers have used AAC to teach a wide arrange of verbal behavior. AAC has mostly been used to teach manding and tacting, with limited research in teaching intraverbals. Common AAC include picture communication symbols, PECS (Bondy & Frost, 1994), and SGDs using iPods and iPads with a variety of software applications. In this chapter, I examined the use of SGDs to teach verbal behavior, writing interventions to target more complex verbal behavior using sentence frames and AAC, and the use of matrix training to promote generative responding across communication skills.

Researchers extensively have examined the use of SGDs to teach manding. The importance of teaching manding skills is well understood due to the autonomy this gives individuals. However, future research should consider teaching more complex verbal behavior such as intraverbals, to enable individuals to communicate for a wider range of purposes and audiences. In addition to teaching more complex verbal behavior it is important to consider teaching students to make multi step selections or construct sentences. Majority of the research in teaching verbal behavior using SGD does not teach students to select an icon for each word. Instead, researchers commonly program two to three words into one icon. This limits the generalizability of these communication skills because students cannot recombine these selections when one icon states “I want.”

Fortunately, researchers have begun to teach these multi-step selections during writing instruction for students with CCN using sentence frames and technology aided instruction (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). Instructional procedures are like other studies teaching tacting skills to students using SGDs in that a stimulus is presented (most often a photo) with a directive like “Write a sentence about the picture” and then a form of response prompting is used to teach sentence construction. Different from the literature on teaching verbal behavior to students using SGDs, these writing interventions have taught students to select each word in the sentence instead of using icons that have combined words.

To effectively support students to communicate using more complex verbal behavior such as sentence frames, strategies to promote generative responding should be considered to maximize teaching time and resources. Matrix training has been successfully used to teach two- to three-word vocal tacts to students with ASD who have CCN, however the research on using matrix training with AAC is limited. Two research teams have used matrix training to teach two component tacts using picture communication symbols (Nigam et al., 2006; Tonsing et al., 2014), and only one research team has used a SGD to teach two component tacts (Marya et al., 2021). More research is needed on using matrix training to support students with CCN who can greatly benefit from generative instruction.

Furthermore, there has only been one study that has examined the use of matrix training to teach sentence construction to students with ASD (Yamamoto & Miya, 1999). This research team used a pre-post design to teach sentence writing with subject-verb-object combinations. Due to the methodology used, a functional relation could not be found. Additionally, this study was conducted in Japan using Japanese characters limiting the generalizability to English speaking students due to the differences in linguistic structures. Research investigating the effects of matrix training to teach sentence construction using AAC is important to support students with CCN to become effective communicators.

CHAPTER 3: METHOD

In this study I used a non-experimental series of A-B designs with multiple modifications (Ledford & Gast, 2018) to analyze the effects of an intervention package consisting of matrix training, response prompting, and sentence frames on sentence writing for students with ASD and CCN. In this chapter, I will describe the methodology including participants and setting; participant recruitment; researcher, interventionists, and secondary observers' roles and training; materials; dependent variables and measurement procedures; experimental design; procedures data analysis; reliability; and social validity.

Participants and Setting

Participants in this study included three special education teachers and four students with ASD and CCN. Teacher and student participants were selected using convenience sampling. Any instructor of students with ASD was eligible as a teacher participant for this study. Student participants were recommended by their teachers if they met the following inclusion criteria: (a) had an educational eligibility of autism, (b) required specialized instruction in writing indicated by IEP goals, (c) exhibited complex communication needs indicated by teacher report, (d) had adequate hearing and visual acuity skills, (e) had match to sample skills (for example when shown a stimulus the student could select the stimulus in an array of three), and (g) attend to instruction for 10 min without severe challenging behavior (e.g., aggression, self-injury, property destruction).

This study took place in a specialized private school located in the southeastern United States. This school served about 30 students year-round, ages 5–22 years, with intellectual and developmental disabilities who require an intensive and individualized education with a focus on supporting challenging behavior. The school used a comprehensive and collaborative clinical service delivery model, incorporating the principles of ABA, special education, and related services into an individualized learning model. Teachers at this school included both licensed special educators, ABA counselors, and board-certified behavior analysts. The teacher to student ratio was 1:1 or 1:2, with embedded opportunities throughout the day in group settings. For this study, sessions were delivered in two classrooms with 5–6 students each. Each classroom had six tables that were used as desks for each student. Additionally, there were several bookshelves, a computer desk, and break areas for each student. Students received instruction throughout the day from ABA counselors and special education teachers.

Participant Recruitment

I contacted the school directors via email (see Appendix A) with information about the study requesting approval to work with teachers and students at the school. Upon approval from the school director, I conducted an in-person visit and asked the school director to nominate teachers to recruit for the study based on the teacher eligibility criteria. Then I distributed teacher consent forms (see Appendix B) to the nominated teachers. Upon receiving teacher consent, teachers nominated student participants who met the inclusion criteria and then parental consent forms (see Appendix C) were distributed in person. In addition, the school director also sent an email to parents using a researcher-provided script (see Appendix D). If parents were interested in having their children participate in the study, they returned the parental consent form to the school.

Student assent was determined by teacher observation during each session due to the communication profiles of each student. Before each session began, the teacher asked the student if they were ready to begin working and if the student sat down at their desk without any challenging behavior it was accepted as assent. Student assent was withdrawn if at any time the student engaged in challenging behavior that would typically result in termination of the session as indicated by school procedures and/or the student's behavior intervention plans.

Teachers

Three teachers (pseudonyms used throughout) were enrolled in the study as interventionists. Ms. Heart served as the primary interventionist for the study because three of the four student participants were in her classroom. She was a 23-year-old, White female. She held a bachelor's degree in psychology and was enrolled in an alternate route to certification program to obtain her special education teaching license. She had taught at the school for 2 years at the time of the study, with no prior teaching experience.

Mr. Barry was a 46-year-old, White male. He held a bachelor's degree in social work and was also enrolled in an alternate route to certification program to obtain his special education teaching license. He had taught at the school for three years. Mr. Barry conducted baseline sessions with George and Darius until George moved to Ms. Heart's classroom. Thereafter, he did not conduct any baseline or intervention sessions.

Ms. O'Hara was a 38-year-old, White female. She held a bachelor's degree in psychology and a master's degree in special education. She was a licensed special education teacher and a Board Certified Behavior Analyst. Ms. O'Hara had 14 years of teaching experience at the time of the study. She served as a floater interventionist in the case that another teacher could not conduct a session.

Students

Four students, ages 10-18 years, participated in the study. All participants received special education services under the educational eligibility category of autism and participated in the state's alternate assessment. Taylor (pseudonym) was a 14-year-old Black female. She used an AAC device (iPad with Proloquo2Go) and gestures to communicate. At the time of the study Taylor used one-word requests on her AAC device to communicate. She did not use any vocal language. Taylor had a history of challenging behavior including aggression, defined as grabbing student and teacher clothing and biting. At the beginning of the study, Taylor had been attending the school for 18 months. Her most recent IEP goal in writing focused on tracing shapes, tracing her last name, and typing. Her most recent IEP goal in communication focused on identifying nouns and verbs on her AAC device and receptively identifying 3D objects.

George (pseudonym) was a 17-year-old White male diagnosed with autism, apraxia, and sensory processing disorder. He had some single-word vocalizations at the time of the study (e.g., hi, bye) and used an AAC device (iPad with Proloquo2Go) to communicate. George used sentences to communicate on his AAC device and was able to comment and ask questions. He received speech therapy, occupational therapy, and physical therapy as related services in the school setting. George had a history of challenging including self-injurious behavior defined as head-butting adults, squeezing others, scratching himself, and biting others. At the beginning of the study, George had been attending the school for over two years. His most recent IEP goal in writing focused on copying multiple sentences using a paper and pencil, writing his name, and writing short sentences. His most recent IEP goal in communication focused on using past and progressive tense verbs and prepositions on his AAC device.

Steven (pseudonym) was a 18-year-old White male, diagnosed with autism and Dravet Syndrome. He communicated using vocal language using one-to-two-word phrases. He also engaged in repetitive speech throughout the day that was socially mediated self-stimulatory behavior. He did not have an AAC device at the time of the study. He received speech language therapy, occupational therapy, and physical therapy as related services. He was monitored throughout the day for seizures and during the study would have a seizure approximately one to two times per month. Steven had a history of engaging in behavior including aggression in the form of pinching, hitting, and kicking, self-injurious behavior described as head banging, elopement, flopping to the ground, and property destruction. At the beginning of the study, Steven had been attending the school for about 1 year. His most recent IEP goal in writing focused on stamping his name and receptively and expressively identifying icons. His most recent IEP goal in communication focused on responding to greetings, following one step directions, and labeling objects and actions.

Darius (pseudonym) was a 10-year-old Black Male. He was diagnosed with autism and a speech language impairment. He used an AAC device (iPad with Proloquo2Go) to communicate. He did not display any vocal language. He received speech language therapy as a related service. Darius had a history of engaging in the following challenging behavior: aggression defined as grabbing and biting towards others, hitting, self-injurious behavior described as pinching and biting self, and property destruction. At the beginning of the study, Darius had been attending the school for 4 months. His most recent IEP goal in writing focused on spelling words, using lowercase letters, typing, and creating a sentence that describes a picture. His most recent IEP goal in communication focused on identifying adjectives, nouns, verbs, and functional icons on his AAC device.

Table 1

Participant Characteristics

Participant	Age	Gender	Race	Eligibility Categories
Taylor	14	Female	Black	Autism
George	17	Male	White	Autism, Apraxia, Sensory Processing Disorder
Steven	18	Male	White	Autism, Dravet Syndrome
Darius	10	Male	Black	Autism, Speech language impairment

Researcher, Interventionists, and Secondary Observers

I served as the primary researcher for this study. At the time of the study, I identified as a White, 33-year-old female. I held a teaching license in special education in Nevada with five years of experience teaching students with extensive support needs. My primary responsibilities included obtaining IRB approval and school approval, obtaining consent from teachers and parents, confirming student assent, training teachers on all intervention components, collecting reliability and procedural fidelity data, graphing student data, administering social validity questionnaires to all participants, and training secondary observers in collecting reliability and procedural fidelity data. The teacher participants served as the interventionists for the study. They delivered instruction across all conditions and collected data on the dependent variables using data collection sheets. An initial teacher training was provided that included an overview of the study to all teacher participants as well as training on the pre-assessment condition. Thereafter, training was provided the day before each condition change using behavioral skills training which consists of instruction, modeling, rehearsal, and feedback (Miltenberger, 2003). Secondary observers included three doctoral students in special education who had experience in teaching students with extensive support needs. Their responsibilities included collecting and storing reliability and procedural fidelity data.

Materials

Several materials were used in this study. These included individual student matrices, speech generating devices, photos, data collection sheets, and token boards.

Student Matrices

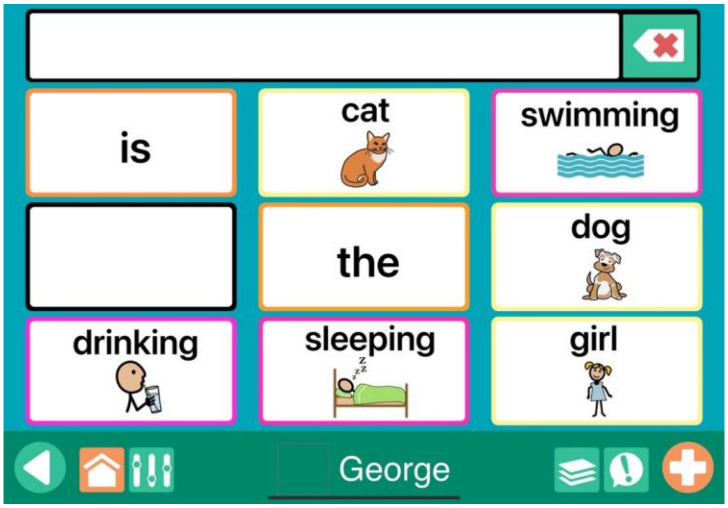
I initially planned to create three, 3x3 matrices for each student. However, after the results from pre-training I decided to create only one, 3x3 matrix for each participant (see

Appendix E). These matrices were created using feedback from the teachers and data from pre-training. Each matrix included three subjects (e.g., boy, girl, mouse) and three verbs (e.g., cooking, reading, hiding) across the horizontal and diagonal axes. These targets were combined in each cell of the matrix using a full sentence (e.g., The boy is cooking). Each matrix was used to organize teaching targets to promote recombinative generalization of subject-verb combinations using the sentence frame "The ____ is ______."

Speech Generating Device

In this study, students wrote about photos using either a researcher-provided iPad with the application GoTalk NOW (Attainment Company, 2011) or a student's iPad with the software Proloquo2Go. GoTalk NOW is an AAC application that uses text to speech with graphic symbols to support learners with CCN. For baseline and intervention sessions that used GoTalk NOW, I programmed each device with one page that included a 3x3 array with eight graphic symbols and one period. The graphic symbols in the array included three subjects, three verbs, "the," "is," and a blank space (see Figure 4 below). The subjects and verbs chosen for the array corresponded to each matrix for each student. For the students that used Proloquo2Go, I programmed one page with a 1x8 array. The graphic symbols in the array included three subjects, three verbs, "the," and "is". I planned to also include a period during intervention; however, not all the devices had the ability to program a period into the array, so the period was removed.

Figure 4



Example of Array Presented to Students

Photos

Teachers presented photos for students to write about across all conditions. There was one photo for every subject-verb combination, totaling nine photos. Each photo was 15.24 cm x 10.16 cm., printed in color and laminated for durability. Each photo was distinct from the other photos. For example, in Taylor's matrix (see Appendix E), three photos were used to show a girl doing three different verbs. Each of these photos had a different girl in the photo. Photos were verified by members of the research team prior to the study beginning by asking each member to list the subject-verb combination the photo represents.

In intervention, photos were presented on a 8.5" x 11" paper with the target sentence printed underneath (see Appendix F). The target sentence was printed under the photo to allow teachers to provide a gestural prompt by pointing to each word on the printed sentence. The bottom of the paper was folded in half during 5s delay sessions to cover the sentence until a student made an error. Then, beginning with Taylor's Intervention C, symbol support was removed, and each word was covered with a flap using Velcro to allow teachers to only prompt one word at a time. I initially planned for the teachers to use a gestural prompt to the words on the iPad as the controlling prompt; however, this was changed to ensure students attended to each word in the sentence and to allow for a cue for a student to select the next word by pointing to the next hidden word in the sentence.

Data Collection Sheets

During all conditions, the teachers collected data using data collection sheets specific to each condition. The teachers used event recording to score writing samples on the percentage of correct sentences, percentage of subject-verb combinations, and the percentage of correct word selections. During baseline sessions, teachers collected data on diagonal and non-diagonal targets (see Appendix G). During intervention sessions, data were collected on diagonal targets. Data sheets varied during intervention, specific to each student's intervention.

Token Boards

Teachers used token boards during their typical instructional procedures, so they were also used for the study. Each student had a laminated token board with 10 spaces for tokens. Students received tokens on an FR1 schedule for exhibiting safe behavior at the end of every trial per sentence, unless specified otherwise by intervention procedures. This reinforcement schedule was typical for each student and was used with other instructional goals in the classroom.

Dependent Variables and Measurement Procedures

The primary dependent variable in this study was the percentage of correct sentences written. A sentence was scored correct when it included the targeted sentence frame (i.e., The ____ is ____) and corresponded to the presented photo (e.g., when shown a picture of a dog jumping, the student writes "The dog is jumping"). Capitalization errors were not counted towards incorrect responses because there were only nine words in the array and the only appropriate capital would be the first word "The" which if capitalized in the array, would prompt the learner to select that word first. I initially planned to include punctuation as part of the criteria for correct sentence construction, but because the first participant's (Taylor) device would not allow a period to be programmed into the array, this criterion was removed to remain consistent across participants.

Teachers scored student responses using a printed data sheet during baseline/posttest sessions (see Appendix G) and intervention sessions taking trial-by-trial data per sentence. At the end of each session, the teacher derived a percentage by taking the number of correct sentences divided by the total number of trials, multiplied by 100. The number of total trials per sentence varied depending on the condition. During baseline sessions, a total of nine trials were delivered when assessing the entire matrix and a total of six trials were delivered when assessing only non-diagonal responses. During intervention sessions, the total number of trials varied depending on the intervention provided. Taylor's sessions had the following number of trials: Intervention A had three trials, Intervention B and C had nine trials, and Intervention D had a total of six trials. Steven and George had nine trials (trials defined as one sentence) across all intervention sessions.

The secondary dependent variable was the percentage of independent, correct subject-verb combinations. These responses were measured to assess recombinative generalization of subject-verb combinations across matrices for diagonal and nondiagonal targets. A correct subject-verb combination was defined as a student selecting a subject and verb that corresponds to the presented photo on their SGD (e.g., a student selects "dog jumping" after being shown a photo of a dog jumping). Word order was not counted towards incorrect responses. For example, if a student selected "swimming boy" when presented with a photo of a boy swimming, it would be counted as a correct subject-verb combination, but not a correct sentence. However, if a student selected additional subjects or verbs that did not correspond with the presented photo (e.g., the swimming boy girl) it was counted as an incorrect subject-verb combination. Teachers scored student responses using a printed data sheet during baseline/posttest sessions (see Appendix G) and intervention sessions by taking trial-by-trial data. At the end of each session, the teacher derived a percentage by taking the number of correct subject-verb combinations divided by the total number of trials, multiplied by 100. Data were collected on this dependent variable until Intervention B was introduced to Taylor. It was no longer measured due to the error correction procedures used in Intervention B that did not allow students to select two consecutive words if they made an error within their first selection. For example, for the sentence "the cat is swimming" if the student selected "dog" as their first selection, the rest of the sentence would be prompted removing the opportunity for students to select a subject and verb.

A third dependent variable, the percentage of correct word selections, was added before Intervention C with Taylor was introduced. This dependent variable was added across all participants at this time and the percentage of subject-verb combinations was removed as a dependent variable on teacher data sheets. A correct word selection was defined as the student selecting a word that matched the sentence frame and the photo presented in correct order. For example, in the sentence "The boy is swimming" there are four correct word selections. Correct word selections were counted only when the word matched the exact location as the target sentence. If a student wrote "boy the is swimming," they would score only two correct word selections. This dependent variable was added because it was more sensitive to growth compared to correct sentences.

The number of trials for correct words selections varied across conditions, based on how many sentences were presented. Each sentence had four words resulting in four opportunities or correct words selections. In full matrix probes during baseline, teachers presented three diagonal sentences totaling 12 possible correct word selections. During nondiagonal probes, six sentences were presented, totaling 20 possible correct word selections. During intervention sessions, nine sentences were presented, resulting in a total of 36 possible correct word selections. At the end of each session, the teacher calculated the percentage of correct word selections by adding the total number of correct word selections, dividing it by the number of opportunities, and multiplying it by 100.

Experimental Design

The following section will present the planned experimental design along with changes that were made.

Multiple Probe Across Behaviors within a Multiple Probe Across Participants Design

I planned to use an experimental, single-case, multiple probe across behaviors design, within a multiple probe across participants design (Horner & Baer, 1978; Ledford & Gast, 2018) to examine the effects of matrix training on sentence writing for students with ASD and CCN. With this design, each student participant would receive the intervention across one matrix at a time in a time lagged fashion, following the multiple probe across behaviors design. Teachers would provide intervention for the diagonal targets in each matrix. Then after participant one would meet the mastery criterion (i.e., 100%; 3 out of 3 trials) for intervention in Matrix 1 across two consecutive sessions on diagonal targets, participant two would begin intervention. The third participant would enter intervention following participant two meeting the same criterion.

Each participant would enter intervention for Matrix 2 upon meeting the mastery criteria of responding on non-diagonal targets in Matrix 1, 83% (5 out of 6 trials) correct sentences across two consecutive sessions. If a student met this mastery criterion, intervention on Matrix 2 would begin. Intervention would continue until the same mastery criterion was met (i.e., 83% responding on non-diagonal targets) for Matrix 2. Once these mastery criteria were met, intervention on Matrix 3 would be introduced.

In this design, when a student did not meet the mastery criteria for non-diagonal targets across any of the matrices after three sessions, overlap training would be provided until mastery was met. During overlap training, teachers would have taught an additional three targets in a matrix, leaving three to be assessed for recombinative generalization. The mastery criteria for the three targets trained during overlap training would be the same as diagonal training, 100% (3 out of 3 trials) across two consecutive sessions. Students would need to meet the mastery criteria of 67% (2 out of 3 trials) for the remaining non-diagonal targets to enter intervention for the next matrix.

