The Effects of Augmentative Assisted Language Matrix Training for Young Children with Down Syndrome

By

Jodi K. Heidlage

Dissertation

Submitted to the Faculty of the
Graduate School of Vanderbilt University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
in
Special Education

May 10, 2019
Nashville, Tennessee

Approved:
Ann P. Kaiser, Ph.D.
Erin E. Barton, Ph.D.
Christopher J. Lemons, Ph.D.
Howard Goldstein, Ph.D.

ACKNOWLEDGEMENTS

I'm incredibly grateful for the funding provided by the Semmel Family and the Peabody Dean's Professional Development Fund. I'm also thankful for all of the wonderful families and children who participated in this study. I could not have completed this dissertation without the wisdom, guidance, and mentorship of my advisor, Dr. Ann P. Kaiser. I'm thankful to her for encouraging and supporting me throughout the process. I also wanted to thank Drs. Howard Goldstein, Erin Barton, and Chris Lemons for taking the time to read my dissertation and for providing feedback and guidance. A huge thanks to Drs Lizzy Fuller, Lauren Hampton, Tatiana Peredo, Katie Zimmerman, and Jennifer Cunningham for supporting me, cheering me on, and providing feedback throughout this process. A final thanks to Fitzhugh Brennan and Janki Merai. I could not have completed this study without both of you and you are both amazing!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Characteristics of Children with Down Syndrome

Down Syndrome (DS) is an intellectual disability (ID) characterized by a distinct phenotypic profile associated with delays across several developmental domains (Fidler, 2009). Expressive language is a critical domain that is typically impaired in this population (Abbeduto, Warren, & Conners, 2007; Fidler, 2005; Miller & Leddy, 1999; Sigman et al., 1999). The pattern of impairment and relative strengths related to language learning suggest a specific phenotypic profile that has implications for developing effective and efficient interventions for children with DS (Fidler, 2009).

Speech and language profile. Children with DS exhibit expressive language skills that are less than predicted by their receptive language and cognitive functioning (Fidler, 2005; Miller & Leddy, 1999; Sigman et al., 1999). Specific areas of delay include development of single words, which emerge around 21 months compared to 12-14 months in typically developing children (Abedduto et al., 2007; Berglund, Eriksson, & Johansson, 2001; Stoel-Gammon, 2001). Children with DS also have unique difficulties moving from single to multi-word utterances. Specifically, children with DS often exhibit a larger single-word vocabulary before they begin combining words. While typically developing children begin combining words when they exhibit an expressive vocabulary of about 50 words, children with DS may have as many as 100 words before producing word combinations (Berglund et al., 2001; Iverson, Longobardi & Caselli, 2003; Windsor, Roberts, & Kaiser, 2012). The transition from single to multiword utterances is an important foundational point toward the development of syntax in young children (Hadley, 2014; Rispoli & Hadley, 2011).

Several behavioral characteristics appear to impact language learning in young children with DS. These include difficulties initiating, responding to, and maintaining coordinated joint attention between social partners and objects and infusing symbols (e.g., using and comprehending language) into ongoing episodes of joint attention (Adamson, Bakeman, Deckner, & Romski, 2009; Sigman et al., 1999). Children with DS may have difficulty initiating language to communicate, as well as difficulty using language to express a range of functions, such as requesting and commenting (Adamson et al., 2009; Thiemann-Bourque, Brady, & Fleming, 2012). Delayed or disordered phonological development is characteristic of children in this population and contributes to overall limited speech intelligibility (Kent & Vorperian, 2003; Stoel-Gammon, 2001). These speech and communication related difficulties contribute to persistent delays in expressive language development. Additional difficulties with language learning may be related to deficits in language related cognitive domains, including constraints on short term auditory and phonological working memory, as well as long-term memory (Byrne, Buckley, MacDonald, & Bird, 1995; Carlesimo et al., 1997; Fidler, 2005, 2009; Hesketh & Chapman, 1998; Jarrold et al., 1999).

Motivational profile. Children with DS present a unique motivational profile which may also limit their participation in opportunities for language learning during everyday social interactions and instruction (Fidler, 2005, 2009; Pitcairn & Wishart, 1994). Children with DS often have relatively limited object interest accompanied by limited motivation to explore causal relationships through early object exploration (Kasari & Freeman, 2001; Ruskin, Mundy, Kasari, & Sigman, 1994). Because children with DS participate less in early cause and effect exploration, they are slower to develop problem-solving strategies and typically exhibit developmental deficits in this area. In turn, children with DS who have fewer problem-solving strategies are less likely to persist with difficult or challenging tasks that require them to engage in a problem-solving process. They may also resist responding to adult directions to engage in difficult tasks (Dunst, 1998; Fidler, Hepburn, Mankin, & Rogers, 2005; Ohr & Fagen, 1994; Uzgiris & Hunt, 1979). Children with DS have been observed to engage in a range of behaviors to avoid difficult or challenging tasks including: crying, elopement, and task refusal. They may also use social strategies (e.g., smiling, giggling) to distract an adult from making further demands or requiring them to complete a task (Fidler, 2006, 2009; Hodapp & DesJardin, 2002; Wishart & Bower, 1984).

Children with DS also have unique strengths that may support their language learning, including relative strengths in visual short-term memory and visual motor performance (Dykens et al., 2001; Fidler, 2005; Gibbs & Thorpe, 1983; Hodapp et al. 1999; Hodapp & Ly, 2003; Rodgers, 1987; Wishart & Johnston, 1990). For cognitively challenging tasks, learning may be supported by incorporating visual supports within language instruction. Structured teaching that utilizes these visual strengths may moderate the impact of areas of weakness (auditory short-term memory, difficulty problem-solving challenging tasks) that make language learning challenging for children in this population.

In addition to relative visual strengths, children with DS are characterized by high levels of social motivation; specifically, children with DS are more likely to seek out social attention from adults than other children with ID (Rosner et al., 2004; Wishart, 2001). While this social strength can be used to distract adults who are placing demands and allow children with DS to avoid difficult tasks, social attention from adults and peers may be a strong reinforcer when it is provided contingent on engaging or persisting with challenging language learning tasks. Contingent social attention may reinforce both learning new information and practicing skills that improve language learning (e.g., persistence with cognitively challenging tasks, response to adult prompts). Learning and practicing these skills ultimately may result in children accessing significantly more language learning opportunities over time.

Early intervention that addresses foundational developmental deficits in children with DS is critical to improve early language learning and to prevent severe, long-term impairments in communication and language (Fidler, 2005, 2009). Early interventions are needed to address motivational weaknesses, difficulties in symbol infused coordinated joint attention, and auditory and short-term memory constraints. At the same time, it is important that early interventions also capitalize on children's strengths in social engagement and visually supported learning. Ideally, early interventions that improve motivation and persistence and support development of strategies for learning could result in more efficient learning in both social and instructional interactions. In particular, there is a critical need and potentially important benefit for innovative intervention approaches that promote rapid learning of expressive language. Given the developmental gap between expressive and receptive language and between cognitive development and expressive language that is typical among children with DS, innovative approaches for teaching expressive language may have unique potential to improve functional communication.

Existing Interventions

There is a substantive body of literature demonstrating the effects of early language and communication interventions on pre-linguistic and linguistic outcomes for children with DS, including both group design and single case design studies (Windsor & Kaiser, 2015). Broadly, these interventions can be classified into two categories: Naturalistic Developmental Behavioral Interventions (NDBI; Schreibman et al., 2015), which target language and communication skills in less structured contexts (e.g., play, home routines), and Discrete Trial Training (DTT; Smith, 2001), which focuses on providing repeated instructional trials targeting a specific behavior in a highly structured teaching context.

Naturalistic developmental behavioral interventions (NDBI). Several studies have examined the impact of NDBI on generalized language and communication outcomes for children with DS and other ID, including: intentional communication, turn-taking, and expressive vocabulary (Windsor & Kaiser, 2015). On average, results from these studies are positive, indicating that existing interventions can improve language and communication outcomes for this population. However, an examination of results from studies examining the differential effect of NDBI for children with DS compared to other children with ID indicates that children with DS may have less positive results for both pre-linguistic and linguistic outcomes (Windsor & Kaiser, 2015).

For example, in a group study analyzing the effects of a NDBI (pre-linguistic milieu teaching; PMT), Warren and colleagues (2008) found that children with DS in both the treatment and control group had lower rates of growth in both pre-linguistic and linguistic skills (intentional communication acts, lexical density, and number of different productive words) relative to children with other ID. Similarly, in a study examining the impact of Enhanced Milieu Teaching (EMT), Kaiser and Roberts (2013) found in both parent plus researcher implemented treatment and researcher only implemented treatment, a DS diagnosis was predictive of lower intervention outcomes for receptive language, productive vocabulary, and syntax.

In an analysis of differential vocabulary outcomes for children with DS as a result of dosage, Yoder, Woynaroski, Fey, and Warren (2014) found that children with DS who received a higher dosage of PMT showed more vocabulary growth six months following intervention than children with DS who received the same intervention at a lower dosage, suggesting that providing these children a higher dosage of language learning opportunities early in development can accelerate language learning over time. The relatively poorer performance of children with DS compared to peers with ID in existing studies (Kaiser & Roberts, 2013; Warren et al., 2008) suggests the need for more effective interventions tailored to the unique language learning and motivational profile of this population.

It is possible that the specific phenotypic characteristics of children with DS may explain their overall poorer intervention outcomes when compared to children with other IDs. This may be especially true for NBDIs which primarily provide response contingent interventions. For example, children with DS may receive less instruction in naturalistic interventions in which language modeling and prompting are provided in response to child requests, interests, and communicative acts. Limited child interest in objects and low frequency communicative initiations limit naturalistic teaching opportunities (Kaiser & Roberts, 2013). Thus, the specific behavioral profiles of children with DS may result in fewer opportunities for learning language within NDBIs, even when children are socially motivated to engage with adults. Additionally, interest in social interactions and relative strengths in social competence that characterize many children with DS may interfere with learning language in naturalistic interventions because children may use social behaviors (e.g., smiling, engaging in playful behavior, reverting to familiar social routines) to avoid responding to prompting or questioning by the adult.

Similarly, limited object interest and difficulty with symbol infused joint attention may reduce learning from adult language modeling (Adamson et al., 2015). Both may contribute to limited communicative initiations with adult language partners, restricting access to language models provided to the child contingent on the focus of their attention. This pattern of behavior during naturalistic interactions suggests that a structured approach to intervention may be more effective because it is not driven by child interest and responding. Initial interventions that are adult-directed may be useful to increase the frequency and diversity of learning opportunities for young children with DS. Structured interventions could also be designed to decrease behaviors that children with DS use to avoid engaging in non-preferred or challenging tasks.

Discrete trial training (DTT). Three single case studies have examined the impact of DTT on early language related behaviors in young children with DS (Bauer & Jones, 2015; Bauer, Jones, & Feeley, 2014; Feeley et al., 2011). These studies examined proximal outcomes during intervention sessions including: speech sound imitation (Bauer, Jones, & Feeley, 2014), pre-linguistic requesting behaviors (Bauer & Jones, 2015; Feeley et al., 2011), and intra-verbal responses to social questions (Bauer, Jones, & Feely, 2014). Overall, the results of these studies were positive, indicating that DTT may be a promising instructional strategy for young children with DS. However, all three studies included proximal measures of limited targets of intervention. For example, Feeley et al., (2011) measured changes in successive approximations of eye gaze shift behaviors (i.e., eye gaze shift, eye gaze shift paired with vocalization, and eye gaze shift paired with word approximation). Although this study demonstrated a functional relation with the onset of intervention across these behaviors, it did not include measures of generalization, nor did it directly assess changes in expressive language. The limited number of studies, proximal measures, and lack of interventions directly targeting expressive language make it difficult to draw conclusions about the effects of this instructional method on expressive language.

Although studies enrolling children with DS are limited, DTT is considered an evidence-based strategy for teaching young children with autism (ASD) with and without ID, and has been shown to effectively teach language and communication behaviors, including: expressive language, grammar, and syntax (Howlin, 1981; Lovaas, 1972; Risley, Hart, & Doke, 1972; Smith, 2000, 2001; Wong et al., 2015). Although children with DS generally differ from children with ASD in terms of their language and motivational profiles, DTT may be an effective intervention for children with DS for several reasons. First, given relative weaknesses in phonological processing and auditory memory, children with DS may need repeated trials to learn expressive language skills. Providing multiple trials in a short amount of time may promote rapid language learning. Second, DTT may address a key behavioral response weakness in children with DS: inconsistent responding to instructions or demands from an adult when the task is non-preferred or difficult. Presenting multiple instructional trials and providing positive adult attention contingent on children responding to adult instructions may increase compliance. Over time, differential reinforcement for responding to initial task directions and prompts may improve child responding in learning trials and thus, improve learning outcomes. Third, DTT can be used to teach children to persist with more difficult tasks if instruction includes breaking complex tasks into small, predictable units, reinforcing responses to the easier tasks and gradually recombining easier tasks into more complex ones (Smith, 2001). The use of task analysis, sequential instruction, and teaching to mastery are key elements of DTT that could be used to instruct children with DS (Smith, 2001). Finally, DTT provides a platform for the adult to teach new expressive language following a sequential curriculum of skills that children with DS might not learn in an approach to teaching that relies solely on teaching opportunities provided contingent on children's interests.

By teaching specific skills to fluency and providing extended practice to improve attention and persistence behaviors, DTT can provide foundational training for both specific language skills and learning related behaviors that may improve responding in natural contexts. When DTT is paired with naturalistic teaching within and across sessions, and there are planned opportunities to transfer newly learned skills and behaviors to play, routine or conversation-based intervention sessions, it is possible learning and use of language and communication skills can be accelerated. In addition, if new skills for learning are acquired, children with DS may benefit more from learning opportunities provided during naturalistic intervention and in their day to day environments. Overall, effective DTT instruction paired with naturalistic instruction may be key to maximizing the effects of early language intervention with this population.

Optimizing Treatment for Young Children with DS

The overall lower performance of children with DS in existing language interventions and the increased risk of severe, long-term language and communication impairments in the absence of effective intervention indicate a need for new intervention approaches. Innovative approaches should include focused instruction on the language skills that are difficult for this population. Although vocabulary is slow to develop in this population, developing syntax may be a more persistent area of challenge for children with DS (Abbeduto, 2003; 2007; Chapman, 2003). Young children with DS use of early word combinations may be rote ("Thank you", "Rockabye baby," "Hey Mom") or simple phrases ("I wanna ____", "Give me____") rather than truly generative combinations indicative of early syntactic development. Even as adolescents, individuals with DS may continue to convey complex messages using simple linguistic utterances, rather than using syntactically correct sentences and phrases (Miles et al., 2004). Thus, to promote long term development, it may be essential for early intervention to target the transition to generative two-word combinations. Once young children with DS demonstrate use of approximately 50 words, intervention to teach specific vocabulary needed for noun and verb phrases (noun agents, action verbs) and instruction on combining words into generative two-word phrases is warranted.

Identifying efficient methods of teaching early two-word combinations may have important implications for supporting the transition from single words to more complex syntax (Hadley, 2014). Noun agent-action verb combinations (e.g., "mom eating") were chosen as targets for intervention in the current study because they are an early developing two-word combination. The cognitive and symbolic representation skills associated with these word combinations emerge at a developmental age of approximately 18 months (Owens, 2015), thus making them appropriate targets for children with DS around 36-48 mos. Further, these combinations can easily be represented with toys and visible actions during play and instructional trials.

Language matrix training. Language matrix training has been shown to be an efficient and effective method for teaching early receptive and expressive word combinations to children with developmental and intellectual disabilities (Curiel, Sainato, & Goldstein, 2018; Ezell & Goldstein, 1989; Goldstein, Angelo, & Mousetis, 1987; Goldstein & Brown, 1989; Goldstein & Mousetis, 1989; Light, Watson, & Remington, 1990; Mineo & Goldstein, 1990; Naoi, Yokoyama, & Yamamoto, 2006; Remington & Watson, 1990). The goal of language matrix training is to teach two-word combinations efficiently by teaching a selected subset of possible word combinations (e.g., noun agent-action verb combinations) and to assess the effects of this instruction on novel combinations of words that have not been directly taught (Goldstein, 1983, 1985). This "differential response to novel combinations of stimulus components that have been included previously in other stimulus contexts" has been defined as *recombinative generalization* (Goldstein, 1983, p. 281), and indicates that children have begun to acquire linguistic rules for combining words.

Language matrix training has been shown to increase production and comprehension of generative two-word combinations, including: action-object combinations (e.g., roll the ball) in preschoolers with developmental delays (Curiel, et al., 2018; Goldstein & Brown, 1989; Mineo & Goldstein, 1990), as well as object-location combinations (e.g., "hat chair"), and object-preposition-location combinations (e.g., juice in cup) in school-age children with intellectual and developmental delays, including participants with DS (Ezell & Goldstein, 1989; Goldstein, et al., 1987; Goldstein & Mousetis, 1989). Language matrix training has also shown to be effective at increasing word combinations in children with ID using augmentative and alternative (AAC) modalities, including: manual signs (Light, Watson, & Remington, 1990; Remington, Watson, & Light, 1990) and the picture exchange communication system (PECS; Frost & Bondy, 1994) (Naoi, Yokoyama, & Yamamoto, 2006).

Given the overall slow growth in expressive syntax that characterizes many children with DS, the prolonged trajectory for developing early generative two-word combinations (Windsor et al., 2012), and the importance of these early word combinations for later syntactic development, children with DS may require targeted, systematic instruction to aid them in bridging from single to multi-word productive utterances (Berglund et al., 2001; Chapman, Schwartz, & Kay-Raining Bird, 1991; Eadie, Fey, Douglas, & Parsons, 2002; Hadley, 2014). Language matrix training includes assessment of generalized learning; the combination of DTT and continuous assessment of generalization has the potential for effective and efficient instruction. Providing focused intervention on productive word combinations (noun agent-verb action combinations) may accelerate acquisition of semantic and phrase structure rules that are the basis for more complex syntax.

Augmentative and assistive support. It is possible that incorporating an AAC mode into language-matrix training can support language learning (e.g., learning to produce noun agent-verb action combinations) for children with DS in several ways. First, incorporating a mode that produces spoken output (synthesized speech) may accelerate language learning by providing an additional phonologically consistent auditory model of target words and phrases. A recent study conducted with children with ASD indicated that providing AAC support may accelerate language learning in children with low rates of language use (Kasari et al., 2014). Minimally verbal children with ASD who participated in a NDBI (Joint Attention Symbolic Play and Regulation plus Enhanced Milieu Teaching; J-EMT) with the addition of a Speech Generating Device (SGD), a specific AAC mode, demonstrated significantly more spoken social communicative utterances, novel words, and comments than children in the group receiving the

NDBI with spoken language alone. These results maintained six months after the intervention, suggesting that incorporating an SGD into teaching may be a promising strategy for promoting spoken language in children with minimal verbal abilities (Kasari et al., 2014).

Like minimally verbal children with ASD, children with DS exhibit low rates of expressive language and limited language learning in naturalistic environments that do not include intentional instruction. It is possible that incorporating an SGD into intervention for minimally verbal children with DS can be useful in several ways. First, because the SGD includes visual symbols and secondary auditory output, it reduces reliance on auditory memory alone and may take advantage of the relative visual strengths of these children (Fidler, 2005). Second, access to an SGD provides the option for an easier motor response as an alternative to spoken language. Having an easier response option creates an extended range of difficult to easy responses to prompt for communication (e.g., spontaneous spoken, imitated spoken, spontaneous motor, imitated motor, hand-over-hand assisted motor) and may minimize challenging behaviors that occur when children are asked to persist with difficult verbal production tasks. For example, when the child has access to an SGD, the adult can prompt an easier alternative communicative response by prompting the child to sequentially press two symbols on the SGD representing "cow" and "eating" rather than repeatedly prompting the child to verbally imitate "cow eating" In this paradigm, the adult teaches the child that it is possible to respond to adult instruction and gain contingent reinforcement with a related motor response and in ways other than refusing to respond or engaging in challenging behavior. Additionally, the inclusion of an SGD allows for the use of a prompting procedure that provides guidelines for systematically providing prompts across teaching trials, contingent on the child's response. Third, difficulties in speech sound production and intelligibility suggest the need to provide a non-speech alternative response for children with DS that supports use of expressive language, especially language they understand receptively (Romski, Sevcik, & Adamson, 2005). Without an alternative non-speech mode, children with DS may exhibit a lower language learning trajectory for several reasons: (a) they are limited by what they can produce productively, (b) they may become frustrated with learning new expressive language because it is difficult, and (c) they may learn that not responding to adults allows them to escape or avoid demands for expressive production, even though not responding circumvents important learning opportunities.

Summary of Benefits of Augmentative Assisted Language Matrix Training

The relative difficulties children with DS have in producing early two-word combinations may be addressed through direct, systematic language interventions. In particular, direct teaching using a language matrix training format may teach early word combinations efficiently and promote the acquisition of the general rule for generating word combinations. Evidence of acquiring the generative principle would be spontaneous generalization of the rule to new forms combinations of noun-agents and action-verbs when presented with novel agent-action stimuli. Further benefits of matrix training potentially include generalized productive use of combination rules outside of the structured learning context; for example, generalized use might be observed as spontaneous commenting using an agent-action combination in play. Providing an augmentative mode of responding (i.e., SGD) may minimize challenging behavior by providing a relative easier motor response during teaching trials and supporting strengths in visual learning.

The purpose of the current study was to examine the effects of an augmentative assisted language matrix training intervention on the production of early word combinations (noun agent-action verb combinations) in four young children with DS. The primary research questions guiding this study were: (1) Does DTT using an augmented language matrix training approach result in increases in the production of trained agent-action combinations during probes? (2) Does DTT using an augmented language matrix training approach result in production of generative (untrained) word combinations during probes? A third exploratory question examined generalization to play-based interactions: (3) Does the intervention result in the production of agent-action combinations in naturalistic language samples?

CHAPTER II

METHOD

Inclusion Criteria

The participants selected for this study were four young children (43-56 months) with Down syndrome (DS) who produced at least 50 different vocabulary words but were not yet generatively combining nouns (agents) and verbs (actions). The following inclusion criteria were used to identify participants for the study: (a) age between 3.5 to 6 years, (b) English as the primary language spoken to the child and spoken by the child, (c) a primary diagnosis of DS and no secondary disabilities including sensory impairment (e.g., blindness) or another developmental disability (e.g., ASD), (d) receptive language equivalent of at least 18 months on the Preschool Language Scale-Fifth Edition (PLS-5; Zimmerman, Steiner, & Pond, 2011), (e) productive use (spoken or signed) of at least 50 words, including at least 10 action verbs and at least 10 noun agents as reported by parents on the MacArthur Bates Communication Developmental Inventory (MCDI; Fenson et al., 2014), (f) use of at least five different nouns and five different verbs observed during a 20-min naturalistic language sample (LS), (g) use of fewer than two unique noun agent-action verb combinations observed during a 20-min naturalistic LS, and (h) fewer than two reported unique noun agent-action verb combinations on a parent questionnaire. Inclusion criteria are summarized in Table 1. A complete description of inclusion measures is in the assessment section below.

Table 1. *Inclusion criteria*

	Assessment	Inclusion Criteria
Age	Parent report	3.5-6 years
Language	Parent report	English
Diagnosis	Parent report	Down Syndrome, and no co-occurring impairments
Receptive Language	Preschool Language Scale-fifth Edition	18-month age equivalent
Expressive Language (diversity)	MacArthur Bates Communicative Development Inventory	50 productive words (10 noun agents, 10 action verbs)
Expressive Language (rate)	Standardized Semi-Structured Language Sample	5 different nouns and 5 different verbs in 20-min
Production of noun agent-action verb combinations	Parent Questionnaire	Fewer than two unique noun agent-action verb word combinations
Production of noun agent-action verb combinations	Standardized Semi-Structured Language Sample	Fewer than two unique noun agent-action verb combinations

Participants. Four preschool aged children with DS participated in the current study. Three participants were recruited from children with DS completing a randomized experimental study examining the effects of a naturalistic language and communication intervention (J-EMT: Kasari et al., 2014) that included the use of an iPad as an SGD delivered by therapists and parents on young children with DS. The three participants had been randomly assigned to the J-EMT treatment and received 48 intervention sessions (two parent training, two therapist-implemented for a total of four times each week for 12 weeks) prior to beginning the current study. Although all three participants increased their production of single words by the end of the intervention, none of the participants produced generative combinations of noun agents and action verbs in two-word combinations using spoken, signed, or SGD modes. The fourth participant was on the waitlist for the J-EMT study, but enrollment closed before he could participate in the study. He was recruited by contacting his parent and assessed to determine if he met inclusion criteria for the current study.

Participant 1 was a 46-month old male. His receptive language age equivalent (36 months) was higher than his expressive language equivalent (23 months) on the PLS-5. He had recently begun to transition from signing alone to spoken language plus signing. He had a relatively large productive single word (spoken+sign) vocabulary (194 total words). His mother reported that he did not produce any agent-actions combinations and he did not produce any agent-action combinations during the LS. Participant 1 had a limited consonant repertoire prior to intervention. He produced 46% of consonants correctly on the PEEPS (19 total consonants). He often dropped the initial consonant from his spoken word utterances; this made his language difficult for a listener to understand when the referent was not immediately apparent. Although his speech intelligibility was limited, he was a relatively high rate communicator. He produced 46 unprompted utterances in the 20-min LS (2.3 utterances per min).

Participant 2 was a 43-month-old female. She had a total of 159 productive (spoken) words prior to intervention. Her mother reported she produced one agent-action combination (baby sleep), but she did not produce any agent-action combinations during the LS. She produced 23 total consonants correctly (56.1%) on the PEEPS and was generally intelligible when communicating with single words. Her receptive language age equivalent on the PLS-5 (26-months) was similar to her expressive language equivalent (25 months). She was a relatively high-rate communicator. She produced 40 unprompted utterances in a 20-min LS (2 utterances per min).

Participant 3 was a 48-month old female. Her expressive language age equivalent was (30 months) was similar to her receptive language age equivalent (31 months) on the PLS-5. Her mother reported she had a total of 117 productive words and she demonstrated a moderate rate of communication (25 utterances in the 20-min LS; 1.25 utterances per min). Her speech was relatively intelligible when she spoke using one or two word utterances. She produced 28 consonants correctly (68.3%) during the PEEPS.

Participant 4 was a 56-month old male. His receptive language age equivalent was slightly higher (33 months) than his expressive language equivalent (27 months) on the PLS-5. His parent reported he produced a total of 159 total words (spoken+sign) and he communicated at a moderate rate (1.25 utterances per minute for a total 25 unprompted utterances during 20-min LS). He produced 20 consonants correctly (48.8%) on the PEEPS. He often omitted the final consonant of words in his spoken utterances. Participant descriptions are provided in Table 2.