I selected the multiple probe across behaviors design to demonstrate intra-and inter-participant replication across three participants. Additionally, I wanted to provide intervention on Matrix 1 in a time-lagged fashion using the multiple probe across participants design to control for possible covariation of the multiple probe across behaviors design. Using both designs would allow me to analyze the data across participants for Matrix 1, and across behaviors (i.e., Matrix 1, 2, and 3) for each participant. Within the multiple probe across participants design for Matrix 1, I planned to control for maturation of participants assigned to later tiers by ensuring four intervention sessions a week would be provided so that later participants are not in baseline for extended periods of time. Next, I planned to control for inconsistent effects across participants by using a stringent inclusion criterion for student participants to ensure they have similar characteristics. Last, I planned to control for attrition bias by randomly assigning students to tiers for the multiple probe across participants design (Ledford & Gast, 2018).

Multiple Probe Across Participants Alone

After conducting the initial assessment across participants, results indicated that students did not have enough mastered subjects and verbs to each have three matrices. Thus, the first change in experimental design was to only use a multiple probe across participants design, using only one matrix per participant. This change was made prior to any baseline sessions across all participants.

This design would introduce participants to intervention one at a time, upon each participant meeting the mastery criterion (i.e., 100%; 3 out of 3 trials across 2 consecutive sessions) for intervention on the diagonal targets in their matrix. This design was used until intervention concluded for the first participant Taylor. Then, due to intervention changes made across Taylor's intervention sessions, the design no longer followed multiple probe logic according to single case design standards.

A-B Design

For the remainder of the study, a non-experimental single case, A-B design was used. This design was selected due to the several changes made to the independent variable for Taylor that could not be replicated across all participants. I started to use this design upon the completion of Taylor's last intervention session. Limitations to this design include no intra-subject replication, and therefore, result in only correlational conclusions.

Data Analysis

Each participants' data were graphed on a line graph and analyzed using visual analysis to evaluate the data in relation to changes in stability, level, trend, immediacy and consistency of effect, and similarity across the same conditions. Visual analysis was also used to assess whether there was a functional relation between the instructional package and the three dependent variables (i.e., the percentage of correct sentences written and the percentage of independent, correct subject-verb combination) across participants.

Procedures

Teacher Training

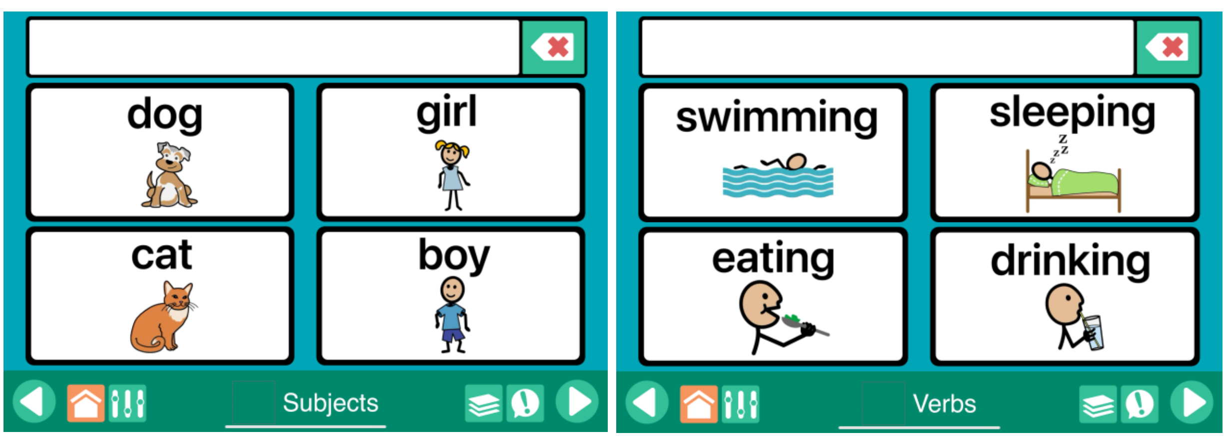
I delivered an initial teacher training with all three teachers prior to the assessment condition, lasting approximately 60 min. The training included an overview of the study and instruction on the assessment condition. To teach the specific assessment procedures, I used behavioral skills training (Miltenberger, 2003) by providing written and verbal directions, modeling the procedures, and then asking the teacher to rehearse the procedures. I provided positive and corrective feedback until each teacher met the training mastery criteria of 100% accuracy across one session using the procedural fidelity checklist. Once criteria were met, the initial training was complete.

Following this initial training, I met with teachers the day before a condition change for each participant to train them on the procedures for the upcoming condition. For example, after a teacher completed the pre-assessment and training condition, I met with them to train them on baseline procedures. These training sessions were delivered the day before the condition change and lasted approximately 30 min. Each session included an overview of the condition, verbal, and written descriptions of the procedures for the condition, modeling of the procedures, rehearsal where the teacher practiced implementing the procedures, and feedback by providing positive and corrective feedback (DiGennaro Reed et al., 2018). The mastery criteria for training were 100% across one session met using the procedural fidelity checklists for each condition.

Target Selection

I conducted an initial interview with each teacher to obtain a list of possible mastered subject and verb tacts for each student. Using this information, I created a list of four possible nouns and verbs. The same nouns and verbs were used across all participants. The nouns included girl, boy, dog, and cat. The verbs included eating, sleeping, drinking, and swimming. Then, the teachers assessed student tacting skills on the isolated subjects and verbs. During the assessment, the researcher's iPad with GoTalk NOW (Attainment Company, 2011) was used for George and Steven. Taylor and Darius used their personal iPads programmed with Proloquo2Go. For each student, two folders were programmed on the SGD with a 2x2 array of four subjects on Page 1, and a 2x2 array of verbs on Page 2 (see Figure 5).

Figure 5



Example of Folders Programmed for Assessment

Note. This is a screenshot of the GoTalk NOW (Attainment Company, 2011) application that was used during the study. The picture symbols were inserted from SymbolStix (n2y LLC, 2014).

To assess tact responses for the subjects across the matrices, the teacher presented a photo representing a subject (e.g., a photo of a dog), and asked “Who is it?” Participants were given 5 s to respond by selecting a graphic symbol on their SGD (e.g., student selects the graphic symbol for “dog”). If participants did not respond within 5s the teacher recorded an incorrect response and presented the next trial.

Using the same procedures, the teacher assessed tact responses for the verbs in each participant’s matrix. The teacher presented a photo representing a verb (e.g., a photo of a person jumping), and asked “What are they doing?” Each target (subject or verb) was presented three times in a session. A target was considered mastered when scored 2 of 3 correct. The assessment was completed once before pre-training and once after pre-training for two of three participants.

Taylor’s results indicated she mastered three of four nouns (boy, dog, cat) and two of four verbs (drinking and swimming). George’s results indicated he mastered three of four nouns (girl, dog, cat) and one of four verbs (drinking). Steven’s results indicated he mastered zero of four nouns, and one of four verbs (sleeping). Darius’s results indicated he mastered two of the four nouns (dog and cat) and four of four verbs (eating, sleeping, drinking, and swimming).

Pre-training

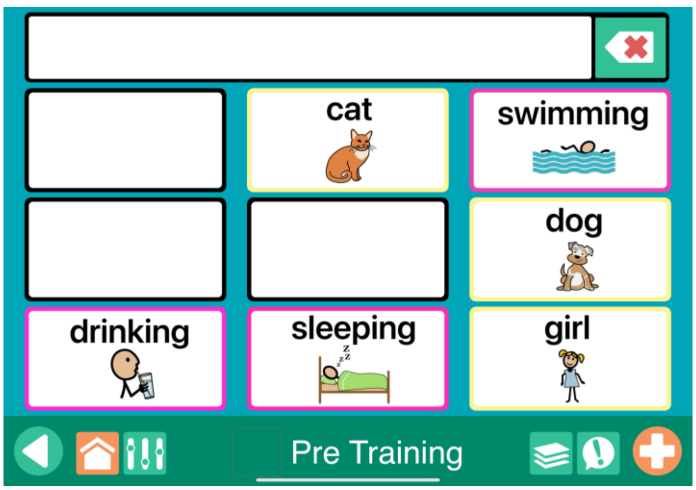
Teachers conducted pre-training to attempt to increase the number of mastered nouns and verbs to three nouns and three verbs for each participant. During pre-training the array on the SGD was programmed to include all nouns and verbs on one page to mirror what would be presented in baseline and intervention. Pre-training used two different interventions, Pre-training

A and Pre-training B. I planned to use one intervention; however, after analyzing results from the first intervention, modifications were made. Materials used during all pre-training sessions, included the same photos and symbols that would be used in intervention.

During Pre-training A, constant time delay was used to teach the unknown subjects or verbs from each student's assessment. Sessions either focused on the subjects or verbs in each student's matrix. For example, for a student that required intervention on subjects, three subjects were presented from their matrix, three times each, resulting in nine trials. The teacher used two sessions of 0s time delay for the unknown targets and used a 4s time delay for the known targets within each session. During 0s delay trials, the teacher presented a photo and asked, either "Who is it?" or "What are they doing?" depending on whether subjects or verbs were targeted. For photos that depicted the unknown subjects or verbs, the teacher immediately provided a controlling prompt by pointing to the correct word on the iPad. During these sessions, the mastered targets were interspersed with the learning target and the teacher used a 4s time delay for these mastered targets. Each session consisted of nine trials, three for each subject or verb. Following the second session of 0s time delay for the unknown targets, a 4s delay was used for all targets presented within a session. During 4s delay trials, the teacher presented a photo and asked, "Who is it?" or "What are they doing?" If the student responded correctly the teacher delivered verbal praise. If the student made an error or did not respond within 4s the teacher erased the selection and presented the controlling prompt. Then, the next trial would be presented. Data were collected on the percentage of correct subjects or verbs by taking the sum of independent correct responses, dividing it by the total number of opportunities (n=9), and multiplying by 100.

During Pre-training B, teachers presented one photo for eight trials and randomly presented the questions “Who is it?” or “What are they doing?” across the eight trials. The teacher conducted two session of 0s time delay using the procedures described above for all eight trials. Then, a 4s delay was inserted following the same procedures in Pre-training A. The difference between Pre-training A and B was that only one photo was presented during a session during Pre-training B and then two question were asked at random across eight trials. Data were collected on the percentage of correct subjects or verbs by taking the sum of independent correct responses, dividing it by the total number of opportunities (n=8), and multiplying by 100.

Figure 6



Example of Array Presented During Pre-training

Taylor. Results from Taylor’s assessment results indicated she mastered three of four nouns (boy, dog, cat) and two of four verbs (drinking and swimming). Thus, all verbs in Taylor’s matrix were selected first for training using the procedures outlined in Pre-training A. The teacher conducted two sessions of 0s time delay and then inserted a 4s delay for 18 sessions. Results indicated that Taylor scored an average of 39% correct verbs across 18 sessions (range=22–55%). Taylor also received Pre-training B. During pre-training B, the following subject-verb combinations were selected, “boy drinking” and “boy swimming”. Taylor received two sessions of 0s time delay and then a 4s delay was inserted for three sessions across both learning targets. Across these three sessions for the learning target “boy drinking” Taylor scored an average of 0% when asked “Who is it?” and an average of 100% when asked “What are they doing?” For the learning target “boy swimming” Taylor scored an average of 0% when asked “Who is it?” and an average of 100% when asked “What are they doing?”.

George. George was the last participant to enter the study so Pre-training A. The teacher used the procedures outlined for Pre-training B to teach “girl drinking” and “dog sleeping”. Two sessions of 0s time delay were used and then a 4s delay was inserted. George received four sessions of 4s time delay trials for each learning target. Across these 4 sessions for the learning target “girl drinking” George scored an average of 31% when asked “Who is it?” (range= 0–75%) and an average of 50% when asked “What are they doing?” (range= 0–100%). For the learning target “dog sleeping” George scored an average of 31% when asked “Who is it?” (range= 0–50%) and an average of 44% when asked “What are they doing?” (range= 0–100%).

Steven. Results from Steven’s assessment indicated he mastered 0 of 4 nouns, and 1 of 4 verbs (sleeping). Thus, all nouns in Steven’s matrix were selected first for training using the procedures outlined in Pre-training A. The teacher conducted two sessions of 0s time delay and then inserted a 4s delay for six sessions. Results indicated that Steven scored an average of 17% correct nouns across six sessions (range=0–33%). Steven also received Pre-training B. During pre-training B, the following subject-verb combinations were selected, “boy eating” and “boy sleeping”. Steven received two sessions of 0s time delay and then a 4s delay was inserted for four sessions across both learning targets. Across these 4 sessions for the learning target “boy eating” Steven scored an average of 19% when asked “Who is it?” (range= 0–50%) and an average of 44% when asked “What are they doing?” (range= 0–75%). For the learning target “boy sleeping” Steven scored an average of 3% when asked “Who is it?” (range= 0–13%) and an average of 0% when asked “What are they doing?”

Darius. Results from Darius’s assessment indicated he mastered 2 of the 4 nouns (dog and cat) and 4 of 4 verbs (eating, sleeping, drinking, and swimming). Thus, the nouns in Darius’s matrix were selected first for training using the procedures outlined in Pre-training A. The teacher conducted two sessions of 0s time delay and then inserted a 4s delay for 17 sessions. Results indicated that Darius scored an average of 89% correct nouns across 17 sessions (range=78–100%). Darius also received Pre-training B. During pre-training B, the following subject-verb combinations were selected, “boy eating” and “boy sleeping”. Darius received two sessions of 0s time delay and then a 4s delay was inserted for three sessions across both learning targets. Across these three sessions for the learning target “boy eating” Darius scored an average of 25% when asked “Who is it?” (range= 0–50%) and an average of 33% when asked “What are they doing?” (range= 0–50%). For the learning target “boy sleeping” Darius scored an average of 58% when asked “Who is it?” (range= 25–100%) and an average of 50% when asked “What are they doing?” (range= 25–75%).

Conclusion of Pre-training

Pre-training concluded after four weeks. At the conclusion of pre-training, the post assessment procedures followed the same procedures as the first assessment. Results indicated that Taylor mastered three nouns and three verbs, George mastered one noun and two verbs, Steven mastered zero nouns and zero verbs, and Darius was absent the week of the post assessment. Results of the post-assessment guided the selection of the first participant to enter intervention, Taylor.

Baseline

Baseline sessions alternated between assessing responses to all nine targets in a matrix in a session to assessing only the nondiagonal targets in a session to reduce continued exposure to teaching targets (see Appendix G). During baseline sessions, each target was presented once (i.e., a trial), resulting in nine trials when assessing the entire matrix, and six trials when assessing the nondiagonal targets.

For each trial, teachers presented a photo that depicted a target sentence (e.g., “The dog is jumping”) and asked, “Write a sentence about the photo.” Students were given 5s to respond using the SGD using the 3x3 array of graphic symbols. The trial was terminated when the student ceased writing for 5s or when the student indicated that they were finished by pressing the speaker bar without prompting or handing the teacher the photo. Then the next trial was presented. This process continued until the teacher presented either all nine targets during odd sessions, or all nondiagonal targets during even sessions. Teachers followed the typical reinforcement procedures used in their classrooms which included delivery tokens for attending to instruction at the end of each trial per sentence. During each session, teachers recorded trial-by-trial data on the dependent variables, using paper and pencil data sheets.

Diagonal Training

During intervention, teachers used response prompting procedures to teach the diagonal sentences of each student’s matrix (see shaded cells in Appendix E). In the section that follows, intervention procedures will be provided separately for each participant. My initial plan was to deliver the same intervention procedures to all participants; however, data indicated no change in level after seven intervention sessions for the first participant thus changes were made. In general, changes included using different response prompting strategies (i.e., simultaneous prompting and constant time delay), changing opportunities to respond with the introduction of correct word selections, removing picture supports from the sentence strip, changing the reinforcement schedule, changing the order of sentences presented, and adding error correction procedures using the sentence strip. Tables 1 and 2 present all intervention modifications and the rationale.

Taylor. Taylor was the first participant to receive intervention. The teacher began with Intervention A, using simultaneous prompting to teach diagonal sentences. After no level change following seven sessions of intervention, Intervention B was implemented. Intervention B used constant time delay instead of simultaneous prompting. Following six sessions of Intervention B with no change, Intervention C was implemented. Intervention C included using constant time delay and the introduction of a third dependent variable, the percentage of correct word selections. Additionally, the picture supports were removed from the printed sentence strips. Following two sessions of Intervention C data indicated a low level of responding, thus Intervention D was implemented. Intervention D used constant time delay to teach one diagonal sentence using a FR1 for unprompted correct word selections. Next, Taylor's interventions will be described in more detail.

Taylor: Intervention A. During this intervention the teachers used simultaneous prompting (Gibson & Schuster, 1992) to teach the diagonal sentences for Taylor. Each session, the teacher first conducted a probe on the diagonal targets using procedures identical to those in baseline sessions. Each diagonal target was presented once, resulting in a total of three trials for the probe (see Appendix H). Immediately following the probe, the teacher conducted a training session on the diagonal targets.

During the training session, the teacher presented a photo that depicted a target sentence, asked “Write a sentence about the photo.” and delivered the controlling prompt by gesturing one word at a time on the printed sentence strip. The controlling prompt of gesturing to the sentence strip was selected for all students so that stimulus control was not bound to a gesture on the iPad. Additionally, all student participants had a history of severe challenging behavior, so physical prompting was avoided. During intervention, Taylor did not consistently respond to the prompt of gesturing to the sentence strip, so a second prompting level was introduced which included gesturing to the word on the iPad. Prompting level data for each word presented was collected on four of the seven intervention sessions. Results indicated that the gesture to the sentence strip elicited a correct response for about 75% of the prompted words, and Taylor required a higher-level prompt (gesturing to the word on the iPad) for about 25% of the words presented.

Once the student had selected all the words in the sentence, the teacher prompted the student to playback the entire sentence on their SGD. Following the sentence playback, the teacher delivered vocal praise and presented the next trial. The teacher repeated these steps, presenting each diagonal target three times in the training session in random order (see Appendix H). I planned to continue training sessions until the student met the mastery criteria of 100% (3 out of 3 trials) correct sentences across two consecutive probes; however, due to no change in level after 7 sessions on the number of correct sentences written, intervention procedures were revised.

Taylor: Intervention B. After seven sessions of intervention using simultaneous prompting, the intervention procedures were revised to use constant time delay instead. I selected constant time delay because I hypothesized that the lack of error correction during the probe in simultaneous prompting may have contributed to Taylor not responding to intervention. During this intervention, the teacher used 5s constant time delay with two different prompts. 0s delay sessions were not selected for this intervention because Taylor had previously received seven sessions of errorless learning during simultaneous prompting sessions.

During these sessions the teacher presented a photo that depicted a target sentence and asked them to “Write a sentence about the photo.” Then they waited 5s for the student to respond. If the student did not respond within 5s or made an error, the teacher would present the sentence strip and prompt the remaining words left of the sentence. Two prompting levels were used. First, they would point to the words on the sentence strip and if the student did not respond by selecting the correct words on their SGD, the teacher would gesture to the correct word on the iPad. Multiple levels of prompting were selected so that students would attend to the words on the sentence strip to limit the chance of responding being controlled by physical prompting. Once the student had selected all the words in the sentence, the teacher prompted the student to playback the entire sentence on their SGD. Following the sentence playback, the teacher delivered vocal praise and presented the next trial. The teacher repeated these steps, presenting each diagonal target three times in the training session in random order (see Appendix I). I planned to continue training sessions until the student met the mastery criteria of 100% (3 out of 3 trials) correct sentences across two consecutive probes; however, due to no change in responding after 6 sessions, intervention procedures were revised.

Taylor: Intervention C. I hypothesized that the previous intervention may have been unsuccessful due to Taylor not having an opportunity to select each word in the sentence after she made an error. Thus, I revised the intervention procedures to include an opportunity to respond for every word in the sentence (see Appendix J). The procedures were identical to Intervention B, with the addition of a 5s delay for every single word in the sentence. For example, a trial would begin with the teacher asking Taylor to "Write a sentence about the photo." Then the teacher waited 5s for the student to respond per word. If the student did not respond within 5s or made an error for the first word "the" the teacher would present the sentence strip and prompt the word "the" using the two prompting levels described previously. After Taylor selected "the" the teacher would point to the next space where the next word would be and would begin the next 5s delay. If Taylor responded by selecting the correct word, the word would be shown, and praise would be delivered. If she made an error or did not respond within 5s, the teacher would follow the error correction procedures above. This process was repeated for each word in the sentence. Additionally, during this intervention, the symbol supports were removed from the teacher's sentence strip because I hypothesized that these may have been controlling her responses for the subjects and verbs. Three intervention sessions were planned to be conducted during this intervention, however during the third session the iPad died in the middle of the session discontinuing the session. Data from the two intervention sessions indicated that the intervention was ineffective.

Taylor: Intervention D. Last, I hypothesized that the schedule of reinforcement may have been reinforcing incorrect responding during intervention because students received tokens for prompted and unprompted corrects in the classroom. During this intervention, the teacher used 5s delay trials and presented one sentence across six trials (see Appendices K–L). Reinforcement was provided on a fixed ratio schedule of 1 for independent correct responses. Taylor scored 0 correct word selections and 0 correct sentences on the first session, so she did not earn any tokens.