Implementer. All pre-intervention assessments and training as well as baseline and intervention sessions were conducted by the researcher, a doctoral candidate in the Early Childhood Special Education at Vanderbilt University. She had over 10 years of experience conducting language and behavioral interventions with young children with a range of developmental disabilities. Her experience included 4 years as a clinical instructor in early intervention programs and 5 years implementing instructional interventions in language related research projects enrolling children with DS and ASD.

Table 2. *Participant Descriptions*

	P1	P2	P3	P4
Age	46 months	43 months	48 months	56 months
PLS-5 Total Score Standard (Raw)	152 (64)	153 (58)	140 (65)	128 (64)
PLS-5 Receptive Language Age Equivalent	36 months	26 months	31 months	33 months
PLS-5 Expressive Language Age Equivalent	23 months	25 months	30 months	27 months
MCDI	194 total words* (27 agents, 30 actions)	159 total words (17 agents, 44 actions)	117 total words (18 agents, 13 actions)	159 total words* (15 agents, 16 actions)
NDW (LS)	15 7 nouns, 6 verbs	28 12 nouns, 7 verbs	18 7 nouns, 7 verbs	27 12 nouns, 6 verbs
Unprompted utterances (LS)	46	40	24	24
Agent-action combinations (LS)	0	0	0	0
Multi-word combinations (LS)	0	0	6	0
Agent-action combinations (parent questionnaire)	0	1	0	0
Multi-word combinations (parent questionnaire)	0	4	11	3
PEEPS PCC (total consonants)	(46%) 19 2 initial 4 medial 13 final	(56.1%) 23 11 initial 5 medial 7 final	(68.3%) 28 12 initial 5 medial 11 final	(48.8%) 20 12 initial 2 medial 6 final

Note. PLS-5=Preschool Language Scale-Fifth Edition. MCDI=MacArthur Bates Communicative Developmental Inventory. LS=Language Sample. NDW=number of different words. PEEPS=Profiles of Early Expressive Phonological Skills. PCC=Percent Consonants Correct. *=manual signs and productive words.

Setting

Pre-intervention and intervention sessions were conducted four days each week, consisted of 10-25 instructional trials, and lasted 20-30 min. Intervention for Participant 1 was conducted exclusively in the home. Intervention sessions took place in his bedroom. He sat on the floor with a small desk placed over his lap. His bedroom contained a crib, bookshelf, and toy box. The room was relatively free from distractions. Intervention for Participant 2 was conducted primarily in her public elementary school. Intervention was conducted in a hallway near her classroom; she sat on the floor with a desk placed over her lap. Because intervention continued into the summer, intervention for Participant 2 was completed in the living room at her home. The living room contained a couch and small kitchen play set. A small desk was placed over her lap and she sat on the floor in front of the couch during home sessions.

Intervention for Participant 3 was conducted in the participant's public elementary school in an unused classroom. The classroom had tables and chairs pushed up against the walls and was generally free from distractions. Participant 3 sat on the floor with a small desk over her lap in the corner of the classroom for instructional sessions. Intervention for Participant 4 was conducted both at his elementary school and a community center that provides resources to children and youth with DS and their families. Intervention in the elementary school was conducted in an unused computer lab. The classroom was large and the computers were distracting to Participant 4, so a table was set up in the corner of the room to minimize access to the computers. Intervention for Participant 4 also was conducted in a therapy room at the center for children with DS. The room was relatively empty except for a small cabinet, table, and chair.

Intervention for Participant 4 was conducted at table in the corner of the room. During all sessions, the researcher was seated beside or in front of the child either in a chair or on the floor.

Materials

All pre-intervention, baseline, and intervention sessions were recorded using a Sony Handycam HDR-CX05 placed on a camera tripod. Primary data, Interobserver Agreement (IOA) data, and Procedural Fidelity (PF) data were measured using ProcoderDV^{DM} (Tapp, 2003) software. An SGD (an iPad programmed with Proloquo2go™ software with visual display and auditory output) was used as an augmentative communication support during pre-intervention assessment and instructional sessions. A small lap desk was used during instructional sessions for participants 1, 2 and 3; a child size table and chair was used for Participant 4. Additional materials used during instructional sessions included up to six toys representing noun agents (e.g., dog toy) and six accessory toys (e.g., ladder for climbing) used for modeling verb actions with the agents. Edible and tangible reinforcers (e.g., bubbles, balloons, goldfish, gummies) were provided for appropriate responding during instructional and probe trials; additional toys were provided during breaks from instructional trials (e.g., magnatile blocks, ball tower). Materials for the language sample sessions included six developmentally appropriate toy sets (dolls and beds, babies and tea set, “Where’s Spot” book, barn, animals, and blocks, cars with ramp, and babies with grooming set).

Experimental Design

This study used a multiple probe single case research design (Gast, Lloyd, & Ledford, 2018) to assess the effectiveness of language-matrix training across behaviors (sets of agent-action combinations). The plan was to conduct the multiple probe design across behaviors with each of the four children with DS, and to replicate the design across all four participants. However, Participant 1 did not complete the multiple probe design across behaviors and thus, the design was replicated across a total of three rather than four children. The design was chosen because the primary research question focused on demonstrating the effectiveness of an instructional strategy for a series of non-reversible behaviors (i.e., language skills). The study was proposed as a multiple probe design with concurrent replication across participants. However, it was not possible for the children to participate simultaneously and thus, the experiment was conducted sequentially with the four participants. In addition, systematic iterative adjustments were made after each participant completed the design and the final design included sequential replications. The same research questions were addressed with each participant in a multiple probe design across behaviors (sets of noun agent-action verb combinations), however, measurement and parameter adjustments were made to the extent feasible without compromising the integrity of the design. Design changes included: reducing the size of the language matrix, adding a more proximal measure of learning, and minor changes to the instructional procedure. These changes are described in detail below.

Intervention for each participant was introduced sequentially across the three intervention tiers (sets of agent-action combinations) after data were stable in the baseline condition and when criterion was met in the current intervention condition as determined via visual analysis. In addition, *a priori* criteria for performance were established to determine when the participants were advanced to the next tier. Threats to internal validity were minimized by intermittently collecting probe data for behaviors in untreated tiers of intervention. Unlike multiple baseline designs, multiple probe designs eliminate the need for continuous baseline measurement of untreated behaviors or skills; thus, a multiple probe design is an ideal design for use with young children who may become frustrated during prolonged baseline phases in which they are not able to perform the task being required of them.

Implementation of the multiple probe design within a language matrix. Figure 1 (below) contains a sample language matrix that formed the basis for the multiple probe across behaviors design. In the matrix shown in Figure 1, noun agents are listed on the far left and action verbs are listed along the top; each cell represents a unique combination of one noun agent plus one action verb (e.g., “cat eating”). Each language matrix was divided into three submatrices (indicated by three different colors and letters A, B, C in Figure 1). Acquisition of the sets of agent-action combinations within each submatrix was evaluated in a separate tier of the multiple probe design.

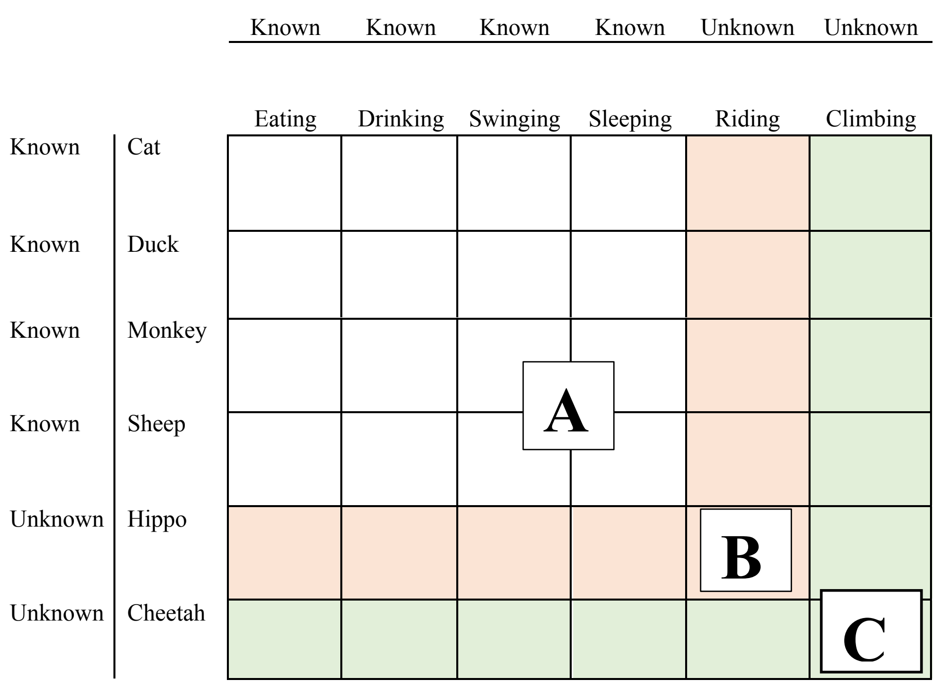

Figure 1. Sample language matrix divided into three submatrices

Prior to beginning the study, a set of four noun agents and four action verbs that each participant was reported to produce on the MCDI (*known*), and two noun agents and two action verbs that each participant did not (*unknown*) produce on the MCDI were selected. Submatrix A (shown in white in Figure 1) was developed using nouns and verbs produced (known) by the participant (per parent report on the MCDI). Submatrix B (peach) and Submatrix C (green) were developed with *unknown* nouns and verbs that the participant was not reported to produce on the MCDI (see Figure 1). The purpose of using *unknown* nouns and *unknown* verbs in Tier 2 (Submatrix B) and Tier 3 (Submatrix C) was to strengthen the multiple probe design by increasing the likelihood that the participant would not produce agent-action combinations in Tier 2 (Submatrix B) and Tier 3 (Submatrix C) prior to intervention as a result of instruction in Tier 1 (Submatrix A). Toys representing each agent and the actions to be acted out with each agent were selected. A sample list of noun agents and action verbs with example toys and actions is in Table 3.

Table 3. *Target noun agent and verb action toys and actions*

Agent	Action	Additional Toys	Adult Action
Dog	Swing	Swing	The dog swings on a swing
Cat	Climb	Ladder	The cat climbs up the ladder
Sheep	Sleep	Bed and blanket	The sheep sleeps in the bed
Cow	Drink	Cup	The cow drinks from cup
Goat	Ride	Bicycle	The goat rides bicycle
Bear	Eat	Cake	The bear eats cake

Intervention Procedures

Pre-intervention sessions. After toys were selected representing nouns (agents) and verbs (actions), an assessment was conducted with the four *known* agents and four *known* actions to evaluate which agents and actions each participant could produce on the SGD prior to intervention (this assessment is described in pre-intervention assessment below). The four *known* agents and four *known* actions were embedded in Submatrix A (Tier 1 of intervention). Prior to beginning intervention in Submatrix A, the four agents and four actions that the child did not produce correctly on the SGD during the pre-intervention assessment were taught using DTT (see instructional procedure below). Pre-intervention instructional sessions continued until each participant met criterion for producing each agent and action individually on the SGD (independent production across three consecutive instructional trials). The purpose of pre-teaching was to promote efficient learning of agent-action combinations during intervention by ensuring that the child could identify each agent and action by selecting the corresponding icon on the SGD. Additionally, pre-intervention instructional sessions provided the opportunity for the participant to learn sit, attend, and respond consistently during structured instructional trials prior to implementing intervention. Pre-intervention instructional sessions were conducted 4 days a week, lasted 20-30 min, and consisted of 10-25 teaching trials. More specific information about pre-intervention procedures is provided below.

Instructional procedure. Pre-intervention instructional sessions were conducted using DTT instruction (Smith, 2001) with a constant time delay prompting procedure (CTD; Wolery, Ault, & Doyle, 1992). DTT is a method of instruction that provides short repeated instructional trials targeting a specific behavior (Smith, 2001). During pre-teaching instructional sessions, the specific behavior targeted was production of agents in isolation (e.g., zebra) and production of actions in isolation (e.g., riding) by selecting the corresponding symbol on the SGD. During DTT instruction, each trial began with a short task direction. A prompt was provided after the task direction to maximize the likelihood of the child responding correctly; reinforcement was provided for correct responding (see instructional prompts below for a detailed description of the teaching procedure). The level of support (prompt) provided was faded across instructional trials so that over time each participant was able to respond correctly to the task direction with less assistance. In this study, the prompting procedure used during DTT instruction was CTD, a method of errorless learning in which a stimulus (task direction) is provided, and a prompt (answer) is given within a set amount of time. In CTD, two different types of delays are provided: (1) trials where the controlling prompt for the correct response is provided immediately after the task direction (0 s delay trials) and (2) trials where the controlling prompt is delivered after the terminal delay (3 s delay trials in the current study). Rules for moving to delay trials are pre-determined and contingent on the child's performance during 0 s trials (Wolery, et al., 1992).

In the current study, trials were presented with a 0 s delay between the task direction and controlling prompt at the beginning of each session until the participant produced five prompted correct responses. After five correct responses, the researcher moved to 3 s (terminal delay) trials. Trials continued with a 3 s delay until the target agent or action was mastered or three total errors were produced. If three errors were produced during terminal (3 s) delay trials, the researcher returned to presenting 0 s trials. These trials (0 s) continued until the participant produced five correct responses, then 3 s trials were again presented until the participant met criterion for correct responding (three consecutive independent responses).