Responding may have not increased because the learner needed time to understand the new contingency of earning tokens for unprompted correct word selections, so the teacher delivered two sessions of 0s delay trials across the next two days. Following the last 0s delay session, the teacher inserted a 5s delay which resulted in 8% (2/24) correct word selections. The intervention was then discontinued.

Table 2

Taylor: Intervention Modifications and Rationale

Intervention	Modification(s) Made from Previous Intervention	Rationale for Modifications
B	Response prompting procedures were modified from simultaneous prompting to constant time delay.	Lack of error correction during simultaneous prompting probe trials may have contributed to student errors.
C	Correct word selections were added as an additional dependent variable and symbol supports were removed on the sentence strip that was used during error correction procedure.	Correct word selections provided Taylor with an opportunity to respond to every word in the sentence. Whereas, in Int. B upon Taylor making an error, the remaining words in the sentence were prompted. Symbol supports were removed to ensure Taylor was attending to the words presented on the sentence strip and not matching the symbols from the sentence strip to the iPad.
D	Reinforcement schedule was modified from the typical reinforcement schedule used in the classroom (i.e., FR1 for target behavior) to FR1 for unprompted correct word selections.	The previous reinforcement schedule used in the classroom (i.e., FR1 for students displaying target behavior regardless of correct or incorrect responding) may have had an inhibitive effect on correct responding because Taylor was reinforced for correct and incorrect responses.

George. Throughout the study, George received three different interventions. Intervention A was identical to Intervention C for Taylor, which included using constant time delay. George received three sessions of 0s time delay and three sessions of 5s time delay. Results indicated a low level of responding thus, Intervention B was introduced. The only change from Intervention A to B was that each word was hidden after it was displayed on the sentence strip during error correction procedure. Last, Intervention C included the use of one controlling prompt during error correction procedures, instead of the prompt hierarchy used in Interventions A and B. The next section will describe each intervention in detail.

George: Intervention A. This intervention included the use of 0s and 5s delay trials. The teacher provided three sessions of 0s delay trials. During 0s delay trial the teacher, presented one photo at a time with the sentence underneath it, and asked George to "Write a sentence about the photo." Then the teacher immediately provided a controlling prompt by pointing to one word at a time on the printed sentence. If the student did not respond to the initial prompt, the teacher gestured to the word on the iPad. Once the student had selected all the words in the sentence, the teacher prompted the student to playback the entire sentence on their SGD. Following the sentence playback, the teacher delivered vocal praise, and a token for their token board. The teacher repeated these steps, presenting each diagonal target three times. The sentences were presented using a mass trial format with each sentence being presented three times in a row. The teacher collected data on a printed data sheet using event recording (see Appendix M).

Following three sessions of 0s delay trials, the teacher inserted a 5s delay. During these sessions, the teacher presented the photo with the sentence hidden, asked George to "Write a sentence about the photo", and pointed to the first hidden word on the printed sentence. Then the teacher waited 5s for George to respond. If George responded correctly, the teacher provided praise and opened the word on the sentence strip. If George did not respond within 5s the teacher opened the correct word and gesture to the word on the sentence strip. If George selected an incorrect word the teacher erased the word and then opened the correct word on the sentence strip and gestured to the correct word. If at any time George did not select the correct word after the gestural prompt on the sentence strip was provided, the teacher then gestured to the correct word on the iPad. As words were revealed on the sentence strip, the words remained visible until the entire sentence was constructed.

Once George selected the correct word on the iPad, the trial for the next word would begin by the teacher pointing to the next covered word on the sentence strip. The teacher then waited for 5s again and followed the error correction procedures described previously. This continued for every word in the sentence. The teacher provided tokens on a VR4 schedule. This schedule was selected because there were 36 possible words and George had a token board of 10 tokens. This schedule allowed the instructor and student to complete the session in one sitting. Once George had selected all the words in the sentence, the teacher prompted George to playback the entire sentence on his SGD and provided general praise for completion of the sentence. The teacher repeated these steps, presenting each diagonal sentence three times. The sentences were presented using a mass trial format with each sentence being presented three times in a row. The teacher collected data on a printed data sheet using event recording (see Appendix N).

George: Intervention B. Intervention B consisted of only 5s delay trials and followed the same procedures as Intervention A for George with one exception. In intervention A when a word was shown, the word would stay revealed for the entire sentence. In Intervention B, immediately after providing error correction, the word would be hidden again. The next trial would begin with the teacher pointing to the next concealed word on the sentence strip. This change was made because anecdotal data revealed George was often selecting the previous word shown during Intervention A. For example, if he scored correct on the word “the” but required error correction on “is”, he would frequently select “the.” It was hypothesized that the previous word being left open on the sentence strip may have been controlling responding on the next word trial. All other procedures remained the same as Intervention A. The teacher collected data on a printed data sheet using event recording (see Appendix N).

George: Intervention C. Intervention C consisted of only 5s delay trials and followed the same procedures as Intervention B for George apart from using two prompting levels. Instead, the teacher used one prompt that included showing the word on the sentence strip and then immediately gesturing to the iPad, removing the opportunity for George to make errors during error correction. This change was made due to data revealing the initial prompt provided in Intervention A and B was not always successful in evoking the correct response. During Intervention A, prompting data taken on 50% of the sessions revealed that the initial prompt of pointing to the word on the sentence strip was effective on average 36% of the prompted trials. Additionally, in Intervention B the initial prompt was effective on average 53% of the prompted trials. The teacher collected data on a printed data sheet using event recording (see Appendix N).

Table 3

George: Intervention Modifications and Rationale

Intervention	Modification(s) Made from Previous Intervention	Rationale for Modifications
B	Procedures were modified so teachers would only display a word on the sentence strip if George made an incorrect selection on the iPad and then the word would be hidden again.	Previously, when the teacher displayed a word on the sentence strip it would remain visible during the next trial. This may have contributed to George's over selectivity of the words "the" and "is".
C	Response prompting procedure was modified from using two prompting levels with constant time delay (i.e., gesture to the word on the sentence strip and gesture to the word on the iPad) to the use of one controlling prompt (i.e., gesture to the word on the iPad).	The initial prompt of pointing to the word on the sentence strip did not always control George's responding which may have impacted George's accuracy.

Steven. Steven received only one intervention during the study. He was the last participant to enter intervention as I attempted to introduce participants using the multiple probe across participants design initially. The teacher used constant time delay to teach the diagonal sentences during Steven's intervention. The teacher implemented two sessions of 0s time delay. During this intervention, the teacher presented a photo with the sentence shown underneath it and asked, "Write a sentence about the photo." Immediately after, the teacher provided the controlling prompt in the form of a physical prompt. The teacher lightly grasped Steven's right hand, pointed his hand to the word on the sentence strip, and then moved his hand to select the same word on the iPad. This continued for each word in the sentence. At the completion of the sentence, the teacher provided praise and a token. The teacher repeated these steps, presenting each diagonal sentence three times. The sentences were presented using a mass trial format with each sentence being presented three times in a row. The teacher collected data on a printed data sheet using event recording (see Appendix O).

Following two sessions of 0s delay trials, the teacher inserted a 5s delay. During these sessions, the teacher presented the photo with the sentence hidden, asked Steven to "Write a sentence about the photo", and pointed to the first hidden word on the printed sentence. Then the teacher waited 5s for Steven to respond. If Steven responded correctly, the teacher provided praise and opened the word on the sentence strip. If Steven did not respond within 5s the teacher opened the correct word and physically prompted Steven to touch the word on the sentence strip and the iPad. If Steven selected an incorrect word the teacher would erase the word and then physically prompted Steven to touch the word on the sentence strip and the iPad. As words were revealed on the sentence strip, they remained visible until the entire sentence was constructed.

Once Steven selected the correct word on the iPad, the trial for the next word would begin by the teacher pointing to the next covered word on the sentence strip. The teacher then waited for 5s again and followed the error correction procedures described previously. This continued for every word in the sentence. The teacher provided tokens on FR1 per sentence constructed. This schedule was selected because a thinner schedule would have required Steven to sit longer than 10m, which at the time of the study was his average length of tasks in the classroom. Once Steven had selected all the words in the sentence, the teacher prompted Steven to playback the entire sentence on his SGD and provided general praise for completion of the sentence and a token. The teacher repeated these steps, presenting each diagonal sentence three times. The sentences were presented using a mass trial format with each sentence being presented three times in a row. The teacher collected data on a printed data sheet using event recording (see Appendix P).

Darius. Darius did not receive intervention because of the level change in baseline on subject-verb combinations.

Posttest

Posttests were originally planned to occur after students met the mastery criteria on diagonal targets; however, none of the participants met the mastery criteria so posttests were not conducted. Next, I will describe the initial plan for posttests. Once students met mastery criteria for diagonal responses in their matrix, teachers would conduct three posttest sessions for the nondiagonal targets (see Appendix G) to assess for recombinative generalization. The mastery criterion for nondiagonal targets would have been 83% (5 out of 6 trials) correct sentences across two consecutive sessions. If students did not meet this mastery criterion, I planned to use remedial procedures outlined by Frampton and Axe (2022) by conducting overlap training described below.

Overlap Training

Overlap training was not introduced to any participants during the study. The initial plan was that teachers would provide overlap training to students who responded below mastery criteria for nondiagonal targets. Overlap training would involve the same teaching procedures outlined for diagonal training for three additional targets in each participants matrix (see starred targets in Appendix E). Following overlap training, three targets would remain untrained in the matrix, allowing for recombinative generalization. If a student met mastery criteria for overlap targets, posttests would be conducted using the same procedures as in baseline. A mastery criterion of 67% would be set on the remaining nondiagonal targets to begin intervention on Matrix 2.

Maintenance

Maintenance sessions were not conducted due to the study ended with all participants in intervention. The initial plan was upon students meeting mastery of nondiagonal targets, maintenance sessions would be conducted 2 and 4 weeks after the last posttest. Teachers would have used procedures identical to those in baseline sessions.

Social Validity

To measure the social validity of the goals, procedures, and outcomes of the study I administered an adapted version of the Intervention Rating Profile-15 (IRP-15; Witt & Elliott, 1985) to teachers after training them on the initial intervention. Only two teachers were trained on intervention procedures, Ms. Heart and Ms. O’Hara. I administered the questionnaires (see Appendix Q) in person after the training session on intervention procedures for Intervention A for Taylor. The questionnaire consisted of 15 items that asked teachers to rate the acceptability, feasibility, and outcomes of the intervention. Each item was scored using a Likert-type scale ranging from 1 (strongly disagree) to 6 (strongly agree). After each administration of the questionnaire, I analyzed the data by calculating the mean scores for each item and the range.

To assess student social validity, students were given the opportunity to complete an alternative writing task once throughout their intervention. The alternative task was the typical writing instruction that took place for the student. During these sessions, the teacher presented these two options by a setting up the materials for both instructional options, with a visual schedule photo, and let the student select which task they would like to complete. If the students selected the alternative, the choice was honored, and the study was not conducted that day. The teachers collected data on this social validity assessment on their typical data collection sheets at the top of each sheet.

CHAPTER 4: RESULTS

This chapter contains the results of the study including interobserver agreement and procedural fidelity followed by results organized by each research question.

Interobserver Agreement

The secondary observers and I collected interobserver agreement (IOA) data on the dependent variables during live instructional sessions. I trained the secondary observers using BST to collect reliability data on all dependent variables across all intervention changes. During instructional sessions, members of the research team stood behind the teacher and student, collecting IOA data using printed data sheets. Then after each session, the research team member's data sheet was compared with the teacher's data sheet. For each dependent variable across all IOA sessions we used point-to-point interobserver agreement by dividing the number of agreements and disagreements and multiplying by 100%.

Taylor. We calculated IOA for 67% of Taylor's baseline sessions on the percentage of correct sentences and percentage of subject-verb combinations with 100% agreement. During Intervention A, we collected IOA data for 71% of the sessions on the percentage correct sentences and percentage of subject verb tacts with 100% agreement. During Intervention B, we collected IOA data across 100% of the sessions, on the percentage correct sentences and percentage of subject verb tacts with 100% agreement. During Intervention C, we collected IOA data on the percentage of correct sentences and percentage of correct word selections across 100% of the sessions, with 100% agreement. During Intervention D, we collected IOA on the percentage of correct sentences and percentage of correct word selections across 100% of the sessions, with 100% agreement.

George. During George's baseline, changes were made to the dependent variables in the study. The teacher collected data on the percentage of correct sentences written across all baseline sessions. We also began the study collecting data on the percentage of subject-verb combinations, however after George's 10th baseline session, data was no longer collected on this dependent variable due to intervention changes with Taylor. For George's remaining baseline sessions, we continued to collect data on the percentage of correct sentences written and we added the percentage of correct words selected.

We calculated IOA data on the percentage of correct sentences written across 73% of all baseline sessions with 100% agreement. We calculated IOA data on the percentage of correct subject-verb combinations across 70% of baseline sessions that used this dependent variable (n=10) with 100% agreement. Last, we calculated IOA data on the percentage of correct word selections across 60% of baseline sessions that used this dependent variable (n=5) with 100% agreement. During Intervention A, we collected IOA data on the percentage of correct sentences written across 67% of the sessions with 100% agreement and on the percentage of correct word selections across 33% of sessions with an average of 95% agreement. During Intervention B, we collected IOA data on the percentage of correct sentences written across 100% of the sessions with 100% agreement and on the percentage of correct word selections across 100% of sessions with an average of 100% agreement. During Intervention C, we collected IOA data on the percentage of correct sentences written across 20% of the sessions with 100% agreement and on the percentage of correct word selections across 20% of sessions with an average of 100% agreement.

Steven. During Steven's baseline, changes were made to the dependent variables in the study. The teacher collected data on the percentage of correct sentences written across all baseline sessions. We also began the study collecting data on the percentage of subject-verb combinations, however after Steven's ninth baseline session, data was no longer collected on this dependent variable due to intervention changes with Taylor. For Steven's remaining baseline sessions, we continued to collect data on the percentage of correct sentences written and we added the percentage of correct words selected.

We calculated IOA data on the percentage of correct sentences written across 56% of all baseline sessions with 100% agreement. We calculated IOA data on the percentage of correct subject-verb combinations across 56% of baseline sessions that used this dependent variable (n=9) with 100% agreement. Last, we calculated IOA data on the percentage of correct word selections across 50% of baseline sessions that used this dependent variable (n=6) with 100% agreement. During Steven's intervention, we collected IOA data on the percentage of correct sentences written and the percentage of correct word selections across 50% of the sessions with 100% agreement.

Procedural Fidelity

I collected procedural fidelity data with two other research members throughout the study. I trained the other research members to take procedural fidelity data across all conditions and interventions using BST. I met with the research members prior to them collecting any procedural fidelity data to provide training. During the training, I presented a procedural fidelity checklist, modeled the completion of the checklist, and then each team member role played collecting procedural fidelity. This continued until each team membered collected procedural fidelity meeting the mastery criterion of 100% IOA when compared to my data sheet for the role play session.

Due to procedural changes during intervention across participants, several procedural checklists were used. I used the same procedural fidelity checklist throughout all baseline and probe sessions (see Appendix R). I planned to use the same procedural checklist for participants in intervention (see Appendix S); however, due to several design changes, checklists were changed throughout the study to meet the need of each participant's intervention. Each checklist contained teacher behaviors to be observed following a trial-by-trial format according to each condition. At the end of an instructional session, the secondary observer calculated the percentage of procedural fidelity by taking the sum of behaviors observed, dividing it by the total number of opportunities, and multiplying by 100.

Taylor. We collected procedural fidelity across 50% of Taylor's baseline sessions achieving an average of 98%. In Intervention A, procedural fidelity was collected across 29% of sessions with an average rating of 100% using Appendix S. In Intervention B, we collected procedural fidelity across 100% of the sessions, with an average of 100% using Appendix T. In intervention C, we collected procedural fidelity across 33% of the sessions with an average of 100% using Appendix U. In intervention D, we collected procedural fidelity across 50% of the session with an average of 100%.

George. We collected procedural fidelity across 40% of George's baseline sessions achieving an average of 100%. In Intervention A, procedural fidelity was collected across 100% of sessions with an average rating of 99.7%. In Intervention B, we collected procedural fidelity across 33% of the sessions, with 98% accuracy. In intervention C, we collected procedural fidelity across 20% of the intervention sessions with 100% accuracy. Across all sessions two procedural fidelity checklists were used, one for 0s delay sessions (see Appendix W) and one for 5s delay sessions (see Appendix X).

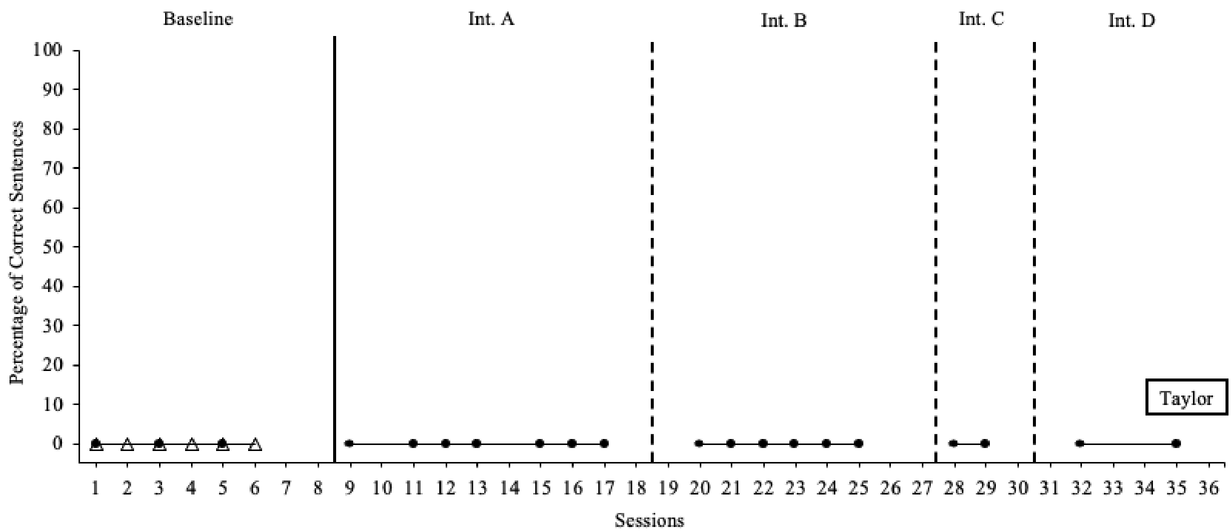
Steven. We collected procedural fidelity across 47% of Steven's baseline sessions achieving an average of 99%. During intervention, we collected procedural fidelity across 50% of the intervention sessions with 100% accuracy.

Results for Research Question 1: Is there a functional relation between matrix training, response prompting, and sentence frames and the percentage of trained and untrained sentences written for students with ASD and CCN?

Results from Question 1 are presented below by each participant. For each participant, all possible sessions were displayed on the x axis. Teachers were instructed to deliver intervention Monday through Friday; however, due to teacher training and student absences, this was not always possible. Sessions represent each day, Monday through Friday, from the beginning of the study to the conclusion, excluding one week of spring break and national holidays. Taylor received seven sessions of intervention during Intervention A, six sessions during Intervention B, two sessions during Intervention C, and four sessions (2-0s delay and 2-5s delay) during Intervention D. In total, Taylor received 19 sessions of intervention across all conditions.

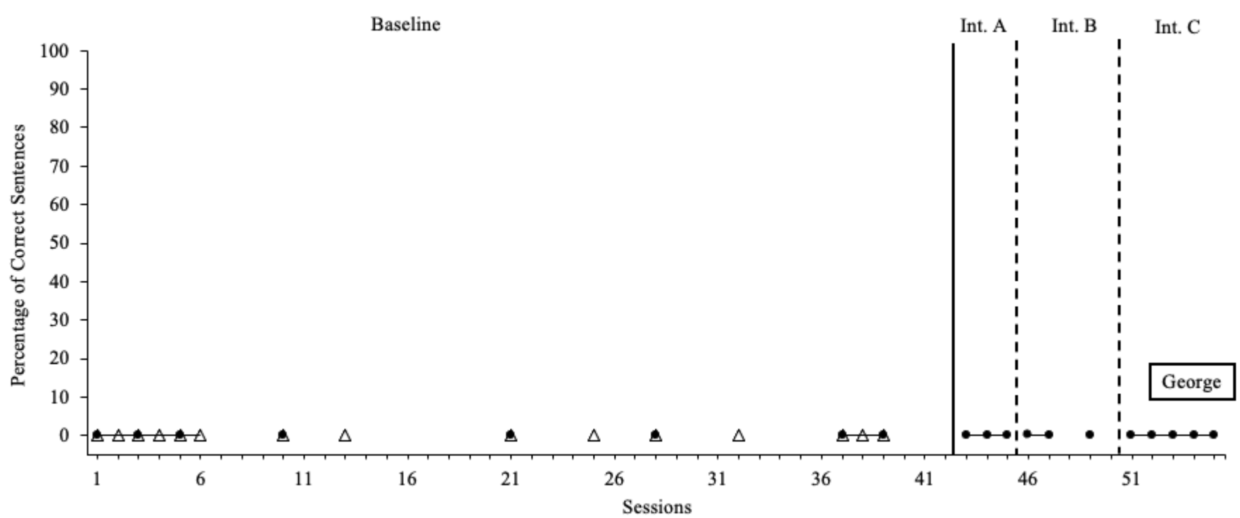
For Research Question 1, Taylor's data are shown in Figure 7, George's data are shown in Figure 8, Steven's data are shown in Figure 9, and Darius's data are shown in Figure 10. In each figure across all participants the closed circles represent participants' responses to diagonal sentences in the matrix, whereas the triangle represents participants' responses to nondiagonal sentences in the matrix. During baseline, all participants scored 0% correct sentences across diagonal and nondiagonal sentences, across all sessions. During intervention, scores for Taylor, George, and Steven did not increase in the percentage of correct sentences written, scoring 0% correct sentences during all intervention sessions. Due to these participants not meeting the mastery criteria on diagonal sentences, I did not probe nondiagonal or untrained sentences for generalization. These results indicate the intervention package of matrix training, response prompting, and sentence frames was ineffective for all participants. Darius did not receive intervention due to his performance showing an increasing trend on the percentage of subject-verb combinations during baseline.

Figure 7



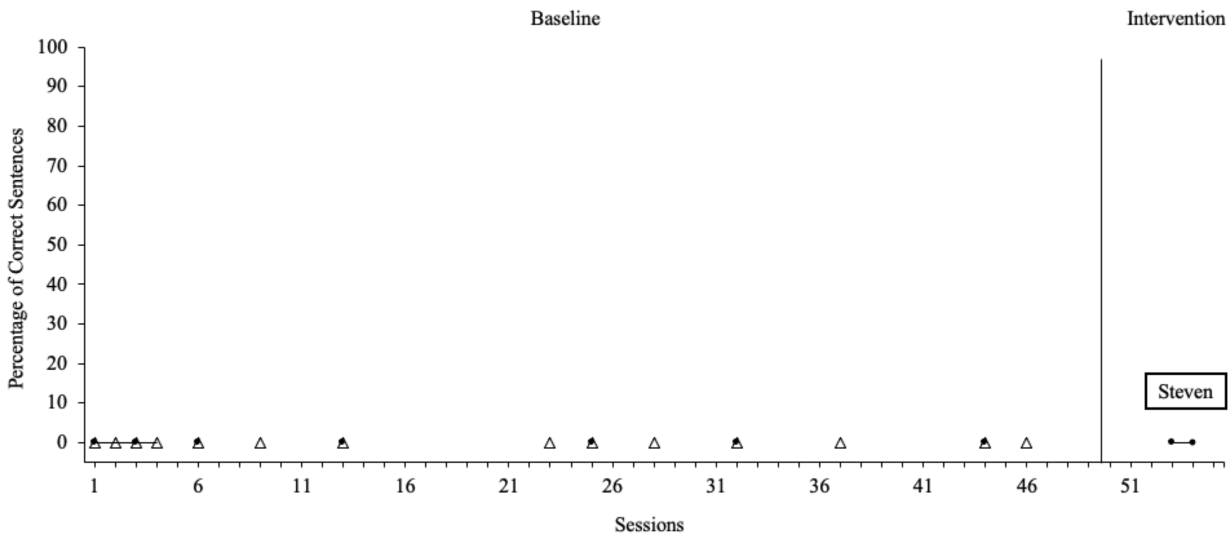
Taylor's Percentage of Correct Sentences

Figure 8



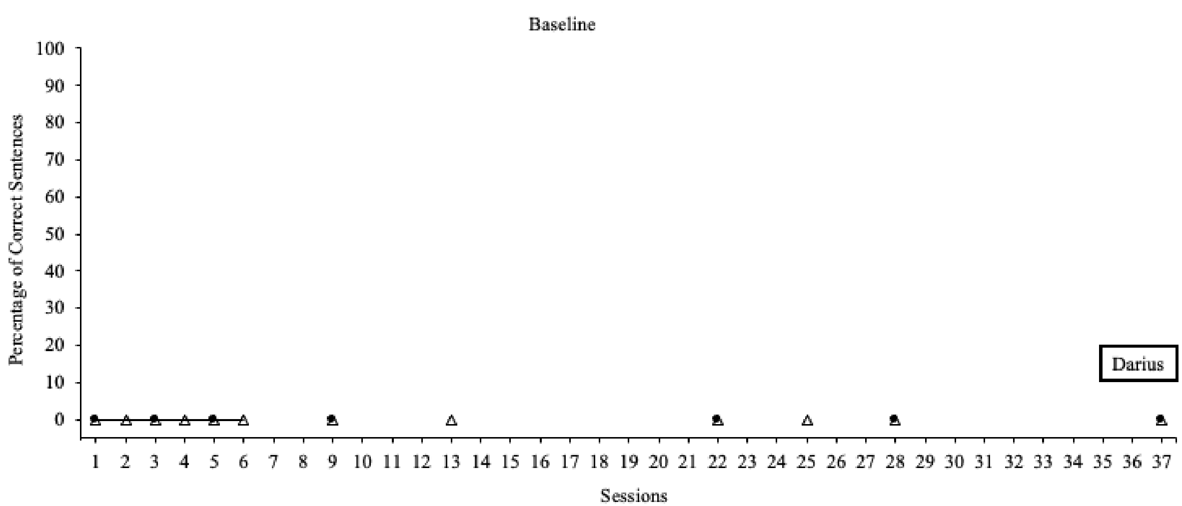
George's Percentage of Correct Sentences

Figure 9



Steven's Percentage of Correct Sentences

Figure 10



Darius's Percentage of Correct Sentences

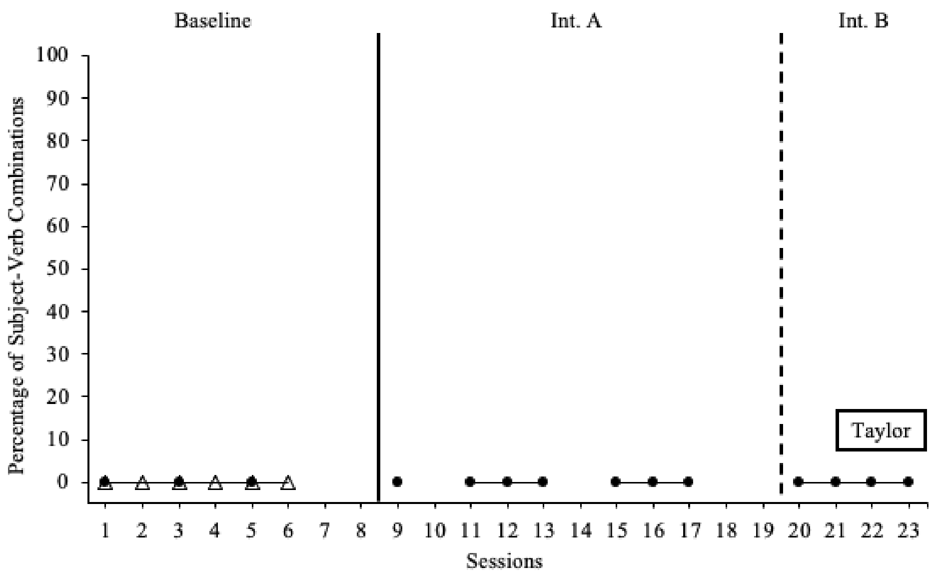
Results for Research Question 2: Is there a functional relation between matrix training, response prompting, and sentence frames and the percentage of trained and untrained subject-verb combinations for students with ASD and CCN?

Data on the percentage of correct subject-verb combinations were collected at the beginning of the study for each participant until Taylor received Intervention C. Data were no longer collected on the percentage of subject-verb combinations after this due to changes in response prompting procedures that removed the possibility of measuring subject-verb combinations. For Research Question 2, Taylor's graphed data are shown in Figure 11, George's data are shown in Figure 12, Steven's data are shown in Figure 13, and Darius's data are shown in Figure 14. The closed circles represent participants' responses to diagonal sentences in the matrix, whereas the triangle represents participants' responses to nondiagonal sentences in the matrix. During baseline, Taylor, George, and Steven scored 0% subject-verb combinations across diagonal and nondiagonal sentences, across all sessions. Taylor was the only participant whose subject-verb combinations were measure during intervention. During Intervention A and B, Taylor's performance did not increase in the percentage of subject-verb combinations, scoring 0% across all intervention sessions. Since she did not meet the mastery criteria on diagonal subject-verb sentences, I did not probe nondiagonal or untrained subject-verb sentences for generalization.

Darius's graphed data for the percentage of subject-verb combinations are displayed in Figure 14. I collected ten sessions of baseline data on the percentage of subject-verb combinations for Darius. During baseline, Darius scored an average of 67% correct subject-verb combinations on diagonal sentences (range=0−100%) and 73% correct subject-verb combinations (range=0−100%) on nondiagonal sentences across all baseline sessions. Due to

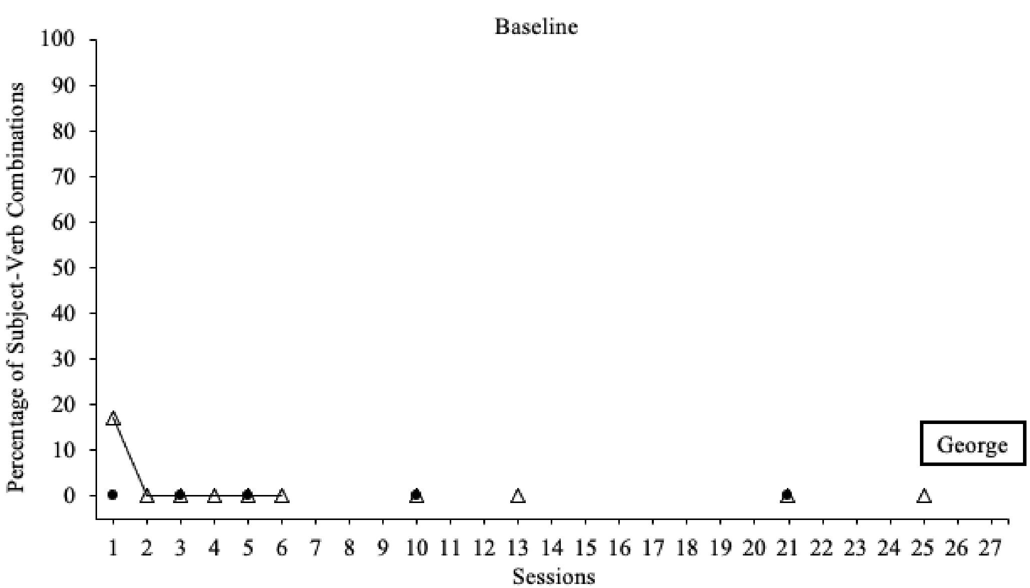
Darius's performance showing an increasing trend during baseline, Darius did not enter intervention.

Figure 11



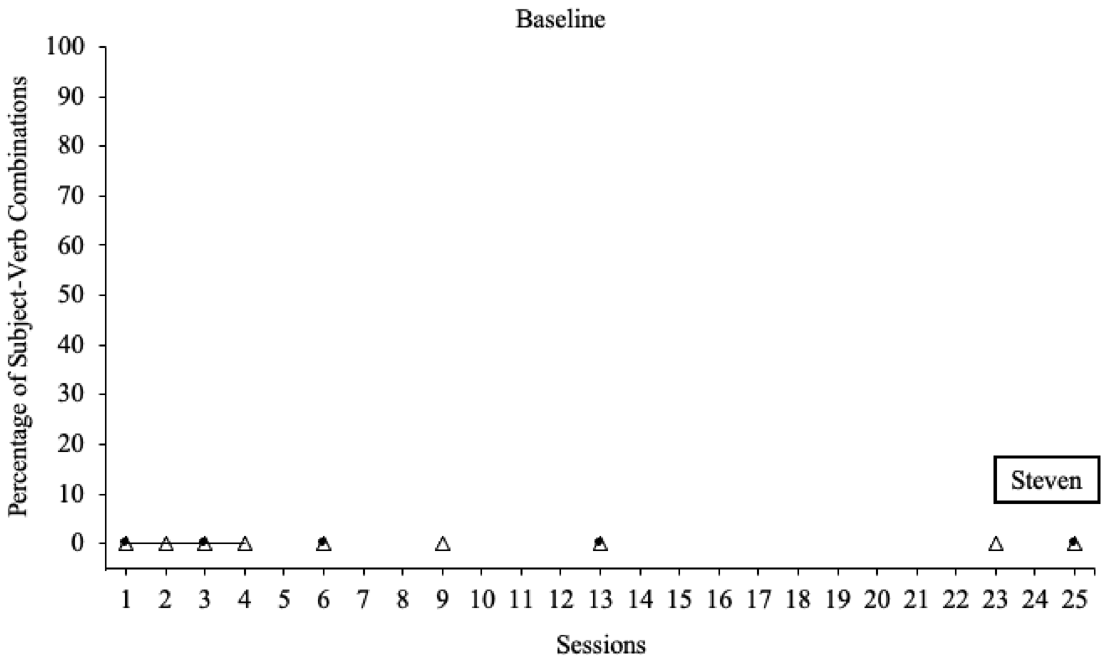
Taylor's Percentage of Subject-Verb Combinations

Figure 12



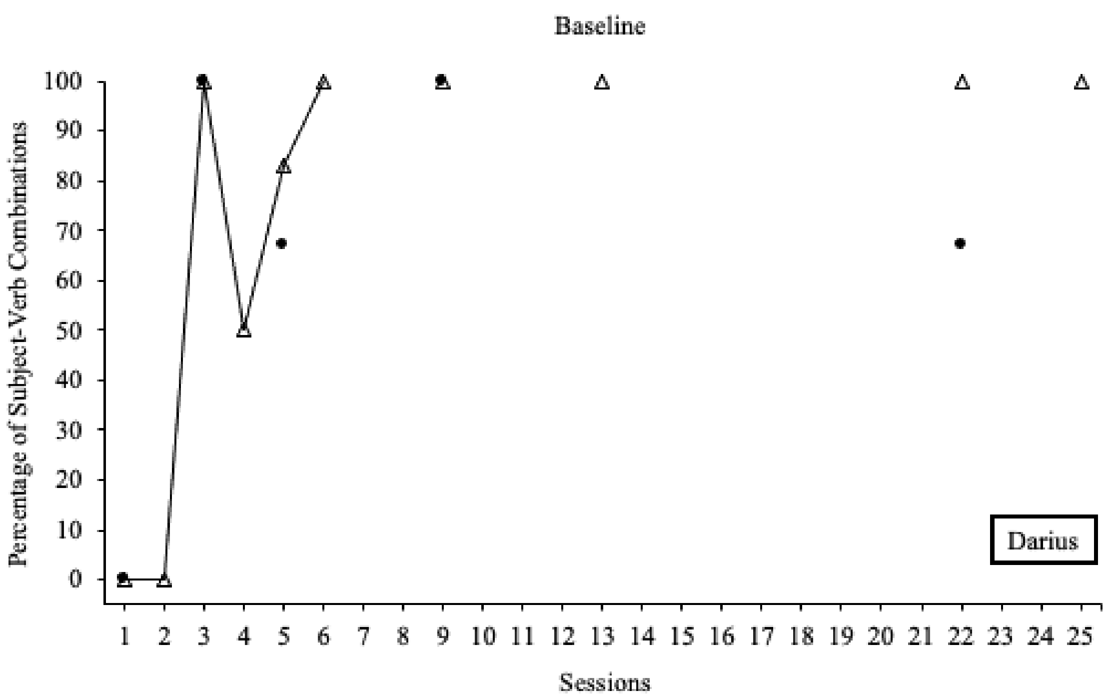
George's Percentage of Subject-Verb Combinations

Figure 13



Steven's Percentage of Subject-Verb Combinations

Figure 14



Darius's Percentage of Subject-Verb Combinations

Results for Research Question 3: How do teacher and student participants perceive the feasibility and overall effects of the intervention package?

Teacher Social Validity

I administered an adapted version of the Intervention Rating Profile-15 (IRP-15; Witt & Elliott, 1985) to Ms. Heart and Ms. O'Hara after training them on the initial intervention and at the conclusion of the study. The questionnaire consisted of 15 items that asked teachers to rate the acceptability, feasibility, and outcomes of the intervention. Each item was scored using a Likert-type scale ranging from 1 (strongly disagree) to 6 (strongly agree) with a possible total score of 90. Mr. Barry did not complete the questionnaire because he was not trained on intervention procedures. Results from the questionnaire are displayed below in Table 2.

At pre-intervention, Ms. Heart rated the intervention at total of 76 and Ms. O'Hara rated the intervention at a total of 75. At pre-intervention both teachers agreed that the intervention was acceptable for teaching writing skills, that most teachers would find the intervention appropriate, they would suggest the intervention to other teachers, that the intervention was appropriate to meet the students' needs, that most teachers would find the intervention suitable for the described purpose, that the intervention was consistent with other interventions they have used in the classroom, the intervention is a fair way to fulfill the intervention purposes, they liked the intervention procedures, that the intervention is a good way to meet the specified purpose, and that overall the intervention would be beneficial for classroom students. The teachers gave Questions 7–9 on the questionnaire different scores. Ms. Heart agreed that she would be willing to use the intervention in a classroom setting (Question 7), whereas Ms. O'Hara strongly agreed. Next, Ms. Heart strongly agreed that the intervention would not result in negative side effects

(Question 8), whereas Ms. O'Hara only agreed. Last, Ms. Heart agreed that the intervention would be appropriate for a variety of students (Question 9), whereas Ms. O'Hara slightly agreed.

At post-intervention, Ms. Heart rated the intervention at total of 75, one point lower than pre-intervention. Ms. O'Hara rated the intervention at a total of 75, which was the same at pre-intervention. Both teachers agreed on the same items as pre-intervention, rating Questions 1–6 and 9–15 as agree. Like pre-intervention results, they scored Questions 7–9 different from each other and some of these items they scored lower or higher than their pre-intervention score. On Question 7, "I would be willing to use this intervention in the classroom setting.", Ms. Heart increased her original rating from agree to strongly agree and Ms. O'Hara decreased her original rating from strongly agree to agree. On Question 8, "This intervention would not result in negative side effects for the students.", Ms. Heart decreased her original rating from strongly agree to agree and Ms. O'Hara scored the same rating as pre-intervention with agree. Last, on Question 9, "This intervention would be appropriate for a variety of students.", Ms. Heart decreased her original rating from agree to slightly agree. Ms. O'Hara increased her original score on this item from slightly agree to agree.

Table 4

Results from IRP-15 Social Validity Questionnaire

Question	Pre- Intervention			Post- Intervention		
	Ms. Heart	Ms. O'Hara	Mean	Ms. Heart	Ms. O'Hara	Mean
1. This would be an acceptable intervention for teaching writing skills.	5	5	5	5	5	5
2. Most teachers would find this intervention appropriate.	5	5	5	5	5	5
3. This intervention should prove effective in meeting the purposes.	5	5	5	5	5	5
4. I would suggest the use of this intervention to other teachers.	5	5	5	5	5	5
5. The intervention is appropriate to meet the students' needs.	5	5	5	5	5	5
6. Most teachers would find this intervention suitable for the described purposes.	5	5	5	5	5	5
7. I would be willing to use this intervention in the classroom setting.	5	6	5.5	6	5	5.5
8. This intervention would not result in negative side effects for the students.	6	5	5.5	5	5	5
9. This intervention would be appropriate for a variety of students.	5	4	4.5	4	5	4.5
10. This intervention is consistent with those I have used in classroom settings.	5	5	5	5	5	5
11. The intervention is a fair way to fulfill the intervention purposes.	5	5	5	5	5	5
12. This intervention is reasonable to meet the specified purpose.	5	5	5	5	5	5
13. I like the procedures used in this intervention.	5	5	5	5	5	5
14. This intervention is a good way to meet the specified purpose.	5	5	5	5	5	5
15. Overall, this intervention would be beneficial for the classroom students.	5	5	5	5	5	5

Note: Based on a 5-point Likert scale. 1 = *strongly disagree*, 2 = *disagree*, 3 = *slightly disagree*, 4= *slightly agree*, 5 = *agree*, *6 = strongly agree*

Student Social Validity

To assess student social validity, students were given the opportunity to complete an alternative writing task at different times throughout their intervention(s). The teacher selected the alternative task to be presented based on the typical writing instruction that took place for the student. During each social validity probe, the teacher presented a visual schedule card that included a photo of a writing of the studies materials along with a picture card of their typical writing task, and then asked them to select which task they would like to complete. In the next section, social validity results are presented for all student participants.