Instructional prompts. Prior to conducting pre-intervention instructional sessions, a brief test was conducted to determine the type of prompt required for each participant to produce a correct response during instructional trials (controlling prompt). This prompt was using during DTT instructional sessions using the CTD prompting procedure. In this test, the researcher provided five trials with an agent-action combination that the child did not know and was not directly taught in the study. During this test, the researcher evaluated two levels of prompting: a) the child produced a response when a verbal model was paired with a gesture to the icon on the SGD (e.g., researcher said: the "dog" and pointed to "dog" on the SGD, waited until the child activated the "dog" icon or produced the verbal response "dog", and then said: "is sitting" and pointed to "sitting" on the SGD) or b) if the child required hand-over-hand assistance to produce a response on the SGD. In providing hand-over-hand assistance, the researcher took the child's hand, formed his/her fingers into a point, and assisted him/her in activating the correct icons on the SGD using the pointed finger. The least intrusive prompt that the child responded to correctly during four out of five trials was used as the controlling prompt throughout the entire study. The controlling prompt identified during this assessment was a verbal model paired with an SGD gesture (gesture to icon on the SGD) for all four participants.

During pre-intervention instructional sessions, the controlling prompt was a verbal model paired with an SGD gesture (gesture to icon on the SGD) for either the agent or action <u>in isolation.</u> For example, to prompt the response "dog", the researcher said: "dog" and gestured to the "dog" icon on SGD. Instructional trials began when the researcher presented a task direction. During instructional trials for agents, the researcher presented the agent (e.g., showed the child a dog toy) and presented the task direction (What is it?). During instructional trials for actions, the researcher performed the action with the agent (one not taught in the intervention) and the object (e.g., the researcher placed the zebra on the swing and pushed the swing back and forth), and provided the task direction (“What is it doing?”). If the participant did not respond or responded incorrectly, the researcher provided the controlling prompt (verbal model+SGD gesture). After the participant produced (prompted or independently), the correct answer (the agent or action in isolation), the instructor reinforced the participant for the correct response by praising him/her and providing praise and tangible or edible reinforcement. After three consecutive independent responses were produced for each agent and each action targeted during pre-instructional sessions, intervention began for agent-action combinations in the multiple probe design.

Intervention sessions. The same DTT instructional procedures (Smith, 2001) and CTD prompting procedure (Wolery, Ault, & Doyle, 1992) used during pre-intervention sessions was used to teach each participant to produce agent-action combinations during intervention sessions. Intervention sessions were conducted 4 days a week, lasted 20-30 min, and consisted of 10-25 teaching trials. The only difference between the instructional procedure in pre-intervention and intervention instructional sessions was that the controlling prompt provided in instructional trials during intervention sessions was a verbal model paired with an SGD gesture to produce the agent-action combination (***both*** the agent and action in sequence). The present progressive form of the verb was used to label the actions (e.g., “swinging,” “climbing”) and noun agent-action verb word combinations were modeled in short grammatically correct phrases stressing the key agent and action (“The CAT is EATING). For example, to model the response “dog swinging” the instructor said: “The DOG” and pointed to the icon “dog” on SGD “is SWINGING” and pointed to the icon “swinging” on SGD. For each trial, after the researcher provided the ***agent*** prompt (said “the dog” and pointed to the “dog” icon on the SGD), she **waited** until the participant produced the agent (spoken word or activated the SGD) and then provided the ***action*** prompt (researcher said "is swinging" and pointed to the "swinging" icon on the SGD). The criteria for implementing the time delay (0 s vs. 3 s trials) were the same as the rules during pre-intervention sessions. Instructional trials for agent-action combinations began when the researcher non-verbally modeled the agent acting out the action with the object (e.g., she placed the dog on the swing and pushed the swing back and forth) and provided a task direction ("What do you see?"). If the participant did not respond or provided an incorrect response, the researcher provided the controlling prompt (verbal model+SGD gesture). After the participant produced (prompted or independently) the correct answer (the agent-action combination spoken or produced on the SGD), the researcher reinforced the participant for producing the correct agent-action response with praise, tangibles, and edibles.

Each agent-action combination was introduced and taught to criterion in isolation. After two combinations met criterion in isolation, the two were intermixed across instructional trials. The first combination taught for each participant was the combination in the upper left-hand corner of Submatrix A. For example, for Participant 1, the first combination taught was "cat eating" (labeled 1 in Figure 2). Teaching continued with this combination until the participant reached criterion (three consecutive independent responses). After the participant mastered this combination, the next target agent-action combination was selected. The selection of each target agent-action combination was contingent on the participant's error patterns across instructional trials during the previously targeted agent-action combination. For example, when the target combination was "cat eating" for Participant 1, he consistently produced the agent (cat), but frequently produced the wrong action (e.g., produced "swinging", "climbing"). The next agent-action combination introduced was the same agent (cat) with a different action (drinking) to cue him to pay attention to the action that was being modeled with the agent (labeled 2 in Figure 2).

After the two agent-action combinations were taught to criterion in isolation, they were intermixed until the participant produced five consecutive independent correct agent-action combinations. The systematic introduction of agent-action combinations in isolation followed by discrimination training in sets of two agent-action combinations continued until the participant met criterion for Tier 1 (correctly produced 3 out of 4 combinations in two consecutive probe sessions). The same process of teaching agent-action combinations in isolation, intermixing agent-action combinations in sets of two, and analyzing error data to inform the selection of each new target agent-action combination was used during intervention in Tier 2 (Submatrix B) and Tier 3 (Submatrix C). The only difference was that the first agent-action combination selected in each submatrix was the agent-action combination in the right corner of the submatrix (hippo riding for Submatrix B and cheetah climbing for Submatrix C; shown in Figure 2).

Assessments

Inclusionary assessments. The MCDI was completed by each participant's parent before beginning the study. The MCDI is a standardized assessment designed for children who are typically developing, but frequently used with children with developmental delays or disabilities to ascertain use of early vocabulary as reported by the parent. Large, significant correlations have been found between parent reports of vocabulary on the MCDI and measures of vocabulary obtained from therapist-implemented language samples for young children with DS (Miller, Sedley, & Miolo, 1995). The MCDI contains a list of 396 early developing words. Parents are instructed to indicate their child's receptive understanding and expressive use of each word

(Fenson et al., 2014). The list of words reported by each participant's parent was examined to determine how many nouns that could function as agents (e.g., cow, dog, chicken) and action verbs (e.g., eat, run, sit, jump) the child produced in interactions with the parent. Action verbs and noun agents identified by parents were used as target vocabulary in the agent-action combinations taught during intervention. To assess how many noun agent-action verb combinations participants currently produced, parents completed an additional form. This form provided a list of examples of early emerging two-word combinations and asked parents to list the combinations that they had heard their children produce (see Appendix A). This assessment was used to determine if the participant met the inclusion criteria of using fewer than two unique agent-action combinations.

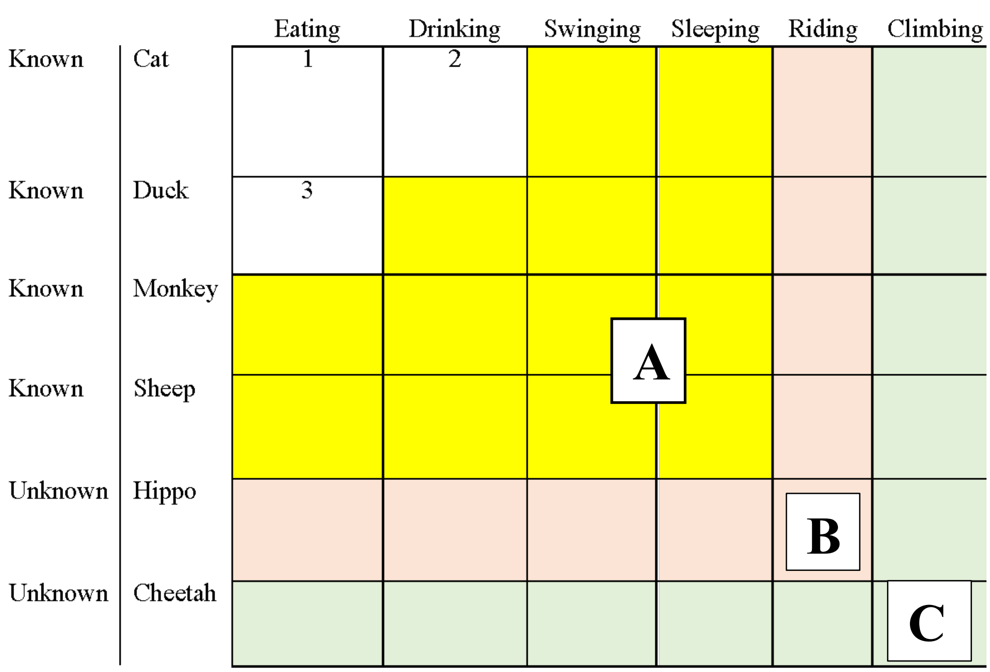

Figure 2. Introduction of target agent-action combinations in each submatrix

]

Additional inclusionary assessments were conducted by a speech-language pathologist with ten years of experience assessing young children with developmental delays. The PLS-5 (Zimmerman, et al., 2011), a norm-referenced comprehensive early language assessment, was administered to determine if children had the receptive language skills that are developmentally necessary for forming early word combinations (i.e., 18-month receptive language equivalent) as well as to provide a global assessment of each participant's language prior to intervention.

To provide additional assessment of each participant's ability to produce noun agent-action verb combinations, a naturalistic LS was conducted using standardized materials and procedures. The purpose of this assessment was to assess each participant's ability to produce agent-action combinations in a play context. For this study, standardized materials (six sets of developmentally appropriate toys) were provided systematically throughout a 20-min period. An SGD (iPad programmed with Proloquo2go™ software) was programmed with noun (agent) and verb (action) vocabulary to provide an additional mode for the participant to respond. Throughout the LS, the researcher engaged with the participant using a responsive interaction style to provide the participant with the opportunity to spontaneously use language while engaging with developmentally appropriate toys. The researcher also modeled 4-5 agent-action play actions during the LS to provide the participant with the opportunity to label or comment using an agent-action combination. For each action modeled, the researcher provided least- to-most support to assist the child in producing a response. First, the researcher modeled the action and waited. If the participant did not produce a response within 3 s of the modeled play action, the researcher modeled again and said: "What do you see?" (verbal prompt). If the participant did not produce a response in 3 s, the researcher provided a specific verbal model (an agent-action phrase) with a simultaneous gesture to each icon on the SGD (e.g., the researcher said:

“The girl is sitting”, and pointed to the two icons for “girl” and “sitting” on the SGD). Child responses were coded as spontaneous, elicited or imitated. This assessment was conducted before intervention began and at the end of intervention to provide a measure of each participant’s ability to produce spontaneous and elicited agent-action combinations using spoken language, signs, or on the SGD in a communicative context. Additional LS assessments were conducted for Participant’s 3 and 4 after they met criterion in each tier of intervention. Procedures for the LS are summarized in Table 4 and a complete protocol is in Appendix B.

Orthographic transcription of each child utterance spoken, signed, or produced on the SGD was completed following the Systematic Analysis of Language Transcripts protocol (SALT; Miller & Chapman, 2008). From the initial LS, the number of action verbs and nouns that could be used as agents were counted to determine if the participant met the inclusion criteria of using at least five different noun agents and five different action verbs. The number of unique noun agent-action verb combinations that the participant produced was counted and used to determine if the participant met the inclusion criteria of producing fewer than two unique noun agent-action verb combinations.

Table 4. *Language Sample Procedures*

Purpose	Description	Stimuli	Prompts
Assessed production of noun agents and action verbs for inclusion Assessed production of noun agent-action verb combinations for inclusion Measured changes in language skills over time	Engaged in responsive interaction style Modeled 4-5 noun agent-action verb play actions Prompted the child to produce noun agent-action verb combinations (spoken or SGD)	Dolls and beds Grooming with babies “Where’s Spot” book Barn, animals, blocks Tea set with babies Car with ramp	Modeled action and waited 3s Modeled action, waited 3s, and said “What do you see? Modeled action and provided a spoken+gesture model for both the agent and action icons on SGD (verbally said: “the dog is sitting” and pressed the “dog” and “sitting” icons on the SGD)

Descriptive assessments. Given the limited speech intelligibility that characterizes many children with DS, (Kent & Vorperian, 2003; Stoel-Gammon, 2001), the Profiles of Early Expressive Phonology (PEEPS; Williams & Stoel-Gammon, 2014), a norm-referenced test that assesses all speech sounds in the English language, was administered to inventory the speech sounds (consonants) participants could produce spontaneously or imitatively within words. Results from this assessment were used to provide an index of the speech accuracy of participants pre- and post-intervention. The primary variable measured was percent consonants correct; the total number of consonants produced as well as correct production of consonants in the initial, medial, and final word positions also were recorded.

Pre-intervention preference assessment. After each language matrix was assembled and toys were chosen representing each noun agents (e.g., cat) and actions (verbs) acted out with toys (e.g., ladder for climbing), a *multiple-stimulus with replacement* preference assessment (DeLeon & Iwata, 1996) was conducted to ensure that each participant did not demonstrate a strong preference for any of the agent toys. In this assessment, toys representing the six noun agents were randomly assigned to sets of three (two sets) and six trials were presented per set (two per agent). During the preference assessment, the three items were placed approximately 3-4 inches apart on the table directly in front of the child. During each trial, the researcher said: "Pick one" and simultaneously gestured to the array of agents. When the participant selected an agent, he/she was allowed to have access to the toy for 15-30 seconds before the researcher removed the item and said: "Ok, it's my turn". If the participant did not want access to the agent, the researcher used praise, tangible, and edibles to reinforce the child for participating in the task. After the first agent was selected, the three agents were re-ordered on the table to control for selection based on location; all three agents were re-presented. The agent on the left was taken and moved to the right, and the other two agents were shifted to the left. None of the participants demonstrated a preference for any of the agents during this assessment, so the preference assessment ended after a total of 12 trials (six trials per set; two per agent) for each participant.

Pre-intervention SGD assessment. During intervention, the experimenter modeled correct responding on the SGD and the participant was allowed to respond during each trial using either spoken language or using the SGD. The decision to include an iPad as an SGD was based on the limited speech intelligibility and relative strengths in visual processing reported for children with Down syndrome (Hodapp & Ly, 2003; Kent & Vorperian, 2003). A single display incorporating six agents and six actions (all possible combinations across the three submatrices), was created on the SGD. Vocabulary words (noun agents and verb actions) for each submatrix were programmed into this display. Each word was represented as an icon with a color line drawing and a printed word at the bottom of the image. In the display, the six agents were programmed on the left side of the page and the six actions were programmed on the right side of the page. Icons for agents and actions were presented in the same relative location on the screen throughout intervention (see Figure 3 for a sample communication display).

After the SGD was programmed, an assessment of each participant's ability to use icons on the SGD to label toys (noun agents) and actions (verbs) acted out with toys by selecting the single word target vocabulary was conducted. The purpose of this assessment was to confirm the participants' production of the four target words identified as *known* per parent report on the MCDI and to confirm that the participant could <u>not</u> produce the two target words identified as *unknown*. In this assessment, probes were conducted to assess the participant's ability to independently identify agents and actions with agents by producing a single word (e.g., agent noun or action verb) on the SGD. During the probe, the agent was placed on the table (e.g., dog alone) or the researcher acted out the action with a randomly selected agent that was not used in the study (e.g., duck climbs a ladder) and the appropriate prop (e.g., ladder). The participants were instructed to identify the corresponding icon on the SGD in response to a task direction provided by the researcher (i.e., “What is it?” for agents, and “What is it doing?” for actions). Each of the 12 unique words (6 agents, 6 actions) was presented once and the order of presenting words was random (12 total trials). Each unique word that the participant did not produce during this assessment was taught during pre-intervention sessions.

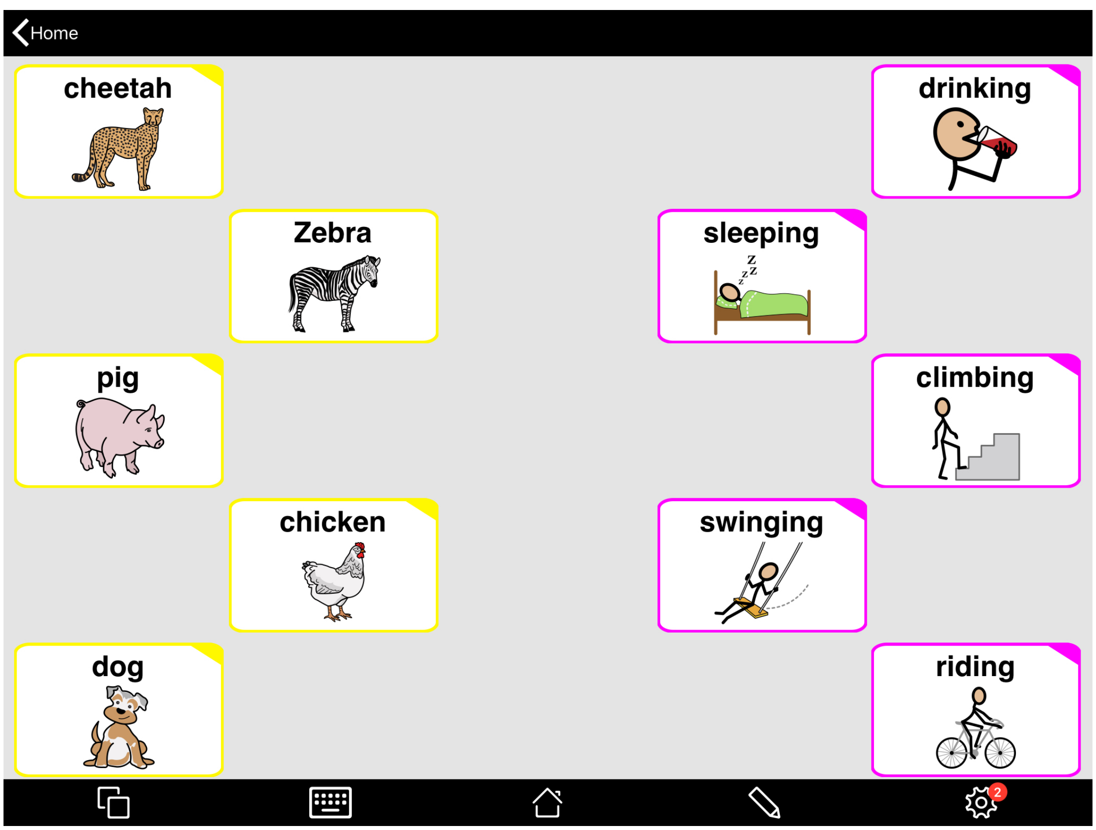

Figure 3. Sample SGD display

Dependent Measures

Data on instructional trials. Data on spontaneous correct, prompted correct, and incorrect responses were collected for each teaching trial during training sessions to inform the researcher when to switch from 0 s to 3 s delay trials and to determine when criteria were met and when to change targets.

Data on untrained agent-action combinations. Production of untrained agent-action combinations was defined as: independent activation of both the agent and action icons on the SGD within 5 s sequentially as indicated by auditory SGD output, spoken production of both verbal label for the agent and the action sequentially within 5 s, or a combination of spoken production of the agent or action and production of the agent or action on the SGD.

Due to low and variable levels of correct responding during probes of untrained combinations for Participant 1 during Tier 1, correct responding during probes of ***trained*** agent-action combinations were added to obtain a more proximal measure of learning. After this systematic adaptation, correct responses to trained combinations during probe trials was used as the primary dependent variable for all participants throughout the remainder of the study. Correct responses to untrained agent-action combinations were still assessed during probes as a measure of generalization, however, determination of a functional relation was based on the visual analysis of graphed data for correct trained combinations for all four participants. The definition for correct trained combinations was exactly the same as the definition for correct untrained combinations; the only difference was that the agent-action combination that was presented in trained combination probes had been taught in previous instructional sessions. Additional information about systematic adaptations and measurement procedures for trained combinations across participants is provided in the results section below.

Measurement occasions. Probe trials for both untrained and trained combinations were embedded within teaching sessions; one probe trial was presented after every three or four instructional trials, on average. Probe trials were interspersed with instructional trials to optimize participant attention and responding.

Data on participant production of untrained (novel) agent-action combinations (initial primary dependent variable) within the target submatrix were collected during probes conducted in every other teaching session. During each measurement occasion for untrained combinations, correct production of four untrained combinations was assessed; the probed combinations were randomly selected from the untrained combinations remaining in the target submatrix. For example, in Submatrix A below (Figure 4), combinations 1 and 2 had been mastered (cat eating, cat drinking) and combination 3 (duck eating) was the current target being trained. Thirteen untrained agent-action combinations (shown in yellow) were available for selection and four agent-action combinations were randomly selected for probe trials. The four agent-action combinations were embedded in the instructional trials, as described above. Note that the number of untrained combinations available to be selected for probing decreased as participants mastered novel combinations.

Baseline probes of untrained agent-action combinations were conducted prior to intervention in Tier 1. After three consecutive sessions with low and stable responding occurred, intervention began in Tier 1. Baseline probes of untrained agent-action combinations in Tier 2 (Submatrix B) and Tier 3 (Submatrix C) were conducted on average after every third session that included probes of untrained combinations from Submatrix A. Baseline probes assessed correct production of untrained agent-action combinations in the two remaining untrained submatrices (Tier 2, Submatrix B; Tier 3, Submatrix C).

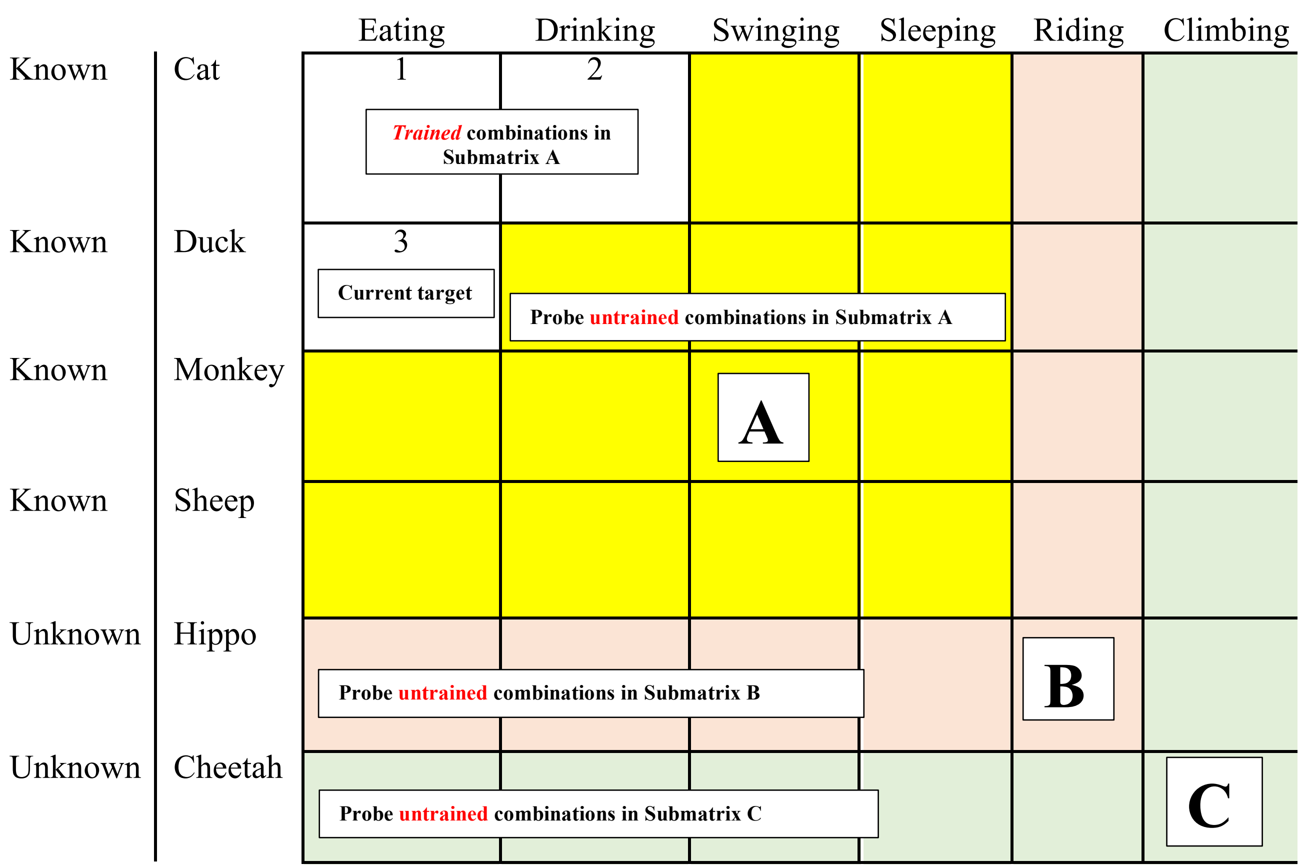

Figure 4. Probes for untrained combinations across Submatrices A, B, and C

Primary data collection. Primary data were collected from video recordings of baseline and intervention sessions using ProcoderDV^{DM} (Tapp, 2003) software. Primary coding was completed by two observers independent of the intervention portion of study. Observer 1 coded data for Participants 1 and 2, and observer 2 coded data for Participants 3 and 4. Event recording was used to indicate when each agent-action opportunity occurred. Each occurrence was coded as either: correct production of the agent-action combination (spoken, SGD, or combination of spoken and SGD responses), correct production of the agent alone or the action alone (spoken or SGD), production of an incorrect answer (error), or a non-response (the participant did not provide an answer). Correct production of agent-action combinations (spoken, SGD, or combination of spoken and SGD responses) are the only data presented in the multiple probe graphs for each participant. A coding manual with descriptions for each code is provided in Appendix C. Data were graphed as the total number of trials (count) in which the participant produced the correct agent-action combination (out of four trials) for each measurement occasion and dependent variable (trained and untrained combinations). Operational definitions and specific examples are provided in Table 5.

Table 5. *Dependent Variables and Operational Definitions*

Dependent Variable	Type	Operational Definition	Example	Dependent Measure
Production of ***trained*** agent-action combinations	Primary	Independent activation of both the agent and action icons on the SGD within 5s of one another as indicated by auditory output, spoken production of both the agent and the action within 5s of one another, or a combination of one spoken agent or action and one agent or action produced on the SGD.	Participant says: "monkey climbing Participant says: "monkey" and presses "climbing" on the SGD Participant says: "monkey climbing"	Number of trained combinations (out of 4)
Production of ***untrained*** agent-action combinations	Generalization	Independent activation of both the agent and action icons on the SGD within 5s of one another as indicated by auditory output or spoken production of both the agent and the action within 5s of one another, or a combination of one spoken agent or action and one agent or action produced on the SGD.		Number of untrained combinations (out of 4)

Interobserver Agreement

Interobserver agreement (IOA) data were coded independently by the researcher from video recordings of baseline and intervention sessions using ProcoderDV^{DM} (Tapp, 2003). IOA data for agent-action combinations were measured for at least 33% of randomly selected sessions across participants and conditions (baseline, intervention, Tiers 1, 2, 3) using event recording to indicate when each agent-action opportunity occurred, and by assigning a code to classify the exact type of response (correct production of the agent-action combination, correct production of either the agent or action in isolation, production of an error, or a non-response). Percentage of agreement for agent-action combinations was based on point-by-point agreement and was calculated for each session by dividing the number of agreements over the number of agreements plus disagreements and multiplying by 100 (Ledford, Lane, & Gast, 2018).