Taylor

The teacher presented an alternative writing task to assess student social validity once during Intervention A and once during Intervention B for Taylor. During this assessment, the teacher placed a schedule card that was used during all intervention sessions in front of Taylor along with a schedule card of her typical writing task. Her typical writing task included tracing her name. Then the teacher asked Taylor to select a writing task. Taylor made a selection by handing the picture card to the teacher. During Intervention A, the social validity assessment was conducted on session 5 and Taylor selected the study. During Intervention B, the social validity assessment was also conducted on session 5 and Taylor selected the study again.

George

The teacher presented an alternative writing task to assess social validity once during Intervention B for George. During this assessment, the teacher placed a schedule card that was used during all intervention sessions in front of George along with a schedule card of her typical writing task. His typical writing task included copying numbers using paper and pencil from a printed model. Then the teacher asked George to select a writing task. George made a selection by handing the picture card to the teacher. The social validity assessment was conducted on session 2 of Intervention B and George selected the study.

Steven

The teacher presented an alternative writing task to assess social validity once during Steven's intervention. During this assessment, the teacher placed a schedule card that was used during all intervention sessions in front of Steven along with a schedule card of his typical writing task. His typical writing task included stamping his name on a piece of paper. Then the teacher asked Steven to select a writing task. Steven made a selection by handing the picture card to the teacher. The social validity assessment was conducted on Steven's last intervention session and Steven selected the alternative task.

Darius

The teachers did not collect social validity data with Darius because he did not receive intervention.

Additional Dependent Variable

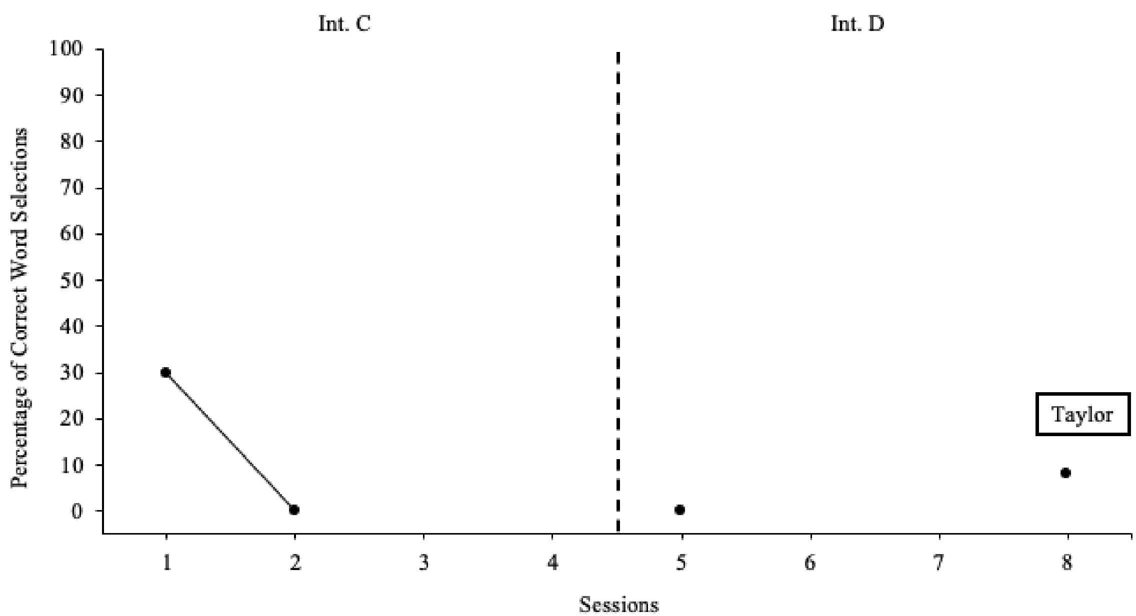
An additional dependent variable, the percentage of correct word selections was added immediately before Taylor's first session of Intervention C across all participants. During Intervention B, the teacher used constant time delay and during 5s time delay sessions if Taylor made an error on the first word in the sentence, the teacher would provide a controlling prompt for the remainder of the sentence. During Intervention C, the teacher also used constant time delay; however, if a student made an error on one word during 5s time delay sessions, the teacher would only provide a controlling prompt for that word and present an opportunity to respond for the next word in the sentence. Thus, adding the percentage of correct word selections allowed me to have a more sensitive dependent variable.

Taylor

Taylor's graphed data for the percentage of correct word selections are displayed in Figure 15. The closed circles represent Taylor's performance on diagonal sentences in the matrix. Because this dependent variable was added during Intervention C, data during baseline and Interventions A-B are not included in this figure. During Intervention C, Taylor received two sessions of intervention using 5s time delay. Taylor scored 30% correct word selections during her first session of intervention and 0% correct word selections during her second session of intervention. After the first session of intervention, the materials were changed due to the possibility that Taylor could see through the paper covering the sentence. This may have contributed to Taylor's moderate level of responding during session one. Prior to session two, black tape was added on top of the paper flap that hid the sentence to ensure that Taylor could not see through the paper. The level change in Taylor's performance from session one to two indicates that Taylor may have been able to see through the covered sentence strip during session one. A third session was started but the iPad died during the session, thus the data are not displayed. As a result, Intervention C was concluded.

During intervention D, four sessions of intervention were provided for just one sentence, "the boy is sleeping." Additionally, a new reinforcement schedule was introduced where Taylor received a token on a continuous schedule for unprompted correct word selections. During session one the teacher used 5s time delay and Taylor scored 0% correct word selections. After this session, I decided the teacher should provide two sessions of 0s time delay using an FR1 for prompted correct word selections so that Taylor could learn the reinforcement contingency. Data from these sessions are not graphed because the sessions used errorless trials where the teacher used 0s time delay. Following two session of 0s time delay, the teacher conducted one session using 5s time delay using a continuous schedule for unprompted corrects. Taylor scored 8% correct word selections. Her average across both 5s time delay sessions was 4% correct word selections (range=0-8%).

Figure 15



Taylor's Percentage of Correct Word Selections

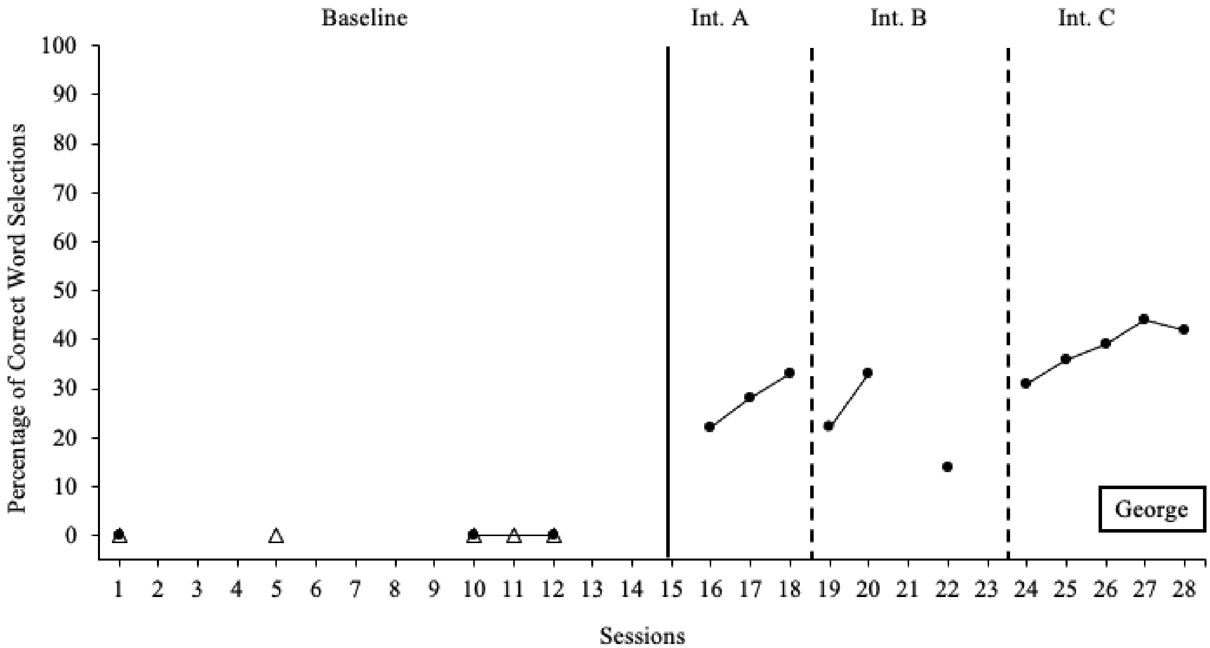
George

George's graphed data for the percentage of correct word selections are displayed in Figure 16. The closed circles represent his performance on diagonal sentences in the matrix, whereas the triangle represents his performance on nondiagonal sentences in the matrix. Throughout the entire study, 15 sessions of baseline data were collected for George. However, the percentage of correct word selections was not added until session 11. The data presented on Figure 16 begin with the first baseline session that included the new dependent variable.

George received three different interventions, represented by the phase change lines. During baseline sessions that included the percentage of correct word selections, George scored

0% correct word selections across all baseline sessions. During Intervention A, after three sessions of 0s time delay, George averaged 28% correct word selections (range=22-33%). Then during Intervention B, George averaged 23% correct word selections (range=14-33%). Last, during Intervention C, George averaged 38% correct word selections (range=31-44%). The team collected data on the selections that George made while collecting IOA and noticed that George selected "the" and "is" most often. Across all intervention sessions, each diagonal sentence was presented three times. Since I used the same sentence frame across all sentences (the ____ is ____), there was a 50% chance that if they selected "the" or "is" for every selection that it would be correct. For example, every intervention session had a total of 36 correct word selections (four words per sentence and nine sentences total), and of those 36 words, "the" appeared nine times (25% of total words), and "is" appeared nine times (25% of total words). Whereas each subject and verb only appeared three times. The research team collected data on the words George selected for one session in Intervention A, three sessions in Intervention B, and three sessions in Intervention C. During these sessions the research team wrote down the exact word George selected for every trial. Results from an error analysis across these sessions revealed that when George selected an incorrect word he selected "the" on average 25% of his errors and "is" 10% of his errors.

Figure 16



George's Percentage of Correct Word Selections

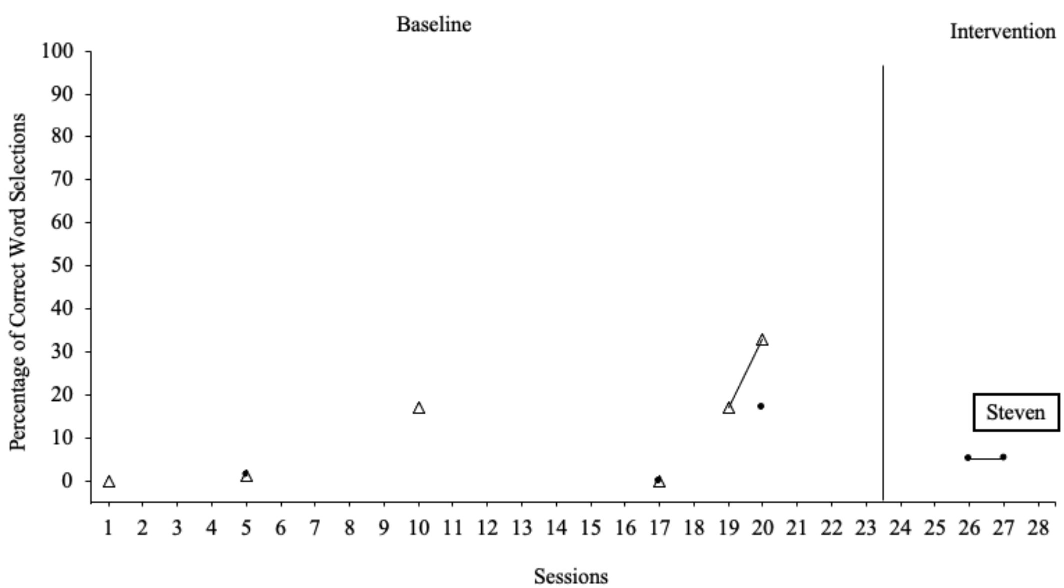
Steven

Steven's graphed data for the percentage of correct word selections are displayed in Figure 17. The closed circles represent Steven's performance on diagonal sentences in the matrix, whereas the triangle represents his performance on nondiagonal sentences in the matrix. Throughout the entire study, 15 sessions of baseline data were collected for Steven. However, the percentage of correct word selections was not added until session 10 of baseline. The data presented on Figure 17 begin with the first baseline session that included the new dependent variable.

Steven received one intervention during the study. During baseline sessions that included the percentage of correct word selections, Steven averaged 4% correct word selections on diagonal targets (range=0-17%), and 11% correct word selections on nondiagonal targets (range=0-33%). During baseline sessions Steven repeatedly selected one word throughout baseline sessions. For example, if the target sentence was "the boy is eating" and Steven selected "eating, eating, eating, eating," he would score 1 correct word selection for that sentence. He frequently engaged in this behavior throughout baseline sessions which resulted in a moderate level change during sessions 10, 18, and 20.

During intervention, the teacher provided two sessions of 0s time delay, followed by two sessions of 5s time delay. Data from the 0s time delay sessions are not graphed because these sessions included prompted responses. Across the two 5s delay sessions, Steven scored 5% correct word selections. The study was concluded after Steven's second intervention session.

Figure 17



Steven's Percentage of Correct Word Selections

Darius

The teacher collected only one session of baseline data on the percentage of correct word selections for Darius. During this one session, Darius scored 0% correct word selections across both diagonal and nondiagonal sentences. Darius did, however, still select the correct subject-verb combination but due to how correct word selections were scored this resulted in a score of

0. This session was Darius's last session in the study. I decided to no longer collect data on Darius's performance due to the fact that his data on subject-verb combinations were at a high level and increasing over time.

CHAPTER 5: DISCUSSION

The purpose of this study was to analyze the effects of matrix training, response prompting, and sentence frames on sentence writing for students with ASD and CCN. I used a series of A-B designs with modifications to examine the effects of the intervention package on the percentage of trained and untrained correct sentences, percentage of subject-verb combinations, and the percentage of correct word selections. Baseline data were collected on all student participants, but only three of the four students received intervention due to Darius's increasing trend of subject-verb combinations in baseline.

I originally planned to use the same intervention for all participants; however, after seven sessions of Intervention A for Taylor and no changes in responding, the intervention procedures were modified. Taylor received four interventions, Intervention A-D. George received three interventions, Intervention A-C. Last, Steven received only one intervention. Results indicated that across all interventions there were no effects on the percentage of trained and untrained correct sentences and subject-verb combinations for all participants.

The percentage of correct word selections was added as an additional dependent variable for all participants prior to Taylor's first session of Intervention C. Results indicated that Taylor made slight increases in the percentage of correct word selections for one out of two sessions during Intervention C and D. Similarly, George's data indicated an increasing trend throughout all his interventions (Interventions A-C). Last, Steven's data indicated no change in responding after two intervention sessions on the percentage of correct word selections.

Due to none of the participants meeting the mastery criteria during intervention on diagonal sentences and subject-verb combinations, generalization probes were not conducted as planned. Additionally, maintenance data were not collected. Results from the teacher social validity questionnaire suggest that overall, teachers found the intervention acceptable and beneficial for students in the classroom. Results from the student social validity assessments indicated that overall, students preferred this writing intervention over their typical writing instruction in the classroom. One student, Steven, preferred his typical writing intervention instead of the intervention used in the study. This section will present a discussion of the findings organized by each research question. Then I will present contributions to the literature, limitations, and suggestions for future research.

Impact of the Intervention on Dependent Variables

Results for Research Question 1: Is there a functional relation between matrix training, response prompting, and sentence frames and the percentage of trained and untrained sentences written for students with ASD and CCN?

Visual analysis of results indicated that there was no demonstration of effect on the percentage of trained and untrained sentences written as a result of the intervention(s) across all participants and intervention conditions. In baseline, all participants scored 0% correct sentences written across all sessions. Untrained sentences were not probed after intervention due to students not meeting the mastery criteria of trained or diagonal sentences during intervention.

Matrix training has predominately been used with individuals who have autism who use vocal communication as their response mode to tact subject-verb-object combinations (Kohler & Malott, 2014), subject-verb combinations (Frampton et al., 2016), color-shape combinations (Frampton et al., 2019), object-prepositions combinations (Pauwels et al., 2015). Two research teams have used matrix training with individuals who use picture communication boards to teach action-object tacts (Nigam et al., 2006) and subject-verb tacts, subject-object tacts, and attribute-noun tacts within story-based lessons (Tönsing et al., 2014). Only one research team has evaluated the use of a matrix training package to teach sentence construction to individuals with autism (Yamamoto & Miya, 1999). In this study, researchers trained three young students to construct subject-verb-object sentences in Japanese using a computer program. The participants were 6–8 years old and communicated vocally using one- to two-word sentences. Unlike this study, the students were trained to name the component subjects, verbs, and objects to criterion prior to the study. Students constructed sentences using a computer software that displayed four objects, four verbs, four subjects, and four particle words. During training, pictures representing the diagonal sentences were presented once per trial. If the student did not construct a correct sentence, the correct answer would appear and then the trial would be represented. Two students reached the mastery criteria for diagonal sentences within six training blocks (three trials per block) and the other student required eight training blocks to meet criterion. Additionally, posttests on the 24 untrained stimuli indicated that two students scored 100% on sentence construction, and the other 79%.

The results of this current study did not replicate these previous findings; however, there were major differences between the two studies. First, the participants were younger in age, and all used some vocal language as well as mastered the component parts of the matrix. Next, intervention procedures differed. In this current study a modified version of simultaneous prompting and constant time delay were used, whereas Yamamoto and Miya (1999) used error correction and modeling. These differences may have contributed to the differences in effect. While this study did not replicate previous findings, Cook and Therion (2017) suggest that null results can inform practitioners “under which conditions, and for which outcomes a practice is and is not likely to improve learner outcomes” (p. 151).

Although there is limited research using matrix training to teach sentence construction, there is an emerging body of literature on the effectiveness of using response prompting to teach sentence construction to individuals with autism and CCN (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). Unfortunately, the extent to which prerequisite skills have been described and/or assessed throughout these studies is limited. In one study, Pennington and Rockhold (2018) screened participants prior to baseline by presenting the words to be used in the study on the iPad and asked participants to select them by name. Additionally, they presented the animal photos that students would write about to test their receptive identification. Next, Pennington, Foreman, et al. (2018) received teacher report that students were sight word readers but did not conduct a screening measure. Similarly, Pennington et al. (2021) required participants to have a sight word reading repertoire of at least 10 sight words to enter the study; however, there was no screener, and it was not clear how this was demonstrated for the minimally vocal or nonvocal participants. Last, Pennington, Flick, et al. (2018) described that students were primarily sight word readers from teacher report, but no screener was conducted on prerequisite skills for the study.

In this study, students were assessed on the component skills of the matrix prior to baseline. During the assessment, the teacher presented one array of subjects, and a separate array of verbs on the SGD, presented a photo and asked, “Who is it?” or “What are they doing?”. Taylor’s results indicated she could label three of four nouns and two of four verbs. George’s results indicated he could label three of four nouns and one of four verbs. Steven’s results indicated that he could label zero of four nouns, and one of four verbs. Darius’s results indicated that he could label two of the four nouns and four of four verbs. Although students displayed some labeling skills during the assessment, the pre-training condition revealed that students had difficulties with more complex conditional discriminations (e.g., discriminating between all the noun and subject symbols presented in the array). This may have been due to the array changing during pre-training. During the assessment, I used a separate folder for subjects and verbs, whereas during pre-training I used one folder/array for all subjects and verbs. This change was made to support the level of discrimination that would be needed during intervention. This required students to engage in more complex auditory-visual conditional discriminations between all the items in the array when presented with a photo and a question (e.g., “Who is it?” or “What are they doing?”).

This type of discrimination is known as an auditory-visual conditional discrimination. In this discrimination, the visual antecedent stimuli and the vocal conditional stimulus occasion a response. For example, during pre-training the teacher presented a photo with an array of response options on the SGD and asked, “Who is it?”. These components together elicit the response “cat” on the device. This is further broken down into a four-term contingency in Figure 18. In this example, students need to attend to the photo presented, scan the array of options, and select the response that matches the conditional stimulus (i.e., the question being asked). Here, the response selection of “cat” on the SGD becomes the discriminative stimulus, whereas the other selections in the array do not result in reinforcement. Auditory-visual conditional discriminations are frequently taught in intensive behavior programs and early intervention (Leaf & McEachin, 1999; Lovaas, 2003). However, some students with autism present unique challenges in acquiring these skills. Kodak et al. (2015) examined the relation between prerequisite skills and performance on auditory-visual conditional discriminations for students ages 4–9 with autism and found that 44% of the participants did not acquire auditory-visual conditional discriminations after intervention. The researchers developed and piloted an assessment of prerequisite skills that included matching, visual discrimination, auditory discrimination, imitation of pointing, and scanning. Four of the nine students did not show mastery level responding in one or more of the prerequisite skills. Of these four students, the assessment was predictive of success during auditory-visual conditional discrimination training for two of those students. All five students who mastered the skills on the assessment met criterion during auditory-visual conditional discrimination training. These results suggest that prerequisite skills may impact auditory-visual conditional discriminations. Thus, students' prerequisite skills in this current study may have impacted their success during intervention.