Procedural Fidelity

Procedural Fidelity (PF) data were coded from video recordings of baseline and intervention sessions using ProcoderDV^{DM} (Tapp, 2003). PF data were coded by two coders independent of the procedures of the study for at least 33% of randomly selected sessions across conditions and participants. Interobserver agreement for PF data were calculated on 33% of randomly selected PF sessions. Event recording was used to tally the occurrence of specific procedural variables for each condition. Table 6 (below) provides operational definitions and examples for all PF variables for probe trials and instructional trials. Overall fidelity for each session was calculated by dividing the number of correctly implemented behaviors over the number of total behaviors and multiplying by 100 (Ledford, Lane, & Gast, 2018).

Coders were trained to measure PF in each condition (baseline agent-action probes, intervention agent-action probes, intervention instructional trials) prior to intervention by reviewing operational definitions and examples of each PF variable and coding a practice video with the primary researcher. After coding the practice video, the primary coder and the researcher independently coded practice videos. Discrepancy discussions were conducted after each practice video in which agreement was below 90% for any PF variable. During discrepancy discussions, the researcher met with the coder, reviewed the video, and discussed disagreements. Practice coding continued until the researcher and primary coder achieved 90% agreement across all PF variables on three consecutive practice videos for each condition. Probes for agent-action combinations conducted during baseline were identical to probes conducted during intervention; the same variables were measured for both conditions.

Table 6. *Procedural Fidelity Variables and Definitions by Condition*

Variable	Definition	Example
	Probe Trials	
Provides a task direction	The researcher models the agent acting out an action, provides the task direction, and waits 3 s for the child to produce a response.	The researcher puts the cat on the swing, pushes the swing, and says: “What do you see?”
Provides reinforcement for correct responses	The researcher provides behavior specific praise and edible, tangible, or social reinforcement within 3 s of correct child responses.	The researcher says: “Nice job telling me the cat is swinging” and blows bubbles for the child within 3s of the child activating both icons correctly on the SGD.
Does <u>not</u> provide a prompt after the task instruction	The researcher does not prompt the child to provide a response after providing the task direction.	The researcher says: “What do you see?”, and then <u>waits</u> for the child response. She <u>does not</u> provide a prompt to the child to produce a response (e.g., says: “the cat” and simultaneously gestures to (“cat”) on the SGD “is swinging” and simultaneously gestures to (“swinging”) on the SGD).
	Instructional trials	
Provides a task direction	The researcher provides the task direction.	The researcher says: “What do you see?”
Provides the correct controlling prompt	The researcher provides the gesture+verbal prompt**.**	The researcher says: “the cat” and simultaneously gestures to (“cat”) on the SGD “is swinging” and simultaneously gestures to (“swinging”) on the SGD.
Correct implementation of 0s time delay trials	The researcher provides the first prompt **immediately** after the task direction for the first <u>five trials</u> at the beginning of each session OR after the child produces <u>3 total errors</u> during 3s trials.	The researcher says: “the cat” and simultaneously gestures to (“cat”) on the SGD “is swinging” and simultaneously gestures to (“swinging”) **immediately (0 s)** after providing the task direction (“What do you see?”).
Correct implementation of 3s time delay trials	The researcher provides the first prompt **3 s** after the task direction after 5 correct trials with a 0 s delay. The researcher continues providing 3 s delay trials until the child makes three total errors.	The researcher says; “What do you see?”, and **waits 3 s**. If the child does not respond or provides an error, the researcher says: “the cat” and simultaneously gestures to (“cat”) on the SGD “is swinging” and simultaneously gestures to (“swinging”).
Correct implementation of error correction procedure	If the child produces an error after the researcher says: “What do you see?”, the researcher prompts the child to produce the correct answer.	The child presses “cat climbing” on the SGD and the researcher says: “the cat” and simultaneously gestures to (“cat”) on the SGD “is swinging” and simultaneously gestures to (“swinging”) on the SGD if the child provides an error.
Provides reinforcement for correct responses	The researcher provides behavior specific praise and reinforcement to the child for correct responses.	The researcher says “Yes, that’s right! the cat is swinging!” and provides a goldfish cracker 3 s after the child produces the correct response.

CHAPTER III

RESULTS

Data on instructional trials for all four participants are in Appendix D, Figures 11-14. Procedural variations for the measurement of trained and untrained combinations are described for each participant separately. Results for each participant are shown in Figures 5, 7, 8, and 9.

Participant 1

Intervention for agent-action combinations across the three submatrices was conducted using the DTT instructional format and the CTD prompting procedure. Results for the Participant 1 are presented in Figure 5 (below). Training data for instructional trials is provided in Appendix D, Figure 11. Although Participant 1 only completed Tier 1 (Submatrix A) of the multiple probe design, there was a variable, increasing trend for the production of trained agent-action combinations after additional discrimination training was provided with Participant 1 starting in session 17. The level of trained combinations approached criterion at the end of Tier 1; the level of untrained combinations remained low and variable throughout Tier 1.

Adaptations of measures and instructional procedures for Participant 1. During baseline for Tier 1, Participant l did not correctly produce any agent-action combinations. Upon the introduction of intervention, there was a small increase in the production of untrained combinations (from 0 to 1) during probe sessions, however, data were variable and low during the first 12 probe sessions in the intervention condition. Across the 12 probe sessions, Participant 1 produced a total of 5 untrained combinations.

Due to continued low and variable correct responding on the probes of untrained combinations, a more proximal measure of learning (probes of ***trained*** combinations) was added after probe session 12. Trained word combinations were defined as agent-action combinations that were learned to criterion during teaching sessions (correctly produced in isolation and discriminated and correctly produced when intermixed with another agent-action combination). For each measurement occasion, four agent-action combinations were selected randomly from the combinations that had been learned to criterion by that point. The logic for this change to a more proximal measure was to determine if the participant maintained combinations that had been directly taught to criterion in the interspersed probes, given that he was not consistently demonstrating generalization to untrained combinations. The probe of trained combinations was considered a measure of transfer and maintenance of correct responding during probe trials conducted with the same stimuli used during training.

Participant 1 correctly produced all 16 agent-action combinations in Tier 1 (Submatrix A) in isolation and in intermixed instructional trials by session 16; he did not meet mastery criterion for trained combination at this point. In session 17, additional discrimination training was conducted in the instructional sessions (indicated with an asterisk on Tier 1 in Figure 5). During discrimination training, the 16 agent-action combinations from Submatrix A that previously had been learned to criterion during instructional sessions were divided into four sets of four based on the order in which they were taught (see Appendix D; Figure 11). In the discrimination training, the DTT instructional format with the CTD prompting procedure was used to teach correct responding. Training to discriminate among the four agent-action combinations in the first set continued until the participant provided five consecutive independent correct answers. After this criterion was reached, the next set of four agent-action combinations was introduced and discrimination among the second four combinations continued until criterion was met. This was repeated until discrimination within all four sets of agent-action combinations was established. Discrimination of combinations across the four different sets was not trained.

Participant 1 frequently produced one component (either the noun agent or verb action) of the agent-action combination correctly during probes for trained agent-action combinations prior to the additional discrimination training, but he did not respond with correct the noun agent and verb action combinations at criterion levels. The rationale for additional discrimination training was that learning to discriminate the correct agent-action combination in a larger set of agent-action combinations would teach the participant to attend to both the agent and the action across trials (e.g., duck swinging, duck eating, cat eating, cat drinking). This discrimination was considered essential for forming the general rule about combining agents and actions and for generalization to untrained agent-action combinations. The additional discrimination training beginning in session 17 differed from the initial discrimination training in prior instruction sessions in which either the noun or the verb was varied but both agent and action did not change (e.g., duck swinging vs. duck eating; or cat swinging vs. duck swinging).

Participant 1 reached criterion for correct responding during discrimination training for all 16 agent-action combinations (four sets of four combinations) at the end of Tier 1 (corresponding to probe session 27). Participant 1's correct responding on probes of trained combination***s*** remained variable after additional discrimination training (see Figure 5 below), however, there was an increasing trend in the data path. Participant 1 approached criterion on probes of trained combinations by probe session 27; he identified 4 out of 4 combinations in session 26 and 2 out of 4 combinations in session 27.

Participant 1 did not correctly produce any untrained agent-action combinations during baseline probes for Tiers 2 and 3, indicating that he did not generalize production of agent-action combinations to unknown agent-action combinations across tiers. Intervention for Participant 1 began on March 13, 2018 and ended on July 27, 2018 and included a total of 58 teaching sessions and 27 probe sessions in Tier 1 (Submatrix A). At the beginning of August, Participant 1's family moved out of state and he was no longer available to participate in the study.

Adaptations for Participant 2. Data collection and intervention for Participant 2 had begun before the decision to change the proximal measure (maintenance of trained combinations) was made based on Participant 1's performance. Three procedural modifications were made for Participant 2. First, given a similar pattern of low and variable responding for untrained combinations in Tier 1 for Participant 2 (she identified two untrained combinations across 9 probe sessions), the proximal measure of ***trained*** combinations was added as the primary dependent variable for Participant 2 after session 9. Untrained combinations were measured every fourth probe sessions for trained combinations (in Tier 1) and in baseline for Tiers 2 and 3. Second, given the large number of teaching sessions required to achieve mastery of agent-action combinations for Participant 1, the language matrix for Participant 2 was reduced before intervention began. Submatrix A included nine agent-action combinations (3 agents x 3 actions) rather than 16 agent-action combinations (4 agents x 4 action matrix; Figure 6 below displays the adapted language matrix). Third, additional discrimination training was conducted for Participant 2 after she mastered the nine agent-action combinations in Tier 1 (Session 14) but before reaching criterion for trained combinations in the probe sessions. In this additional discrimination training, the first three agent-action combinations taught were intermixed in instructional trials until Participant 2 reached mastery criteria (five consecutive independent responses). The rationale for additional discrimination training was based on the increasing trend in trained combinations observed for Participant 1 when discrimination training was conducted with a larger set of agent-action combinations.

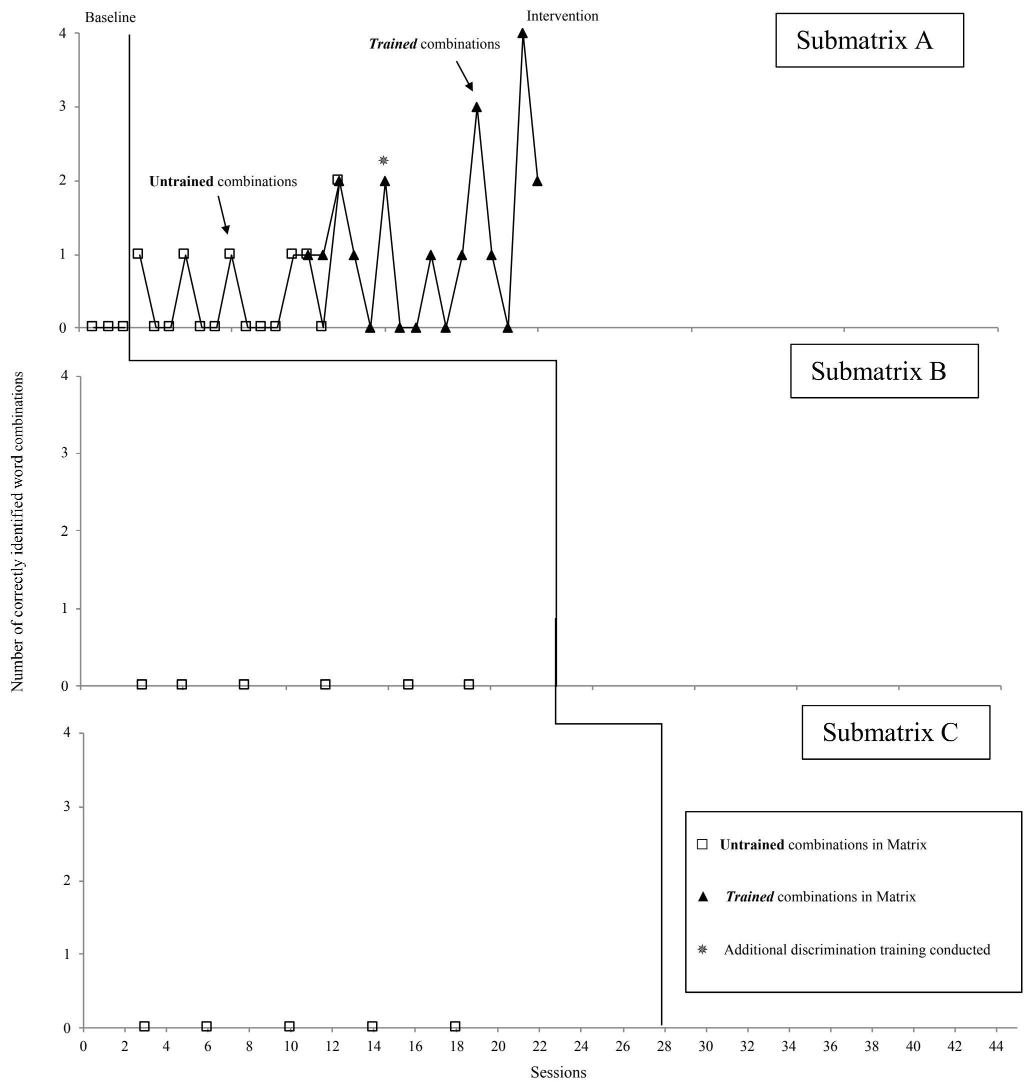

Figure 5. Participant 1's number of correct responses during probes of trained and untrained combinations

Participant 2

The procedure for teaching agent-action combinations for Participant 2 was conducted using the same DTT instructional format and the CTD prompting procedures used with Participant 1. Results for Participant 2 are shown in Figure 7 (below). Complete training data from instructional trials is in Appendix D, Figure 12. During intervention in Tier 1, Participant 2 demonstrated increases in the level of trained combinations after additional discrimination training was provided in session 14. There was an immediate increase in the level of trained combinations after intervention began in Tiers 2 and 3. The level of untrained combinations were low and variable in Tier 1 and high in both Tiers 2 and 3.