Figure 18

Visual Antecedent Stimuli	Conditional Stimulus	Student Response	Consequence
Photo of a cat swimming and an array of subjects and verbs are presented	The teacher asks, "Who is it?"	Student selects the icon "cat" on the SGD	Teacher delivers praise

Example of Auditory-visual Conditional Discrimination

An additional factor that may have impacted students' success is their previous experience with SGDs, including how symbols were displayed, and their history of being reinforced for tacting in their environment. All students had previous experience with SGDs except for Steven. These students used iPads programmed with Proloquo2go as their SGD every day in the classroom. Although students were familiar with SGDs, the display used in the study differed from what they typically used. Students' devices were programmed with several folders that were categorized by group (e.g., places, people, things, numbers, food). The use of one folder that included multiple categories of symbols in this study may have impacted students' progress. Last, students most often used mands or requests to communicate throughout the school day. There were fewer opportunities presented to receive reinforcement for tacts during the study. This may have impacted motivational variables for students in the study.

Furthermore, although previous research indicates response prompting to be effective in teaching sentence construction to individuals with autism and CCN (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018), the level of detail in participant descriptions of language/communication was mixed making these findings difficult to generalize to individuals with CCN. For example, Pennington et al. (2021) provided participant disability categories, IQ assessments, and a general communication level (i.e., vocal, minimal vocal, and nonvocal). Pennington, Flick, et al. (2028) included students' diagnoses, IQ scores, language assessment data for two of three students, and a general statement that all participants could emit one to three word spoken requests and labels. Pennington, Foreman, et al. (2018) provided participant diagnoses, IQ scores, language assessment scores, and academic achievement scores. Last, Pennington and Rockhold (2018) provided participant IQ, language assessment, and autism rating scale scores, as well as provided a general statement that two students spoke in one-to-two-word utterances and the third student was nonvocal. Although these studies provide assessment scores and general communication descriptions, it may be beneficial for future researchers to use assessments related specifically to verbal behavior such as the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg, 2014) when targeting language or writing for students with CCN. There are, however, barriers to obtaining assessment scores and including them in participant descriptions when assessments like the VB-MAPP are not typically delivered in school settings and having research team members conduct these assessments may not be feasible.

Early quality indicators of single-case research designs included two criteria for a study to meet “acceptable” methodological rigor related to the description of participants (a) “Participants are described with sufficient detail to allow others to select individuals with similar characteristics (e.g., age, gender, disability, diagnosis)”, and (b)” The process for selecting participants is described with replicable precision.” (Horner et al., 2005, p. 174). Several researchers have made recommendations following these initial standards. For example, Ledford et al. (2023) suggested researchers should “Report recruitment information, inclusion criteria, relevant descriptive data, and demographic characteristics (race-ethnicity, age, languages spoken, gender [including nonbinary choices], relevant individual or context-specific [e.g., school] socioeconomic status information); Report relationship between participant and implementer; Content experts are required to determine what descriptive data are relevant given study goals, but demographic data should always be reported” (p. 388). Another recent recommendation from Ganz and Ayres (2018) suggests that participant descriptions should include “Diagnostic assessment and psychometric information that is relevant to the study and not just tangential (e.g. reading comprehension scores from a standardized test in a study about reading) along with other descriptions” (p. 7). Even though these researchers have proposed more detailed descriptions, the scientific community does not follow one set of guidelines. This lack of consensus across may contribute to the wide variety of participant descriptions used in single-case research. A recent review sheds light on these issues reporting that out of 162 single-case research design studies using AAC interventions for individuals with ASD or IDD to support communication or behavioral skills, only 51% of studies included assessment data under participant characteristics (Ganz et al., 2023).

Results for Research Question 2: Is there a functional relation between matrix training, response prompting, and sentence frames and the percentage of trained and untrained subject-verb combinations for students with ASD and CCN?

Visual analysis of results indicated that there was no demonstration of effect on the percentage of trained and untrained subject-verb combinations because of the intervention package across all participants and intervention conditions. Taylor, George, and Steven scored 0% correct subject-verb combinations across all baseline and intervention sessions. Untrained subject-verb combinations were not probed after intervention due to students not meeting the mastery criteria of trained or diagonal sentences. During baseline, Darius scored an average of 67% correct subject-verb combinations on diagonal sentences (range=0−100%) and 73% correct subject-verb combinations (range=0−100%) on nondiagonal sentences across all baseline sessions. Due to Darius's performance showing an increasing trend during baseline, Darius did not enter intervention.

Only one other study has investigated the use of matrix training to teach verbal behavior using SGDs (Marya et al., 2021). Three participants ages 3, 6, and 16 were enrolled in the study. All students had prior experience using SGDs and scored as Level 2 learners on the VB-MAPP (Sundberg, 2014). The researchers designed two 3x3 subject-verb matrices (training matrix and generalization matrix) for each participant using mastered subjects and verbs. Animal figurines were used to depict the subject-verb combinations. Diagonal training was used with a discrete trial teaching format with multiple trial instruction, error correction procedures, and reinforcement. All three participants met mastery criteria for diagonal responses within seven sessions and engaged in high levels of recombinative generalization on the nondiagonal probe. Furthermore, two of three participants generalized responding to the generalization matrix.

Robin, the 16-year-old participant, required additional training to generalize to targets outside of the training matrix.

Researchers have also effectively used matrix training with individuals with autism to increase vocal subject-verb-object combinations (Kohler & Malott, 2014), subject-verb combinations (Frampton et al., 2016), color-shape combinations (Frampton et al., 2019), and object-prepositions combinations (Pauwels et al., 2015). Additionally, matrix training has been used with communication boards to teach action-object tacts (Nigam et al., 2006) and subject-verb tacts, subject-object tacts, and attribute-noun tacts within story-based lessons (Tönsing et al., 2014). Across these investigations, researchers either used mastered component skills (Kohler & Malott, 2014; Frampton et al., 2016, 2019; Nigam et al., 2006) or unknown component skills (Pauwels et al., 2015). Tönsing et al. (2014) did not indicate if component skills were mastered. Pauwels et al. (2015) included two students, ages 19 and 20, one who communicated vocally using complete or fragmented sentences and the other using one-word mands or fragmented sentences.

Additionally, when considering the auditory-visual conditional discriminations that students need to make during intervention, the conditional stimulus used during baseline and intervention is more complex. See Figure 19 for an example. Most often when teaching subject-verb tacts, the antecedent question used is “What’s happening?” or “What are they doing?” In this study I decided to use “Write a sentence about the story.” This conditional stimulus was intended to occasion the sentence frame and subject-verb combination (i.e., The girl is swimming). However, the question used implies that the sentence includes a subject and a verb (i.e., a who and a what). A more effective conditional stimulus may have been “Write a sentence that tells me who is in the story and what they are doing.” This may have affected the subject-verb combinations because "who" and "what" may occasion the selection of the subject and verb.

Figure 19

Auditory - Visual Antecedent Stimuli	Conditional Stimulus	Student Response	Consequence
The teacher asks, "Write a sentence about the photo." Presenting an array of subjects and verbs on the SGD	The teacher presents a picture depicting a cat eating	Student selects the icon "The cat is eating" on the SGD	Teacher delivers praise

Example of Auditory-visual Conditional Discrimination During Intervention

Last, when response prompting procedures were modified in Taylor's Intervention B from simultaneous prompting to constant time delay, this no longer allowed the measurement of subject-verb combinations. When using a sentence frame, subject-verb combinations can only be measured during probe trials. This is due to the error correction procedures used during constant time delay, that include presenting the controlling prompt to match the sentence sample. For example, for the target sentence "The girl is running," if a student makes an error on the first word, that word is erased, and a controlling prompt is delivered for the rest of the words in that sentence. This removes the opportunity for the student to select a subject-verb combination without being corrected.

Additional Dependent Variable: Percentage of Correct Word Selections

Visual analysis of results indicated that there was no demonstration of effect on the percentage of trained and untrained subject-verb combinations as a result of the intervention package across all participants and intervention conditions. Taylor, George, and Steven scored 0% correct subject-verb combinations across all baseline sessions. During session 1 of Intervention A, Taylor scored 30% correct word selections; however, the trend decreased back to 0% at the next session. Additionally, I noticed that she may have seen through the hidden sentence, so the materials were revised before session 2. George's data also demonstrated a slight increasing trend on the percentage of correct word selections. During Intervention A, after three sessions of 0s time delay, George averaged 28% correct word selections (range=22-33%) across three sessions. Then during Intervention B, George averaged 23% correct word selections (range=14-33%) across five sessions. Last, during Intervention C, George averaged 38% correct word selections (range=31-44%) across five sessions. Although there was an increasing trend across George's interventions, additional data collected on his word selections indicated that when George made an error, he selected "the" 25% of the time and "is" 10% of the time. This may have been due to "the" being the first word and "the" and "is" being consistent throughout all trials, whereas the subjects and verbs changed.

Most of the research that has used response prompting to teach sentence writing to students with autism and CCN has used the percentage of correct sentences as their primary dependent variable (Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). In one investigation, Pennington et al. (2021) used the percentage of correct sentences *and the percentage of correct word selections* for one participant. Thomas scored 0% correct sentences and 41–65% correct word selections across 11 sessions of intervention. The researchers noted that he would select "I see the" often but not the final word. Booster sessions were delivered after session 15 and 18 to teach the final word selection. This resulted in an average of 72% correct word selections; however, he did not select the final word during any of the trials.

In another study, Pennington et al. (2020) used response prompting, sentence frames, and technology to teach opinion writing to students with mild to moderate intellectual disability. Three students ages 10–12 who used vocal language were enrolled in the study. Researchers collected data on the percentage of correct word selections. This was defined as "independently touching (i.e., without a response prompt) a word within a predetermined order within 5s of the teacher's request to write or the participant's selection of the previous word in the sequence" (p. 402). During baseline and intervention, students were instructed to read a leveled text and asked to "Write about the story and make sure to tell me your opinion of it or how you feel about the story" (p. 402-403). Students responded using the Clicker Sentences application on an iPad with a 3x4 word array of words with no symbol supports. Students were taught to construct two sentences, I read about (noun), and I liked (noun). Intervention consisted of two sessions of 0s time delay trials and then on the third session a 5s delay was introduced. During 5s delay sessions when a student selected a correct word praise was delivered and another 5s trial began for the next word. If the student selected an incorrect word, the teacher erased the word and pointed to the correct word. All three students selected 0% correct words across baseline sessions. During intervention, a mastery criterion was set at 100% correct word selections across three consecutive days. Students met criterion after 9–16 intervention sessions.

Using correct word selections allows researchers to measure growth more sensitively when teaching sentence writing. For example, during my study, each intervention session consisted of a session of nine trials per sentence. Each sentence had four words which resulted in a total of 36 possible correct word selections. Most often when percentage of correct sentences is used, once a student makes an error in the sentence, the remainder of the sentence is prompted, removing the opportunity to construct the remainder of the sentence. Pennington et al. (2020) discussed how prompting at the word level can also increase engagement when providing reinforcement upon every correct word selection. Additionally, Pennington et al. (2021) stated this type of instructional format could have an inhibitive effect because students are not shown complete models of a sentence during instruction. This may have impacted the study findings, but more research is needed in this area to support this conclusion.

Social Validity

Results for Research Question 3: How do teacher and student participants perceive the feasibility and overall effects of the intervention package?

Teacher Participants

Social validity is an essential tenant of applied research. In his seminal piece, Wolf (1978) outlined that social validity should assess the social significance of intervention goals, the appropriateness and acceptability of procedures, and the social importance of the effects of an intervention. Unfortunately, social validity remains understudied in single-case research. Snodgrass et al. (2018) examined single-case research in special education across six journals from 2005–2016 and found that of 429 articles, only 6.5% of articles evaluated the social validity of the goals, procedures, and outcomes. Similarly, Ganz et al. (2023) reviewed the single-case AAC literature from 2018 to 2020, finding 162 articles that met What Works Clearinghouse standards with or without reservations. Of those 162 articles, 79% did not me the criteria for measuring social validity which included (a) social significance of the dependent variable, (b) significant change in behavior, (c) intervention was natural, (d) "all individuals involved, who were surveyed, are satisfied with the procedures and outcome" (p. 5 of supplemental materials), and (e) intervention was efficient and affordable. These results indicate that although intervention results are effective, the social significance of AAC interventions for individuals with IDD and CCN is largely unknown.

In this study, results from the adapted Intervention Rating Profile-15 (IRP-15; Witt & Elliott, 1985) indicated that the teachers found the intervention socially valid at pre- and post-intervention. Ms. Heart rated the intervention a total of 76 out of 90 at pre-intervention and 75 out of 90 at post-intervention. Ms. O'Hara rated the intervention at total of 75 out of 90 at both pre and post intervention. Changes in total scores from pre to post intervention were minimal indicating that teachers' opinions did not change much after implementing the intervention. This was unexpected due to the lack of effects of the interventions.

The changes in scores on Questions 7–9 warrant several discussion points. On Question 7 (i.e., I would be willing to use this intervention in the classroom setting) Ms. Heart increased her original rating from agree to strongly agree after intervention. A possible reason for her score increase is that after delivering intervention to the three students it increased her opinion of the feasibility of the intervention. On the same question, Ms. O'Hara decreased her original rating from strongly agree to agree. The lack of positive results may have impacted her score on this item; however, it should be noted that Ms. O'Hara only implemented one intervention session in total. On Question 8, "This intervention would not result in negative side effects for the students.", Ms. Heart decreased her original rating from strongly agree to agree. This may have been due to the lack of positive results. On the same question, Ms. O'Hara scored the same rating as pre-intervention with agree. Last, on Question 9, "This intervention would be appropriate for a variety of students.", Ms. Heart decreased her original rating from agree to slightly agree. Again, this may have been due to the lack of positive results. On the same question, Ms. O'Hara increased her original score on this item from slightly agree to agree. Future research should consider using interviews to gather more information on changes in scores.

Student Participants

Social validity of direct consumers is rarely assessed in behavioral research. In a recent review of the behavioral intervention research across 43 peer-reviewed journals, from 2010–

2020, Huntington et al. (2024) found that of the 425 articles included, 28% assessed social validity for all direct consumers of intervention(s). Additionally, 75% of the articles that did not conduct a social validity assessment with the direct consumers, included individuals with communication delays. This is alarming given that students who have CCN may not be able to communicate when they dislike an intervention, their opinions on it, preferences, or if it is causing them harm.

Like the findings in Huntington et al. (2024) student or participant social validity data was absent from the tacting matrix training literature (Kohler & Malott, 2014; Frampton et al., 2016, 2019; Marya et al., 2021; Pauwels et al., 2015) and from the sentence writing literature previously reviewed (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). In this study, I measured students' preferences in terms of intervention to gather social validity data. Results from the students' social validity assessment indicate that students preferred this writing intervention over their typical writing instruction in the classroom. For Taylor, the teacher presented an alternative writing task which was to trace her name, once during Intervention A and once during Intervention B. Across both assessments Taylor selected the study. For George, the teacher presented an alternative writing task which was copying numbers using paper and pencil from a printed model once during Intervention B and George selected the study. For Steven, the teacher presented an alternative writing task which included stamping his name on a piece of paper and the study once during his intervention. Steven selected the alternative task.

This social validity assessment was developed based on a concurrent-chains arrangement (Hanley et al., 1997). A concurrent-chains arrangement is when two or more interventions are paired with antecedent stimuli such a colored cards or in this instance activity schedule photos, and after exposure to both interventions, the student is presented with a choice using the antecedent stimuli (i.e., activity schedule photos) to show preference. In this study, two option were presented the student's typical writing intervention and the studies intervention. Hanley (2010) suggests when using a concurrent-chains arrangement, a third option should be presented that does not include any reinforcement to increase the strength of the preference selected. A third option that could have been presented during this study was the student sitting at their desk without reinforcement. This was not used because students do not typically engage in this behavior. Additionally, in this study, student preference was only gathered twice for Taylor and only one time for Steven and George thus results should be interpreted with caution.

Contributions of the Study

This study contributes to the literature in several ways. First, this is the first study that used matrix training to teach sentence writing to with students with ASD and CCN using SGDs. Previous literature used matrix training to teach sentence writing using computer software (Yamamoto & Miya, 1999) and teach subject-verb combinations using SGDs (Marya et al., 2021). Second, most matrix training studies involve young students with autism (ages 3-10; Curiel et al., 2020) and this study included four students ages 10-18. Fifth, this is the first study to collect teacher and student social validity data across the tacting matrix training literature (Kohler & Malott, 2014; Frampton et al., 2016, 2019; Marya et al., 2021; Pauwels et al., 2015) and the sentence writing literature previously reviewed (Pennington et al., 2021; Pennington, Flick, et al. 2018; Pennington, Foreman, et al. 2018; Pennington & Rockhold, 2018). Last, this study contributes to the SGD literature by teaching tacting using multi-step selections. Previous literature on using SGDs used 1-2 selections (Tincani et al., 2020) and this study included four selections using a sentence frame.

Limitations of the Study and Directions for Future Research

There are several limitations that should be considered when interpreting the results of the study. First, by using an A-B design, this removed the possibility of conducting an experimental analysis. I originally planned to use a multiple probe across behaviors replicated across participants design. Then results from the assessment indicated participants did not have enough subjects or verbs mastered to include in three, 3x3 matrices. As a result, I changed the design to a multiple probe across participants design. Then, due to intervention modifications made for the first participant Taylor, an A-B design was used across all participants.

Additionally, I planned to use the following student inclusion criteria: (a) had an educational eligibility of autism, (b) required specialized instruction in writing indicated by IEP goals, (c) exhibited complex communication needs indicated by teacher report, (d) label nine verbs and nine people and/or animals vocally or using AAC when shown a photo identified by a pretest, (e) had adequate hearing and visual acuity skills, (f) had match to sample skills (for example when shown a stimulus the student could select the stimulus in an array of three), and (g) attend to instruction for 10 min without severe challenging behavior (e.g., aggression, self-injury, property destruction). Due to limited participant selection and assessment results, I removed criteria (d) label nine verbs and nine people and/or animals vocally or using AAC when shown a photo identified by a pretest. This may have influenced student responding due to prerequisite skills not being mastered. Future research should evaluate whether these prerequisite skills are needed when teaching two or more selections on a SGD using matrix training.

One previous study that used matrix training to teach vocal verbal behavior indicated that students did not always need to have the component skills mastered (Pauwels et al., 2015). However, results from this study indicate that prerequisite skills or mastery of component skills may be necessary when teaching sentence construction using subject-verb combinations with SGDs. Future research should consider including prerequisite skills when teaching chained responses of three or more selections on a SGD. For example, if planning to teach subject-verb tacts through matrix training, researchers should plan to first teach the component tacts of the students' matrices if students do not have these skills mastered. This would include teaching students to tact the subjects and verbs in isolation prior to diagonal training. Some additional considerations should include the arrays that will be programmed on the SGD and the antecedent questions that will be asked. For students that require intensive support to complete simple discriminations, it may be beneficial to use two separate folders initially during pre-training, one folder with subjects and one with verbs. After students meet a predetermined mastery criterion, the array can be modified to include all subjects and verbs on one page, or researchers can select to use separate folder during matrix training. The use of separate folders during matrix training may assist some learners because the folders can act as discriminative stimuli.

Second, based on the results of the initial assessment and pre-training, the task difficulty during intervention may have decreased responding. Future research could teach subject-verb combinations prior to teaching the sentence frame or start with a smaller array of options. Additionally, the controlling prompt used throughout the study did not always result in the student emitting a correct response. This is a major limitation because during teaching trials that used a 0s delay errorless learning did not occur. This may have decreased responding during 5s delay trials.

Third, the various schedules of reinforcement used in the study as well as motivational variables posed a limitation. Before the study, all four student participants received tokens during typical instructional in the classroom typically on a continuous schedule for engaging in target behaviors listed on their behavior plan. Tokens were not delivered based on the accuracy of responding. During Taylor's Interventions A-C and Steven's intervention, the teacher followed the typical reinforcement schedule for each student as prescribed in their behavior intervention plan. This may have had an inhibitive effect on correct responding since students received tokens for remaining safe and in their area. Based on this hypothesis, I changed the reinforcement schedule for Taylor's Intervention D using a FR1 for unprompted correct responses. Two sessions were delivered using this schedule and results indicated minimal effects. All of George's intervention sessions used a VR4 for unprompted correct responses per word. Results on the percentage of correct word selections indicated an increasing trend; however, George never reached the mastery criteria during intervention. Future research should examine the effects on schedules of reinforcement during matrix training.