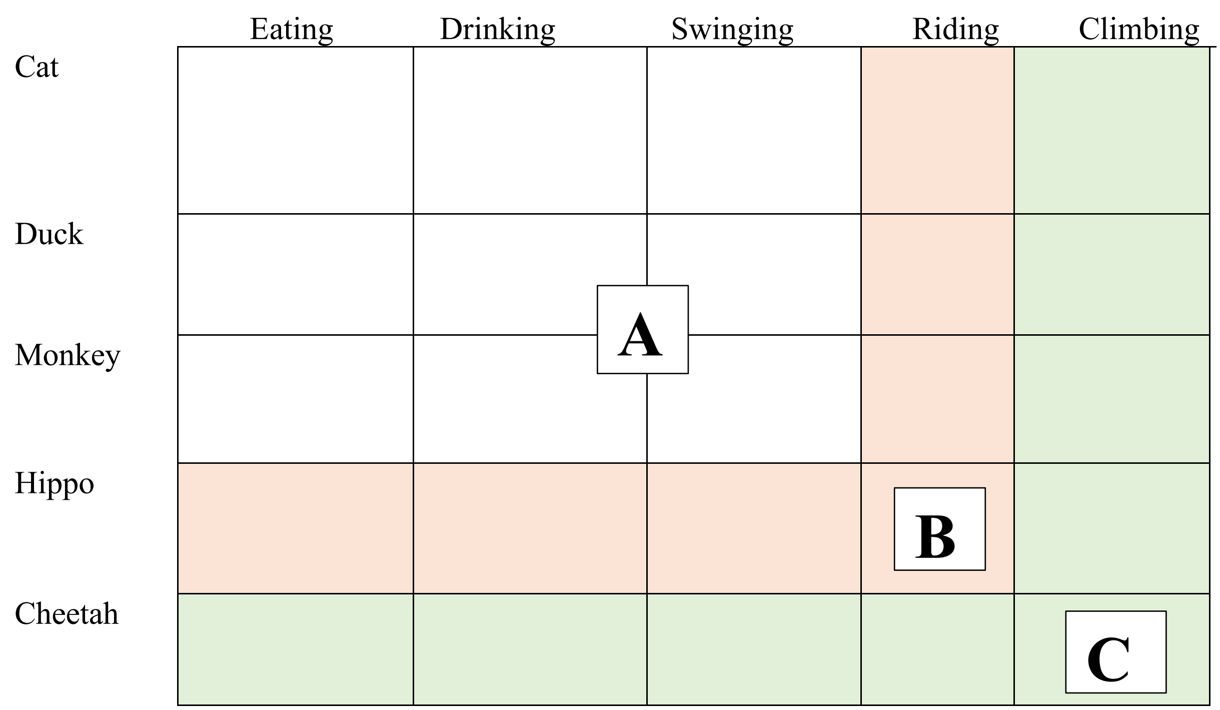

Figure 6. Modified language matrix for participant 2

In Tier 1, Participant 2 did not produce any untrained agent-action combinations during baseline probes. When intervention began in Tier 1 (Submatrix A), Participant 2 correctly responded with a total of two untrained agent-action combinations across nine probe sessions. After probes for trained combinations began in session 9, data remained low until session 12, when there was an increase in level (she produced 3 out of 4 combinations produced correctly). This shift in level maintained with some variability in the data path until session 14. At this point, Participant 2 mastered all nine Submatrix A agent-action combinations during instructional sessions, but had not reached criterion during probe sessions for trained agent-action combinations in Tier 1. Additional discrimination training was conducted after session 14 (noted with an asterisk on Tier 1 in Figure 7). Upon the introduction of additional discrimination training, there was an immediate increase in the level of trained combinations; she correctly produced all four trained agent-action combinations during sessions 16 and 17. She also produced 2 out 4 untrained combinations in session 15.

In baseline for Tier 2, Participant 2 did not produce any untrained combinations until probe session 5 in which she produced 2 out of 4 combinations correctly. During probe sessions 6 and 7 in Tier 2 (immediately prior to intervention), she did not produce any untrained combinations. There was an immediate increase in the level of trained combinations in probe sessions when intervention began in Tier 2 (Submatrix B). Participant 2 correctly produced all four trained combinations during the first three probe sessions in intervention for Tier 2. She also demonstrated generalization to untrained combinations by producing all four untrained combinations in session 4.

In baseline for Tier 3, Participant 2 did not produce any untrained combinations until session 7, when she produced 3 out of 4 combinations correctly. The level of untrained combinations remained relatively stable in baseline sessions 8 and 9. After intervention began in Tier 3 (Submatrix C), there was an immediate shift in the level of trained combinations during probe sessions. Participant 2 correctly produced all four trained combinations during three consecutive probe sessions and demonstrated generalization to untrained combinations by producing all four untrained combinations in session 4.

There was a clear functional relation between the introduction of intervention and increases in the production of trained agent-action combinations across the three tiers of intervention. Although the pattern of results was slightly different in Tier 1 than in Tiers 2 and 3, there was an immediate increase in the level of trained combinations after the additional discrimination training was conducted with the first three agent-action combinations in session 15. This pattern was replicated in Tiers 2 and 3. Participant 2 also identified untrained combinations at high levels in Tiers 2 and 3 as well during baseline probes in Tier 3, indicating that she had begun to learn the rule for combining agents and action together (*recombinative generalization*).

Participant 2 completed the multiple probe design across submatrices. Intervention for Participant 2 began on March 21, 2018 and ended on September 19, 2018 and included a total of 54 instructional sessions (50 in Tier 1; 2 each in Tiers 2 and 3) and 27 probe sessions. The length of calendar time required to complete the design was the result of school absences due to participant illnesses and limited availability for sessions during the summer because of the participant's mother's work schedule.

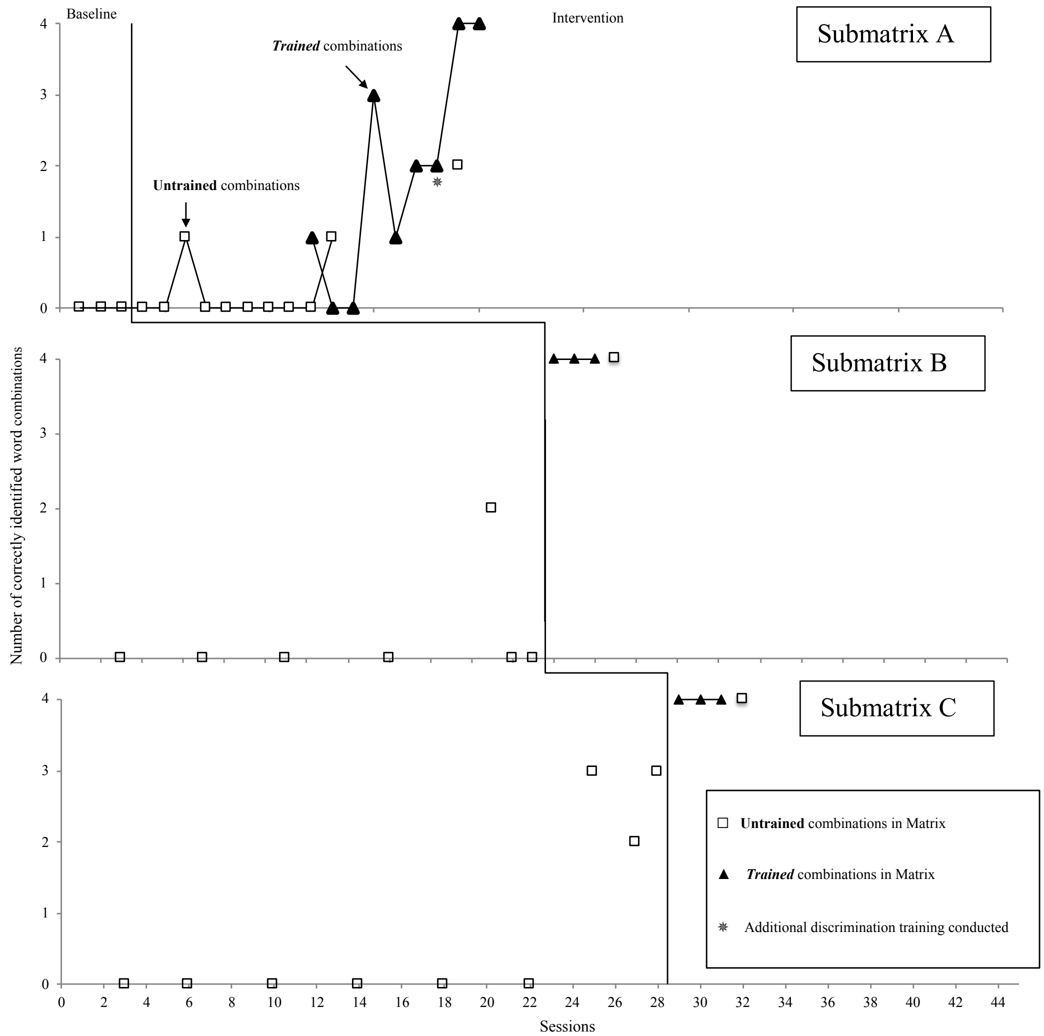

Figure 7. Participant 2's number of correct responses during probes of trained and untrained combinations

Adaptations for Participants 3 and 4. The language matrix used with Participants 3 and 4 was the modified 5 x 5 matrix used with Participant 2 (see Figure 6). Language sample assessments were added at the end of each tier after the participant met criterion for trained agent-action combinations. These were in addition to pre-and post-intervention LS to assess changes in agent-action combinations and multi-word utterances over time. The discrimination training procedures and probe measures of trained and untrained combinations were slightly adapted for Participants 3 and 4.

The primary dependent variable for Participants 3 and 4 was trained combinations (agent-action combinations that were previously learned to criterion during teaching sessions). The frequency of measurement for trained combinations was increased for these participants; probes of trained combinations were conducted during each teaching session (four probes per session) rather than every other teaching session; generalization to untrained combinations was measured every other teaching session.

Because of the immediate shift in the production of trained combinations for Participants 1 and 2 with the introduction of additional discrimination training in larger sets, discrimination training during intervention for the last two participants began concurrently with intervention; agent-action combinations were not taught in isolation. During intervention in Tier 1, three agent-action combinations were selected from Submatrix A (labeled 1, 2, and 3 in Submatrix A; see Figure 8 below) and intermixed in instructional trials until the participant reached criterion (five consecutive correct independent responses). Next, a fourth agent-action combination (labeled 4 in Submatrix A; see Figure 8 below) was added and all four combinations were intermixed in instructional trials. At this point, measurement for trained combinations was conducted with the three combinations that were mastered (a total of four probes for trained combinations were measured each session; one agent-action combination was randomly selected to be measured twice each session).

The same procedure for discrimination training used in Tier 1 was conducted in Tiers 2 and 3. The first three combinations targeted are indicated for Tier 2 (Submatrix B) and Tier 3 (Submatrix C) in Figure 8 by the numbers 1, 2, and 3. After the first three agent-action combinations met mastery criterion (five consecutive correct independent responses), the fourth combination in Tiers 2 and 3 was introduced and all four agent-action combinations were randomly intermixed. The fourth agent-action combination was chosen based on each participants' error patterns during training with the first three agent-action combinations.

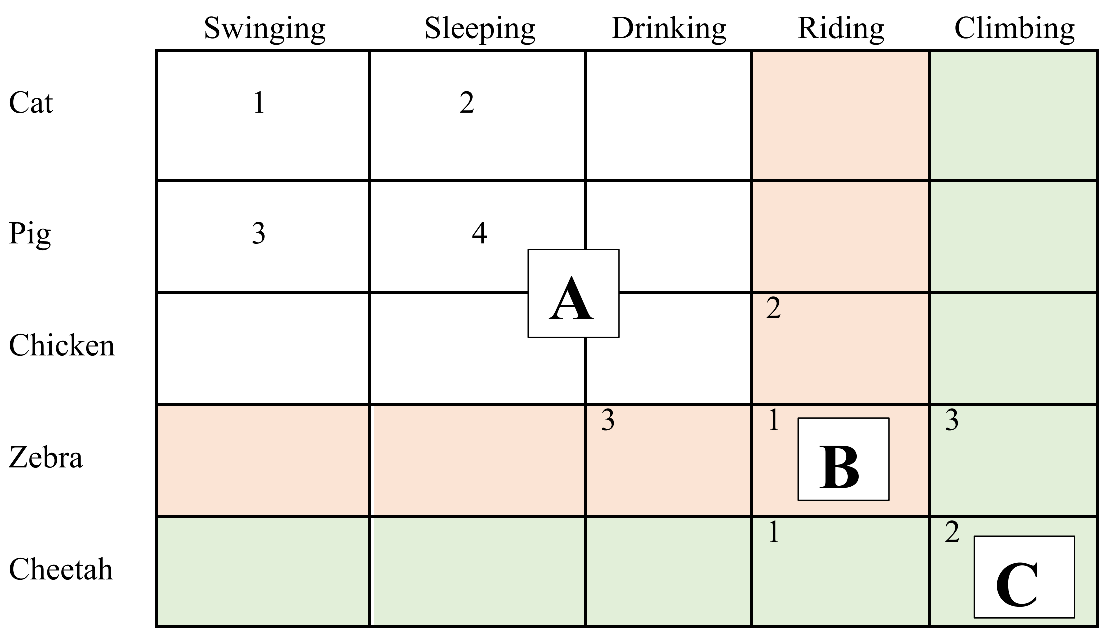

Figure 8. Adaptations to discrimination training procedure

Participant 3

Results for Participant 3 are provided in Figure 9. Complete training data is provided in Appendix D, Figure 13. Instructional trials for agent-action combinations across the three tiers of intervention were conducted using the same DTT instructional format with the constant time delay prompting procedure that was used for Participants 1 and 2. Participant 3 showed an increase in the level of trained combinations immediately after intervention began in Tiers 1, 2, and 3. The level of untrained combinations was low in Tier 1 and systematically increased across Tiers 2 and 3.