Fourth, there are several limitations related to the materials used in the study. First, the use of one static folder during baseline and intervention sessions may have affected participants' responding. Outside of the study, Taylor, George, and Darius used folders on their SGD that organized symbols into categories such as people, places, things, food, etc. I decided to use one folder to display all the subjects, verbs, and articles (the, is) for the study because the folders within each student's device contained different symbols. Additionally, participants would need to make more complex discriminations by navigating through multiple folders to write a sentence and then discriminating from a larger array of symbols, some unrelated to the study. Marya et al. (2021) used folders organized by subjects and verbs for their study. Future research should evaluate if the way symbols are presented on SGDs or other AAC effect responding. Another limitation was the use of still photos to display subject-verb combinations. Some researchers have used animal figurines (Marya et al., 2021) or videos (Kohler & Malott, 2014) to better capture action words. The use of still photos in this study may have decreased stimulus saliency, in that the verb was difficult for students to select based on the photo. A more salient stimulus would be a video of an action. Future research should compare material types when teaching subject-verb combinations to deem if some materials are more effective than others. Another limitation related to the materials was the restrictions around programming a period in the array on Proloquo2Go. Future research should consider using one application across all students for consistency.

Last, this study was conducted in a specialized school setting that had 1:1 staff ratios and highly trained counselors and teachers in ABA. This limits the generalizability to public school classrooms or to implementers that do not have background in ABA. This may have also contributed to high social validity ratings around feasibility from the teachers, as they were used to behavior analytic practice. Future research should be conducted with special education teachers in public school settings.

Implications for Practice

Findings from this study provide several implications for practice. First, when planning to use matrix training for individuals with ASD and CCN, practitioners should evaluate the student’s prerequisite skills before developing a matrix and consider teaching these skills to mastery. This study suggests that some students may benefit from knowing the component parts of a matrix before intervention. Kodak et al. (2022) also demonstrated that some students may need to master prerequisite skills before engaging in auditory-visual conditional discrimination skills. Before practitioners assess prerequisite skills, a curricular area should be selected for matrix training. A helpful tool that can be used to determine language skills for matrix training is the VB-MAPP (Sundberg, 2014). The VB-MAPP is a criterion-referenced assessment and curriculum guide that is based on verbal behavior and developmental milestones. For example, one milestone of the assessment that can be targeted through matrix training is tacting 50 two-component noun-verb combinations. Prior to this, the assessment outlines that students should master single tacts first, following typical developmental milestones. This provides a skill progression that is developmentally appropriate for learners acquiring language.

After a curricular area is selected (e.g., tacting subject-verb combinations) practitioners can develop a matrix and then assess the component parts. This assessment should use the same response mode and instructional arrangement the practitioner will use during instruction. For example, if planning to teach subject-verb combinations using video clips, an assessment set of videos can be made to assess responding to the component subjects and verbs. Using assessment results, practitioners can develop teaching plans if needed to teach the component skills. This may be essential when teaching students to use sentence frames with the subject-verb combinations as this study set out to do.

Next, when teaching sentence frames with two or more combinations, practitioners should consider teaching combinations (e.g., subject-verb combinations) first and then teaching the sentence frame. This may be particularly advantageous for students with limited prerequisite skills as described above. For example, practitioners could teach the diagonal responses in 3x3 subject-verb matrix to criterion, probe for generalization to nondiagonal targets, and then teach the sentence frame “The (subject) is (verb)” using response prompting procedures. This would allow subject-verb combinations to meet criteria and gain stimulus control before adding sentence frames.

Third, there are several considerations to make when selecting response prompting procedures when using matrix training to teach sentence writing. In general, time-delay can be more efficient than system of least or most to least prompts because it does not require a hierarchy of prompts (Collins, 2021). Additionally, simultaneous prompting is more feasible in that it uses a probe then training format, so there is no error correction. This study used a modified version of constant time delay and simultaneous prompting. Results from this study suggest that constant time delay may be more effective when using matrix training on SGDs for multi-selections. Additionally, practitioners should select scoring measures that align with response prompting procedures. When providing error correction for the entire sentence, if a student makes an error on the first word, the controlling prompt includes prompting the correct word for that selection and the remaining words in the sentence. This removes the opportunity for measuring correct word selections and subject-verb combinations because the opportunity to respond to the remaining words in the sentence is removed. Practitioners should consider using correct word selections because it is a more sensitive measure. Furthermore, using a system of least prompts can be beneficial for students who may require full physical prompting because they may not attend to the word. For example, Pennington, Flick, et al. (2018) used a system of least prompts for two participants to ensure participants had an opportunity to respond to a printed sentence model.

Fourth, when selecting materials to depict subject-verb combinations in the matrix, practitioners should consider using different types of materials, affordability, and incorporating student interests. Researchers have used videos (Kohler & Malott, 2014) and animal figurines (Marya et al., 2021) to show subject-verb combinations instead of photo cards. These are great alternatives to photos because the action or verb is more salient in a video or with a figurine; however, finding or making videos of certain subject-verb actions may prove difficult. Next, when selecting technology to use for writing practitioners should consider affordable options like

GoTalkNow and if needed, can use a low-tech option like printed word cards. Additionally, incorporating student interests into the stimuli can increase motivation. For example, if a student is interested in Bluey, a matrix could be developed to include actions that Bluey characters can do. In this study, students' reinforcers were not embedded as stimuli; however, that may have impacted motivation.

Summary

This study examined the effects of matrix training, response prompting, and sentence frames on sentence writing for students with ASD and CCN. A series of A-B designs with modifications was used to examine the effects of the intervention package on the percentage of trained and untrained correct sentences, percentage of subject-verb combinations, and the percentage of correct word selections. Overall, results indicated that across all interventions, there were no effects on the percentage of trained and untrained correct sentences and subject-verb combinations for all participants. Taylor and George did, however, increase their percentage of correct word selections. Results indicated that Taylor made slight increases in the percentage of correct word selections for one out of two sessions during Intervention C and D. Similarly, George's data indicated an increasing trend throughout all his interventions (Interventions A-C). Generalization probes and maintenance data were not collected for any participants due to participants not meeting the mastery criteria during intervention. Overall, teachers found the intervention acceptable and beneficial for students in the classroom. Furthermore, three of four students preferred this writing intervention over their typical writing instruction in the classroom. Implications of this study provide several considerations for practitioners who would like to use matrix training to teach subject-verb combinations and/or sentence writing with students who have autism and CCN.

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APPENDIX A: RECRUITMENT EMAIL SCRIPT TO SCHOOL DIRECTORS

Hello,

I am reaching out to see if you would be interested in continuing to partner with us for our research study "Using Technology and Response Prompting to Teach Generative Writing Skills to Students with Extensive Support Needs". This study is still being conducted by myself, under the supervision of my advisor Dr. Robert Pennington.

The purpose of the study is to determine the effects of technology-aided response prompting on writing skills for students with autism spectrum disorder. We would train teachers as interventionists to implement a writing strategy using matrix training to organize learning targets to focus on recombinative generalization. We would provide the materials and a brief training to teachers. Then they would implement it with a few students for about 10-15 minutes a day about 3-4 times a week.

The information learned from this study may help educators learn how to create strategies to help students with intellectual and/or developmental disabilities learn to write.

If you are interested in continuing to partner with us for this research study, please reply to this email at your earliest convenience.

Thank you,

Monique Pinczynski mpinczyn@uncc.edu
Robert Pennington rpennin7@uncc.edu

APPENDIX B: TEACHER CONSENT FOR PARTICIPATION IN RESEARCH

UNIVERSITY OF NORTH CAROLINA
CHARLOTTE

Department of Special Education and Child Development
9201 University City Boulevard, Charlotte, NC 28223-0001

Consent for Participation in Research

Title of the Project: Using Technology and Response Prompting to Teach Generative Writing Skills to Students with Extensive Support Needs
Principal Investigator: Monique Pinczynski MED., BCBA, University of North Carolina Charlotte
Faculty Advisor: Robert Pennington PhD BCBA-D, University of North Carolina Charlotte

You are invited to participate in a research study. Your participation in this research study is voluntary. The information provided is to help you decide whether or not to participate. If you have any questions, please ask.

Important Information You Need to Know

- The purpose of this study is to find out if using a specific teaching method will improve students with autism skills in the area of written expression.
- You may participate in this study if you are an instructor of students with intellectual and/or developmental disabilities. You will be asked to implement a writing strategy with up to four of your students. We will train you to implement a specific strategy called response prompting. This procedure involves using prompts (e.g., pointing to words) to help your students construct a simple sentence about a photo. We will also ask you to ask your students to verbally describe the photo. Writing lessons will last 10-15 minutes and will be conducted 3-5 days a week for several weeks.
- We do not believe that you will experience any risk from participating in this study. The writing lessons will occur during normal class time and will involve materials like those you likely use in your classroom. We will prepare them for you. Your students may benefit from the procedures, but we can't say this for sure. The information we learn may help us learn how to create strategies to help students with intellectual and/or developmental disabilities learn to write.
- If you decide not to participate or continue participating at any time, we will provide you with resources on how to use simultaneous prompting.
- Please read this form and ask any questions you may have before you decide whether to participate in this research study.

Why are we doing this study?

There are few research studies on strategies to support the writing skills of students with intellectual and/or developmental disability. This study will extend the field's current knowledge in this area. The purpose of this study is to find out if using a specific teaching method will improve your student's writing skills

Why are you being asked to be in this research study?
You are being asked to participate because you are an instructor of students with intellectual and/or developmental disabilities.

What will you do in this study?
You will be asked to conduct writing lessons 3-5 days a week during the school day. Depending on student pre-requisite skills, you may need to provide pre-training that involves teaching students to identify subject and noun words on a speech-generating device. If a student requires pre-training, you will deliver instruction for at most three weeks.

After pre-training, you will assess student writing skills by presenting a photo and asking them to write about it on a speech-generating device. These sessions will be delivered between 1-4 days a week across 1-4 weeks depending on student responding. Then, you will conduct intervention sessions where you will present a photo to your student and then support them to write a sentence about the photo using an iPad (e.g., The boy eats candy.). You will collect data on your students' performance each during each session to see if progress is being made. Intervention sessions will be implemented 4-5 days a week and may last anywhere from 1-3 weeks dependent on student progress. Following intervention, you will assess student responding to new photos across three sessions. If your student(s) do not make progress you will be asked to provide booster training for 1-2 weeks.

We will also observe weekly either in person or via Zoom to determine if the procedures are being carried out as planned. Observations conducted over Zoom will not be recorded and will only be used in special situations where the researchers can not physically be in the classroom. At the beginning and end of the intervention you will be asked via a questionnaire on the acceptability and effectiveness of the intervention.

You will be provided with an initial training for 60 minutes that will provide an overview of the study and training on the pre-baseline procedures. Thereafter, prior to the baseline, intervention, generalization, and booster conditions, a brief 30-minute training will be delivered before school for each condition's procedures.

In addition, information from your students' educational records will be collected about their age, race, disability category, intellectual, writing and communication skills. This information will not be stored with the students' names.

What benefits might children experience?
The benefits of participation in this study are that your students might learn new writing skills and that you will learn a new instructional strategy.

What risks might you experience?
We do not believe that there are any risks to you because this study will occur as part of routine classroom teaching however, due to weekly observations and data collection your privacy during observations may be limited.

How will information be protected?
We will not use your or your students' names in any records or publications. Instead, we will use a pseudonym (fake name) and this fake name will be used on any work children create in class. Paper materials will be stored in a locked filing cabinet and electronic materials will be stored in a University Dropbox folder that the researcher team can access. Only the research team will have routine access to the study information. Other people with approval from the Investigator, may need to see the information we collect. Including people who work for UNC Charlotte and other agencies as required by law or

allowed by federal regulations.

We will provide you with a questionnaire at the beginning and end of the intervention to assess how acceptable and effective the intervention was, along with gathering any other feedback you provide.

How will information be used after the study is over?
After this study is complete, study data may be shared with other researchers for use in other studies without asking for consent again or as may be needed as part of publishing our results. The data we share will NOT include information that could identify you or your students.

Will you receive an incentive for taking part in this study?
You will not receive any payment for being in this study.

What other choices are there if I don't to take part in this study?
If you decide not to take part in this study, we will still provide you resources on strategies to increase writing with your students.

What are my rights if I take part in this study?
Participating in this study is voluntary. Even if you decide to be part of the study now, you may change your mind and stop participation at any time. You will not lose any benefits to which you are entitled.

Who can answer my questions about this study and participant rights?
For questions about this research, you may contact Monique Pinczynski at mpinczyn@uncc.edu or Dr. Charles Wood at clwood@uncc.edu

If you have questions about research participant's rights, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Protections and Integrity at 704-687-1871 or uncc-irb@uncc.edu.

Participant Consent

By signing this document, you are agreeing to participation in this study. Make sure you understand what the study is about before you sign. You will receive a copy of this document for your records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above. I understand what the study is about and my questions so far have been answered. I agree to take part in this study.

____
Participant Name (PRINT)

____
Signature Date

____
Name and Signature of person obtaining consent Date

APPENDIX C: PARENT OR LEGAL GUARDIAN CONSENT FOR CHILD/MINOR PARTICIPATION IN RESEARCH

UNIVERSITY OF NORTH CAROLINA
CHARLOTTE

Department of Special Education and Child Development
9201 University City Boulevard, Charlotte, NC 28223-0001

Parent or Legal Guardian Consent for Child/Minor Participation in Research

Title of the Project: Using Technology and Response Prompting to Teach Generative Writing Skills to Students with Extensive Support Needs
Principal Investigator: Monique Pinczynski, MED., BCBA, University of North Carolina Charlotte
Faculty Advisor: Charles Wood, PhD, BCBA-D, University of North Carolina Charlotte

Your [child/legal ward] is invited to participate in a research study. Your [child's/legal ward's] participation in this research study is voluntary. The information provided is to help you decide whether or not to allow your [child/legal ward] to participate. If you have any questions, please ask.

Important Information You Need to Know

- The purpose of this study is to find out if using a writing strategy will improve your child's skills in the area of written expression. This method involves using modeling and prompts to help your child select words on an iPad to write about a photo.
- Your [child/legal ward] may participate in this study if they autism and require specialized instruction in writing. Writing lessons in this study will be in their typical classroom with their teacher. We will train a teacher to implement a specific strategy called response prompting in which involves repeatedly supporting your child to select the correct words to write a simple sentence and then testing whether they can do it independently. This procedure involves the teacher using prompts (e.g., pointing to words) to help your child construct a simple sentence about a photo they have been shown. The teacher will also ask your child to verbally state what is shown in the photo. Writing lessons will last 10-15 minutes and will be conducted 3-5 days a week for several weeks.
- We will take data on your child's writing samples so that we can measure their progress. We will also observe your child's teacher working with your child to ensure the strategy is used as planned.
- We do not believe that your [child/legal ward] will experience any risk from participating in this study. The writing lessons will occur during normal class time and will involve materials similar to those already presented by your child's teacher. Your [child/legal ward] may benefit from the procedures but we can't say this for sure. The information we learn may help us learn how to create strategies to help students with intellectual and/or developmental disabilities learn to write.
- Your [child/legal ward] will still take part in normal classroom learning and activities, even if you decide to not let them participate in this study.

- Please read this form and ask any questions you may have before you decide whether to participate in this research study.

Why are we doing this study?
There are few research studies on strategies to support the writing skills of students with intellectual and/or developmental disability. This study will extend the field's current knowledge in this area. The purpose of this study is to find out if using a specific teaching method will improve your child's writing skills.

Why is your [child/legal ward] being asked to be in this research study.
You are being asked to allow your [child/legal ward] to participate in this study because they have autism and complex communication needs and have been identified as needing additional support in the area of writing.

What will children do in this study?
Your [child/legal ward] will be asked to participate in writing lessons 3-5 times per week with their teacher during the school day. The teacher will show a photo to your child and then support your child to write about the photo using a software application on a tablet that has text to speech software. Some students may require pre-training that will be provided for up to three weeks before the intervention begins. Thereafter, depending on your child's progress the study may last anywhere from 5-7 weeks.

If your child already uses a tablet with text to speech software, we will program their device to support this intervention. This programming will include adding a folder on their speech-generating device software that will include words and symbols your child can use during writing lessons. At the completion of the study, we will contact you to see if you would like this folder to remain on your child's device or if you would like us to remove it. If your child does not have access to a tablet, we will provide the tablet.

The teacher will collect data on your child's performance during each session to see if progress is being made. We will also provide your child with an option to write using their typical curriculum materials or the study materials once every two weeks to gauge what they find more acceptable. We will observe the teacher weekly during intervention either in person or via Zoom. Zoom sessions will not be recorded.

In addition, information from your child's educational records will be collected about their age, race, disability category, intellectual, writing and communication skills. For example, we will want to know whether or not they receive services under the category or autism, intellectual disability, or developmental delay. We will also collect data related to IQ or formal communication and writing assessments. This information will not be stored with your child's name.

What benefits might children experience?
The benefits of participation in this study are providing your child with access to systematic writing instruction. Our hope is that your child will increase their writing skills.

What risks might children experience?
We do not perceive there to be any risks associated with the specific intervention however, some students with a history of challenging behavior may engage in problem behavior when presented with the novel academic tasks. If student problem behavior persists, we will consider their assent with withdrawn and let them discontinue participation.

How will information be protected?

We will not use your [child's/legal ward's] name. Instead, we will use a pseudonym (fake name) and this fake name will be used on any work children create in class. It will also be attached to any demographic and assessment data to protect your child's information. Paper materials will be stored in a locked filing cabinet and electronic materials will be stored in a University Dropbox folder that the researcher team can access. Only the research team will have routine access to the study information. Other people with approval from the Investigator, may need to see the information we collect. Including people who work for UNC Charlotte and other agencies as required by law or allowed by federal regulations.

How will information be used after the study is over?

After this study is complete, study data may be shared with other researchers for use in other studies without asking for consent again or as may be needed as part of publishing our results. The data we share will NOT include information that could identify your child.

Will [children/legal wards] receive an incentive for taking part in this study?

Your [child/legal ward] will not receive any payment for being in this study.

What other choices are there if I don't want my [child/legal ward] to take part in this study?

If you decide not to let your [child/legal ward] take part in this study, they will still take part in the routine classroom activities as they would on a normal day. The classroom teacher will still teach all students the daily lessons. We might also withdraw your child from the study if they repeatedly indicate they do not want to participate (e.g., protest, engage in challenging behavior).

What are my [child's/legal ward's] rights if they take part in this study?

Participating in this study is voluntary. Even if you decide to allow your [child/legal ward] to be part of the study now, you may change your mind and stop their participation at any time. You and your [child/legal ward] will not lose any benefits to which you are entitled.

Who can answer my questions about this study and participant rights?

For questions about this research, you may contact Monique Pinczynski at mpinczyn@uncc.edu or Dr. Charles Wood at clwood@uncc.edu

If you have questions about research participant's rights, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Protections and Integrity at 704-687-1871 or uncc-irb@uncc.edu.

Parent or Legally Authorized Representative Consent

By signing this document, you are agreeing to [your child's **OR** the person's named below] participation in this study. Make sure you understand what the study is about before you sign. You will receive a copy of this document for your records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about and my questions so far have been answered. I agree for [my child OR the person named below] to take part in this study.

____

Participant Name (PRINT)

____

Parent/Legally Authorized Representative Name and Relationship to Participant (PRINT)

____
Signature   Date

If your child already owns an individual speech-generating device, please indicate the extent to which you would allow the device to be used in this study.

____ I consent to the research team using my child's device for the use of this study.

____ I do not provide consent for the research team to use my child's device for the use of this study.

____
Name and Signature of person obtaining consent   Date

APPENDIX D: RECRUITMENT EMAIL TO PARENTS FROM DIRECTOR

Hello,
I am reaching out to see if you would be interested in allowing your child to be a part of a research study that involves teaching writing to students with autism spectrum disorder. This study is being conducted by Monique Pinczynski, a doctoral student at the University of North Carolina Charlotte under the supervision of her advisor Dr. Robert Pennington.

This study would involve writing lessons implemented by regular instructors at our school, under the supervision of the research team. This intervention will use a specific strategy and prompts (e.g., pointing to words) to help your child construct a simple sentence about a photo using an assistive technology device (e.g., iPad with text to speech capability). The intervention uses evidence-based practices in special education and would be 10-15 minutes long, happening 3-5 days a week for several weeks.

The information learned from this study may help educators learn how to create strategies to help students with intellectual and/or developmental disabilities learn to write. Your child's participation in this research study is voluntary.

If you are interested, please return the consent forms and parent questionnaire we have sent home with your child at your earliest convenience.

Additionally, if you would like to contact members of the research team their contact information is below.

Monique Pinczynski mpinczyn@uncc.edu
Robert Pennington rpennin7@uncc.edu

APPENDIX E: STUDENT MATRICES

Taylor			
	boy	dog	cat
sleeping	The boy is sleeping.	The dog is sleeping.	The cat is sleeping.
drinking	The boy is drinking.	The dog is drinking.	The cat is drinking.
swimming	The boy is swimming.	The dog is swimming.	The cat is swimming.

George			
	girl	dog	cat
drinking	The girl is drinking.	The dog is drinking.	The cat is drinking.
sleeping	The girl is sleeping.	The dog is sleeping.	The cat is sleeping.
swimming	The girl is swimming.	The dog is swimming.	The cat is swimming.

Steven			
	boy	dog	cat
eating	The boy is eating.	The dog is eating.	The cat is eating.
sleeping	The boy is sleeping.	The dog is sleeping.	The cat is sleeping.
swimming	The boy is swimming.	The dog is swimming.	The cat is swimming.

Darius			
	boy	dog	cat
eating	The boy is eating.	The dog is eating.	The cat is eating.
sleeping	The boy is sleeping.	The dog is sleeping.	The cat is sleeping.
swimming	The boy is swimming.	The dog is swimming.	The cat is swimming.

APPENDIX F: EXAMPLE OF PHOTO WITH TEXTUAL PROMPT WITH AND WITHOUT SYMBOL SUPPORT

the cat is swimming .

the cat is swimming

APPENDIX G: BASELINE AND PROBE DATA SHEET

Student:____________ Date: _____________ Circle: Baseline / Posttest
Teacher Name: __________
If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

Directions:
1. Select the appropriate deck of photos and shuffle them.
2. Present a photo, iPad, and say, "Write a sentence about the photo."
3. End the trial if the student does not respond after 5s or after writing stops for 5s.
4. Prompt the student to playback their writing.
5. Provide general praise for completing the activity.
6. Repeat steps 2-5 for each target.

ODD SESSIONS - Full Probe, Diagonal (gray), Nondiagonal (white)

Trial	Target	Subject/Verb	Sentence
1	The **boy** is **sleeping**	+ -	+ -
2	The **boy** is **drinking**	+ -	+ -
3	The **boy** is **swimming**	+ -	+ -
4	The **dog** is **sleeping**	+ -	+ -
5	The **dog** is **drinking**	+ -	+ -
6	The **dog** is **swimming**	+ -	+ -
7	The **cat** is **sleeping**	+ -	+ -
8	The **cat** is **drinking**	+ -	+ -
9	The **cat** is **swimming**	+ -	+ -
	Total		

EVEN SESSIONS - Nondiagonal Probe

Trial	Target	Subject/Verb	Sentence
1	The **boy** is **drinking**	+ -	+ -
2	The **boy** is **swimming**	+ -	+ -
3	The **dog** is **sleeping**	+ -	+ -
4	The **dog** is **swimming**	+ -	+ -
5	The **cat** is **sleeping**	+ -	+ -
6	The **cat** is **drinking**	+ -	+ -
	Total		

APPENDIX H: TAYLOR INTERVENTION A DATA SHEET

Student:____________ Date: ___________ Teacher or Observer Name: __________

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

Probe Session

Trial	Target	Subject/Verb	Sentence
1	The **boy** is **sleeping**	+ -	+ -
2	The **dog** is **drinking**	+ -	+ -
3	The **cat** is **swimming**	+ -	+ -
	Total		

Training Session

Directions:

1. Select the appropriate deck of photos and shuffle them.
2. Present a photo with the target sentence, iPad, and say, "Write a sentence about the photo."
3. Immediately present the controlling prompt for the target sentence.
4. Prompt the student to playback their writing.
5. Provide general praise for completing the activity.
6. Repeat steps 1-5, presenting each photo 3 times.

Trial	Target	Prompted Sentence
1	The **boy** is **sleeping**	+ -
2	The **boy** is **sleeping**	+ -
3	The **boy** is **sleeping**	+ -
4	The **dog** is **drinking**	+ -
5	The **dog** is **drinking**	+ -
6	The **dog** is **drinking**	+ -
7	The **cat** is **swimming**	+ -
8	The **cat** is **swimming**	+ -
9	The **cat** is **swimming**	+ -
	Total	

APPENDIX I: TAYLOR INTERVENTION B DATA SHEET

Student: ___________Date:________ Teacher:_________Delay: __0s__/__5s____delay session

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

0s Time Delay Trials

1. Teacher shuffles the deck.
2. Teacher presents the photo and sentence with the iPad.
3. Teacher says, "Write a sentence about the photo."
4. Teacher delivers the controlling prompt.
5. If the student makes an error, the teacher moves to a higher-level prompt.
6. Teacher or student play back the sentence.
7. Teacher delivers verbal praise for correct sentence completion.

5s Time Delay Trials

1. Teacher shuffles the deck.
2. Teacher presents the photo with the sentence hidden and the iPad.
3. Teacher says, "Write a sentence about the photo."
4. Teacher waits 5s until the first response or non-response.
5. If error or no response, teacher presents sentence strip and delivers the controlling prompt for first incorrect word through end of sentence.
6. Teacher or student play back the sentence.
7. Teacher delivers verbal praise for correct sentence completion.

Trial	Target Sentence	Independent Correct
1	The **boy** is **sleeping**	+ -
2	The **boy** is **sleeping**	+ -
3	The **boy** is **sleeping**	+ -
4	The **dog** is **drinking**	+ -
5	The **dog** is **drinking**	+ -
6	The **dog** is **drinking**	+ -
7	The **cat** is **swimming**	+ -
8	The **cat** is **swimming**	+ -
9	The **cat** is **swimming**	+ -
Total Independent Correct		

APPENDIX J: TAYLOR INTERVENTION C DATA SHEET

Student: _____Date:________ Teacher:_________Delay: 0s / 5s delay session

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

Scoring Directions: Under the target sentence column, circle any correct word selections the students make and strikeout words when students make an error or do not respond. Correct word selections must match the exact order of the target sentence.

5s Time Delay Trials

1. Teacher presents the photo with the sentence hidden and the iPad.
2. Teacher says, "Write a sentence about the photo."
3. Teacher waits 5s until the first response or non-response
4. If the student makes an error, the teacher erases the word and presents the controlling prompt for the incorrect word.
5. If the student selects the correct word, the teacher provides praise.
6. Teacher points to the blank space for the next word.
7. Teacher repeats steps 3-5 for every word in the sentence.
8. Upon the completion of the sentence, the teacher or student play back the sentence.
9. Teacher delivers verbal praise for correct sentence completion.

Trial	Target Sentence	# of Correct Word Selections	Sentence Correct
1	The **boy** is **sleeping**		+ -
2	The **boy** is **sleeping**		+ -
3	The **boy** is **sleeping**		+ -
4	The **dog** is **drinking**		+ -
5	The **dog** is **drinking**		+ -
6	The **dog** is **drinking**		+ -
7	The **cat** is **swimming**		+ -
8	The **cat** is **swimming**		+ -
9	The **cat** is **swimming**		+ -
Total Number Independent Correct		/36	/9
Percentage Correct			

APPENDIX K: TAYLOR INTERVENTION D 5S DELAY SESSIONS

Student: ____________ Date:_________ Teacher:__________Delay: 5s delay session

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

Scoring Directions: Under the target sentence column, circle any correct word selections the students make and strikeout words when students make an error or do not respond. Correct word selections must match the exact order of the target sentence.

5s Time Delay Trials

1. Teacher presents the photo with the sentence hidden and the iPad.
2. Teacher says, "Write a sentence about the photo."
3. Teacher waits 5s until the first response or non-response
4. If the student makes an error, the teacher erases the word and presents the controlling prompt for the incorrect word.
5. If the student selects the correct word, the teacher provides praise and a token.
6. Teacher points to the blank space for the next word.
7. Teacher repeats steps 3-5 for every word in the sentence.
8. Upon the completion of the sentence, the teacher or student play back the sentence.
9. Teacher delivers verbal praise for correct sentence completion.

Trial	Target Sentence	# of Correct Word Selections	Sentence Correct
1	The **boy** is **sleeping**		+ -
2	The **boy** is **sleeping**		+ -
3	The **boy** is **sleeping**		+ -
4	The **boy** is **sleeping**		+ -
5	The **boy** is **sleeping**		+ -
6	The **boy** is **sleeping**		+ -
Total Number Independent Correct		/24	/6
Percentage Correct			

APPENDIX L: TAYLOR INTERVENTION D 0S DELAY SESSIONS

Student:______ Date:_______ Teacher:_________Delay: __0s

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

0s Time Delay Trials

1. Teacher presents the photo and sentence with the iPad.
2. Teacher says, "Write a sentence about the photo."
3. Teacher delivers the controlling prompt for each word.
4. If the student makes an error, the teacher moves to a higher-level prompt.
5. Teacher or student play back the sentence.
6. Teacher delivers verbal praise for correct sentence completion.

Trial	Target Sentence	Prompted Correct
1	The **boy** is **sleeping**	+ -
2	The **boy** is **sleeping**	+ -
3	The **boy** is **sleeping**	+ -
4	The **boy** is **sleeping**	+ -
5	The **boy** is **sleeping**	+ -
6	The **boy** is **sleeping**	+ -
Total Prompted Correct		

APPENDIX M: GEORGE INTERVENTION A 0S DELAY SESSIONS

Student: ____________ Date:________ Teacher:_________Delay: __0s__/__5s__ delay session

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

Scoring Directions: Under the target sentence column, circle any correct word selections the students make and strikeout words when students make an error or do not respond. Correct word selections must match the exact order of the target sentence.

0s Time Delay Trials

1. Teacher presents the photo and sentence with the iPad.
2. Teacher says, "Write a sentence about the photo."
3. Teacher delivers the controlling prompt for each word.
4. If the student makes an error, the teacher moves to a higher-level prompt.
5. Teacher or student play back the sentence.
6. Teacher delivers verbal praise for correct sentence completion.

Trial	Target Sentence	# of Correct Word Selections	Sentence Correct
1	The girl is drinking		+ -
2	The girl is drinking		+ -
3	The girl is drinking		+ -
4	The dog is sleeping		+ -
5	The dog is sleeping		+ -
6	The dog is sleeping		+ -
7	The cat is swimming		+ -
8	The cat is swimming		+ -
9	The cat is swimming		+ -
Total Number Independent Correct		/36	/9
Percentage Correct			

APPENDIX N: GEORGE INTERVENTION A–C 4S DELAY SESSIONS

Student:____________ Date:____________ Teacher:_________Delay:_5s___delay session

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

Scoring Directions: Under the target sentence column, circle any correct word selections the students make and strikeout words when students make an error or do not respond. Correct word selections must match the exact order of the target sentence.

5s Time Delay Trials

1. Teacher presents the photo with the sentence hidden and the iPad.
2. Teacher says, "Write a sentence about the photo."
3. Teacher waits 5s until the first response or non-response
4. If the student makes an error, the teacher erases the word and presents the controlling prompt for the incorrect word.
5. If the student selects the correct word, the teacher provides praise.
6. Teacher points to the blank space for the next word.
7. Teacher repeats steps 3-5 for every word in the sentence.
8. Teacher provides a token on a VR4 schedule for unprompted correct word selections.
9. Upon the completion of the sentence, the teacher or student play back the sentence.
10. Teacher delivers verbal praise for correct sentence completion.

Trial	Target Sentence	# of Correct Word Selections	Sentence Correct
1	The girl is drinking		+ -
2	The girl is drinking		+ -
3	The girl is drinking		+ -
4	The dog is sleeping		+ -
5	The dog is sleeping		+ -
6	The dog is sleeping		+ -
7	The cat is swimming		+ -
8	The cat is swimming		+ -
9	The cat is swimming		+ -
Total Number Independent Correct		/36	/9
Percentage Correct			

APPENDIX O: STEVEN INTERVENTION DATA SHEET 0S DELAY SESSIONS

Student: __________ Date ______________ Teacher Name: __________

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

0s Time Delay Trials

1. Teacher presents the photo and sentence with the iPad.
2. Teacher says, "Write a sentence about the photo."
3. Teacher delivers the controlling prompt for each word, showing one word at a time, then hiding it.
4. Teacher or student play back the sentence.
5. Teacher delivers verbal praise for correct sentence completion.

Trial	Target	Prompted Sentence
1	The **boy** is **eating**	+ -
2	The **boy** is **eating**	+ -
3	The **boy** is **eating**	+ -
4	The **dog** is **sleeping**	+ -
5	The **dog** is **sleeping**	+ -
6	The **dog** is **sleeping**	+ -
7	The **cat** is **swimming**	+ -
8	The **cat** is **swimming**	+ -
9	The **cat** is **swimming**	+ -
	Total	

APPENDIX P: STEVEN INTERVENTION DATA SHEET 5S DELAY SESSIONS

Student: ____________Date:________ Teacher:_________Delay: 5s delay session

If alternative was presented, circle what choice was made: STUDY / ALT CHOICE

Scoring Directions: Under the target sentence column, circle any correct word selections the students make and strikeout words when students make an error or do not respond. Correct word selections must match the exact order of the target sentence.

5s Time Delay Trials

1. Teacher presents the photo with the sentence hidden and the iPad.
2. Teacher says, "Write a sentence about the photo."
3. Teacher waits 5s until the first response or non-response
4. If the student makes an error, the teacher erases the word and presents the controlling prompt for the incorrect word.
5. If the student selects the correct word, the teacher provides praise.
6. Teacher points to the blank space for the next word.
7. Teacher repeats steps 3-5 for every word in the sentence.
8. Upon the completion of the sentence, the teacher or student play back the sentence.
9. Teacher delivers verbal praise for correct sentence completion.

Trial	Target Sentence	# of Correct Word Selections	Sentence Correct
1	The **boy** is **eating**		+ -
2	The **boy** is **eating**		+ -
3	The **boy** is **eating**		+ -
4	The **dog** is **sleeping**		+ -
5	The **dog** is **sleeping**		+ -
6	The **dog** is **sleeping**		+ -
7	The **cat** is **swimming**		+ -
8	The **cat** is **swimming**		+ -
9	The **cat** is **swimming**		+ -
Total Number Independent Correct		/36	/9
Percentage Correct			

APPENDIX Q: SOCIAL VALIDITY QUESTIONNAIRE FOR TEACHERS

	Strongly Disagree	**Disagree**	**Slightly Disagree**	**Slightly Agree**	**Agree**	**Strongly Agree**
1. This would be an acceptable intervention for teaching writing skills.						
2. Most teachers would find this intervention appropriate.						
3. This intervention should prove effective in meeting the purposes.						
4. I would suggest the use of this intervention to other teachers.						
5. The intervention is appropriate to meet the students' needs.						
6. Most teachers would find this intervention suitable for the described purposes.						
7. I would be willing to use this intervention in the classroom setting.						
8. This intervention would not result in negative side effects for the students.						
9. This intervention would be appropriate for a variety of students.						
10. This intervention is consistent with those I have used in classroom settings.						
11. The intervention is a fair way to fulfill the intervention purposes.						
12. This intervention is reasonable to meet the specified purpose.						
13. I like the procedures used in this intervention.						
14. This intervention is a good way to meet the specified purpose.						
15. Overall, this intervention would be beneficial for the classroom students.						

Adapted from: Witt, J. C. and Elliott, S. N. (1985). Acceptability of classroom intervention strategies. In T. R. Kratochwill (Ed.), Advances in School Psychology, 4, 251-288. Mahwah, NJ: Erlbaum.

APPENDIX R: PROCEDURAL FIDELITY CHECKLIST BASELINE AND PROBES

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Circle one: Full Matrix Probe or Nondiagonal Probe

Date: ________

Full Matrix Probe

1	Teacher shuffles the photo deck.	+ -								
Trials		1	2	3	4	5	6	7	8	9
2	Teacher presents a photo with the iPad and asks, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	The trial is terminated after 5s of no writing or student indicates they are finished.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	Student plays back their selection with or without prompting.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
5	Teacher delivers general praise for completion of activity	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: ____/37 opportunities = ________%

Nondiagonal Probe

1	Teacher shuffles the photo deck.	+ -					
Trials		1	2	3	4	5	6
2	Teacher presents a photo with the iPad and asks, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -
3	The trial is terminated after 5s of no writing or student indicates they are finished.	+ -	+ -	+ -	+ -	+ -	+ -
4	Student plays back their selection with or without prompting.	+ -	+ -	+ -	+ -	+ -	+ -
5	Teacher delivers general praise for completion of activity	+ -	+ -	+ -	+ -	+ -	+ -

APPENDIX S: PROCEDURAL FIDELITY CHECKLIST TAYLOR INTERVERNTION A

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

Diagonal Probe

1	Teacher shuffles the photo deck.	+ -		
Trials		1	2	3
2	Teacher presents a photo with the iPad and asks, "Write a sentence about the photo."	+ -	+ -	+ -
3	The trial is terminated after 5s of no writing or student indicates they are finished.	+ -	+ -	+ -
4	Student plays back their selection with or without prompting.	+ -	+ -	+ -
5	Teacher delivers general praise for completion of activity	+ -	+ -	+ -

Total Correct: _____/16 opportunities = _________ %

Training Trials		1	2	3	4	5	6	7	8	9
1	Teacher presents photo with the sentence and the iPad.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher delivers the controlling prompt.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	Student plays back their selection with or without prompting.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
5	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/45 opportunities = _________ %

APPENDIX T: PROCEDURAL FIDELITY CHECKLIST TAYLOR INTERVENTION B

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

5s Delay Session		1	2	3	4	5	6	7	8	9
1	Teacher shuffles the photo sentence cards.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher presents the photo with the sentence hidden and the iPad.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	Teacher waits 5s until the first response or non-response.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
5	If error or no response, teacher presents sentence strip and delivers the controlling prompt for first incorrect word through end of sentence.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
6	Teacher or student play back the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
7	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/ _____opportunities = _________ %

APPENDIX U: PROCEDURAL FIDELITY CHECKLIST TAYLOR INTERVENTION C

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

5s Delay Session		1	2	3	4	5	6	7	8	9
1	Teacher presents the photo with the sentence hidden and the iPad.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher waits 5s until the first response or non-response.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	If the student makes an error, the teacher erases the word and presents the controlling prompt for the incorrect word.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
5	If the student selects the correct word, the teacher provides praise.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
6	Teacher points to the blank space for the next word.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
7	Teacher repeats steps 3-5 for every word in the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
8	Upon the completion of the sentence, the teacher or student play back the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
9	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/ _____opportunities = _________ %

APPENDIX V: PROCEDURAL FIDELITY CHECKLIST TAYLOR INTERVENTION D

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

0s Delay Session		1	2	3	4	5	6
1	Teacher presents the photo and sentence with the iPad.	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher delivers the controlling prompt for each word & a token.	+ -	+ -	+ -	+ -	+ -	+ -
4	If the student makes an error, the teacher moves to a higher-level prompt.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
5	Teacher or student play back the sentence.	+ -	+ -	+ -	+ -	+ -	+ -
6	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/ ____ opportunities = _________ %

APPENDIX W: PROCEDURAL FIDELITY CHECKLIST GEORGE INTERVENTION A

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

0s Delay Session		1	2	3	4	5	6	7	8	9
1	Teacher presents the photo and sentence with the iPad.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher delivers the controlling prompt for each word & a token.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	If the student makes an error, the teacher moves to a higher-level prompt.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
5	Teacher or student play back the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
6	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/ ____ opportunities = _________ %

APPENDIX X: PROCEDURAL FIDELITY CHECKLIST GEORGE INTERVENTION A–C 5S DELAY SESSIONS

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

5s Delay Session		1	2	3	4	5	6	7	8	9
1	Teacher presents the photo with the sentence hidden and the iPad.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher waits 5s until the first response or non-response.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	If the student makes an error, the teacher follows error correction procedure.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
5	If the student selects the correct word, the teacher provides praise and a token on VR4 schedule.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
6	Teacher points to the blank space for the next word.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
7	Teacher repeats steps 3-5 for every word in the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
8	Upon the completion of the sentence, the teacher or student play back the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
9	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/ _____opportunities = _________ %

APPENDIX Y: PROCEDURAL FIDELITY CHECKLIST STEVEN INTERVENTION 0S DELAY SESSIONS

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

0s Delay Session		1	2	3	4	5	6	7	8	9
1	Teacher presents the photo and sentence with the iPad.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher delivers the controlling prompt for each word.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	Teacher or student play back the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
5	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/ ____ opportunities = _________ %

APPENDIX Z: PROCEDURAL FIDELITY CHECKLIST STEVEN INTERVENTION 5S DELAY SESSIONS

Teacher Name: ____________________ Observer: ____________________

Target student: ________ Date: ________

5s Delay Session		1	2	3	4	5	6	7	8	9
1	Teacher presents the photo with the sentence hidden and the iPad.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
2	Teacher says, "Write a sentence about the photo."	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
3	Teacher waits 5s until the first response or non-response.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
4	If the student makes an error, the teacher follows error correction procedure.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
5	If the student selects the correct word, the teacher provides praise.	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a	+ - n/a
6	Teacher points to the blank space for the next word.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
7	Teacher repeats steps 3-5 for every word in the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
8	Upon the completion of the sentence, the teacher or student play back the sentence.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
9	Teacher delivers verbal praise for correct sentence completion.	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -

Total Correct: _____/ _____opportunities = _________ %