In Tier 1 (Submatrix A), Participant 3 did not produce any untrained combinations during baseline probes. After intervention began, a total of 10 teaching sessions were conducted before Participant 3 met criterion for the first three combinations in Submatrix A. Measurement began in Tier 1 after the first three combinations were mastered. After measurement began, there was an immediate increase in the level of trained combinations. Participant 3 reached criterion for trained combinations in Tier 1 in three consecutive sessions. She mastered a total of four agent-action combinations during instructional sessions in Tier 1 before reaching criterion for trained combinations. She did not produce any untrained combinations in session 2 and produced 1 out of 4 untrained combinations in session 4.

In baseline for Tier 2, Participant 3 did not produce any untrained combinations. After intervention began, five teaching sessions for Tier 2 combinations were conducted before she reached criterion for the first three combinations in Submatrix B. After the first three combinations were mastered and measurement for trained combinations began, there was an immediate increase in the level of trained combinations. Participant 3 reached criterion for trained combinations within three consecutive sessions. She mastered a total of four agent-action combinations in training in Tier 2. She produced 1 out 4 untrained combinations in session 2 and 2 out of 4 untrained combinations in session 4.

In baseline for Tier 3, Participant 3 did not produce any untrained combinations. After intervention began, a total of four teaching sessions were conducted before she reached criterion for the first three combinations in Tier 3. After the first three combinations were mastered and measurement for trained combinations began, there was an immediate increase in the level of trained combinations. Participant 3 reached criterion for trained combinations for Tier 3 in three consecutive sessions. She also reached criterion for untrained combinations (3 of 4 correct responses) in Sessions 2 and 4 in Tier 3.

There was a clear functional relation between the introduction of intervention and increases in the production of trained agent-action combinations from baseline to intervention replicated across the three tiers of intervention for Participant 3. Correct production of untrained combinations was low in Tier 1 but increased with each tier of intervention. In Tier 3, untrained combinations were produced at criterion level, indicating that *recombinative generalization* had occurred. Intervention for Participant 3 began on November 7, 2018 and ended on December 13, 2018 and included a total of 19 teaching sessions (10 in Tier 1; 5 in Tier 2; 4 in Tier 3); 9 of the 19 sessions included embedded probes.

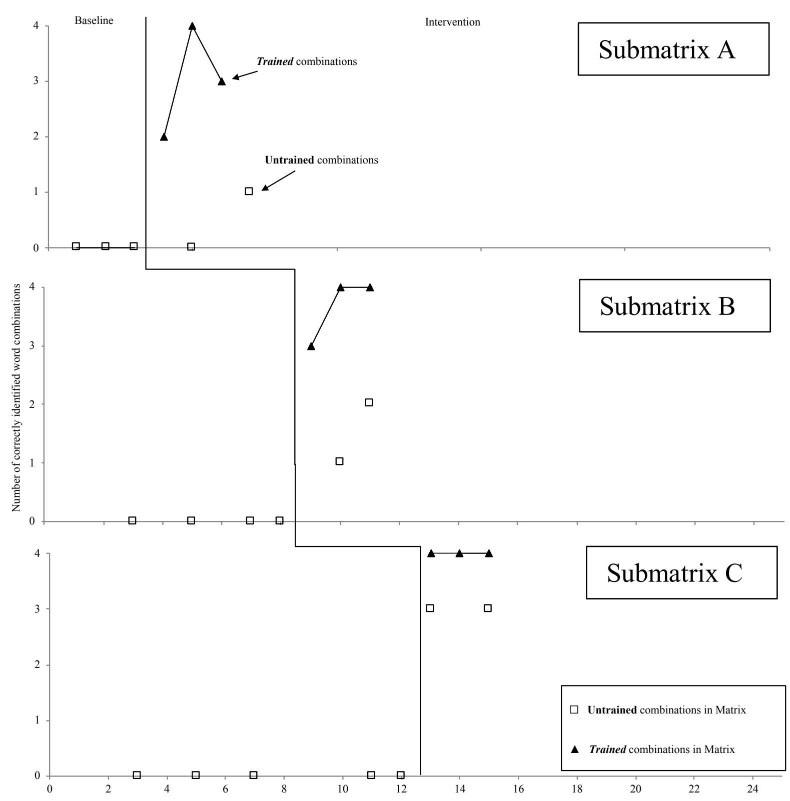

Figure 9. Participant 3's number of correct responses during probes of trained and untrained combinations

Participant 4

Instructional trials were conducted using the same DTT instructional format with the CTD prompting procedure that was used with Participants 1, 2, and 3. Results for Participant 4 are provided in Figure 10 below. Complete training data are provided in Appendix D, Figure 14. Participant 4 showed immediate increases in the production of trained agent-action combinations after intervention began in each Tier. He did not produce any untrained combinations in Tier 1, produced 1 untrained combination in Tier 2, and produced low levels of untrained combinations in Tier 3.

Participant 4 did not produce any untrained combinations during baseline probe sessions in Tier 1. After intervention began, a total of 27 instructional sessions were conducted before Participant 4 met criterion for the first three agent-action combinations in Tier 1. After the first three combinations were mastered, measurement began in interspersed probes and there was an immediate increase in the level of trained combinations. Participant 4 reached criterion for Tier 1 trained combinations in three consecutive sessions. He did not correctly produce any untrained combinations during probes in Tier 1.

In baseline for Tier 2, Participant 4 did not produce any untrained combinations. After intervention began, a total of 12 instructional sessions were conducted before Participant 4 met criterion for the first three agent-action combinations in Tier 2. After the first three combinations were mastered and measurement began, there was an immediate increase in the level of trained combinations. Participant 4 reached criterion for trained combinations in three consecutive sessions. He did not produce any untrained combinations in session 2, and he produced 2 of 4 untrained combinations in session 4.

Participant 4 did not produce any untrained combinations in sessions 1 and 2 in baseline for Tier 3. In session 3, he produced 1 out of 4 combinations, and in session 4 (measured immediately before intervention began in Tier 3) he did not produce any untrained combinations. After intervention began, a total of 10 instructional sessions were conducted before Participant 4 mastered the first three agent-action combinations in Tier 3. After mastering the first three combinations, measurement began in Tier 3; he met criterion for trained combinations in three consecutive sessions. He also identified 1 out of 4 untrained combinations in session 2 and 1 out of 4 untrained combinations in session 4.

There was a clear functional relation between the introduction of intervention and changes in the production of trained agent-action combinations for Participant 4. The level of trained combinations in Tiers 1, 2, and 3 increased immediately after he reached criterion in teaching sessions in each Tier. Participant 4 reached criterion for trained combinations in three consecutive probe sessions in each of the three tiers of intervention. Participant 4 did not produce any untrained combinations in Tier 1. He produced 2 out of 4 combinations in the second probe session for untrained combinations in Tier 2 and he produced 1 out 4 combinations in each of the two probe sessions for untrained combinations in Tier 3. Although small changes in the production of untrained combinations were observed, *recombinative generalization* was minimal for Participant 4. Intervention for Participant 4 began on November 6, 2018 and ended on February 28, 2019. Intervention for Participant 4 included a total of 52 instructional sessions (27 in Tier 1; 12 in Tier 2; 10 in Tier 3) with probes interspersed in 9 sessions.

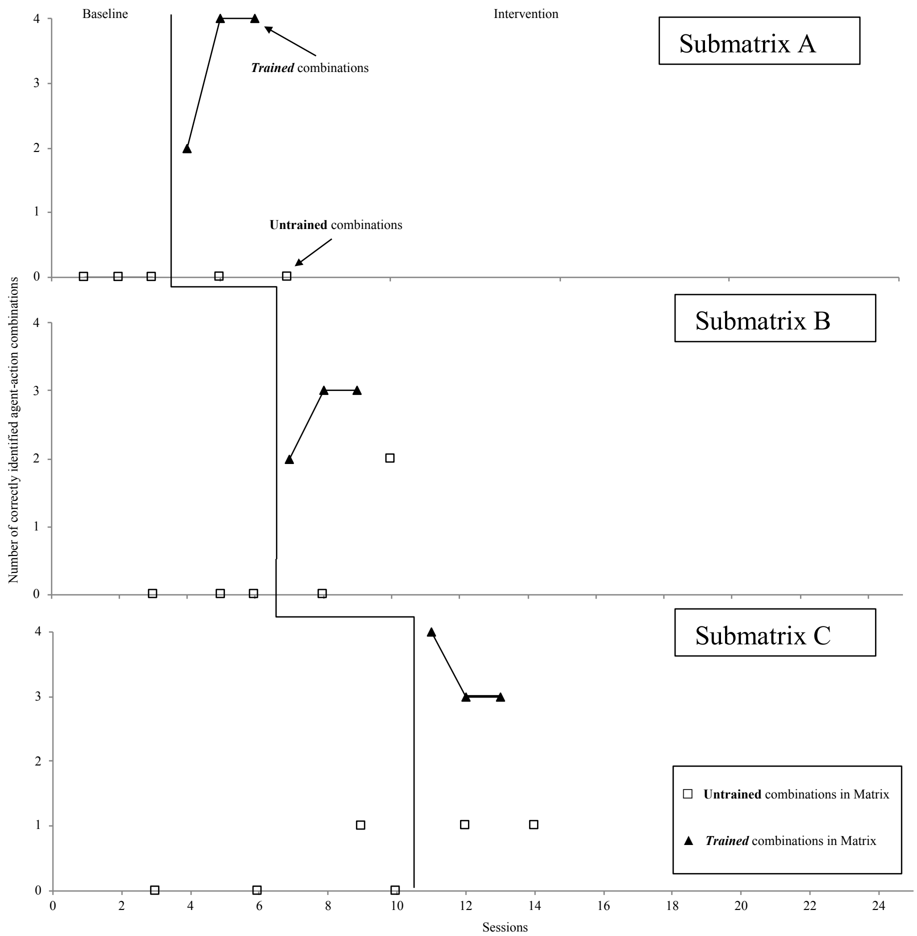

Figure 10. Participant 4's number of correct responses during probes of trained and untrained combinations

Pre- and Post-Intervention Assessments

Language samples were conducted for Participant 2 (pre-and post-intervention) and Participants 3 and 4 (pre-intervention and after Tiers 1, 2, and 3 [post-intervention]). These data are summarized in Table 7. Parents of all participants reported increased production of multi-word utterances on a questionnaire administered before and after intervention. Participant 1 was the only participant who increased his production of agent-action combinations post intervention according to parent report. He did not produce any agent-action combinations prior to intervention but produced three combinations after intervention ended. Participants 2, 3, and 4 also increased the overall percentage of consonants correctly produced from pre-to post-intervention on the PEEPS assessment.

Language Sample Results for Participants 3 and 4

Participants 3 and 4 both increased in the diversity (number of different words produced) and rate (unprompted utterances) of their communication throughout intervention as measured by language samples conducted after each participant met criteria for trained agent-action combinations at the end of each tier and pre-and post-intervention. Both participants also showed increases in their production of multi-word combinations across the study. Participant 3 showed increases in her production of agent-action combinations over time. Participant 4 did not produce any agent-action combinations during the LS at any point during intervention (LS data for Participants 3 and 4 are provided in Table 7).

Interobserver Agreement

IOA data on the coding of the dependent variables and PF data on the instructional and probe procedures were collected for at least 33% of sessions across all conditions and participants. The exact percentage of sessions in which IOA was measured and means and ranges for each participant are reported in Table 8. IOA was 100% for production of trained and untrained agent-action combinations during all measurement occasions in baseline and intervention conditions across all four participants.

Table 7. Language Sample and Pre-and Post-Intervention Assessment Results

	P1	P2	P3	P$
NDW (LS)	Pre: 15 Tier 1: -- Tier 2: -- Post: --	Pre: 28 Tier 1: -- Tier 2: -- Post: 67	Pre: 18 Tier 1: 41 Tier 2: 31 Post: 44	Pre: 27 Tier 1: 36 Tier 2: 31 Post: 52
Unprompted utterances (LS)	Pre: 46 Tier 1: -- Tier 2: -- Post: --	Pre: 40 Tier 1: -- Tier 2: -- Post:126	Pre: 24 Tier 1: 34 Tier 2: 33 Post: 54	Pre: 24 Tier 1: 44 Tier 2: 65 Post: 177
Agent-action combinations (LS)	Pre: 0 Tier 1: -- Tier 2: -- Post: --	Pre: 0 Tier 1: -- Tier 2: -- Post: 2	Pre: 0 Tier 1: 1 Tier 2: 0 Post: 13	Pre: 0 Tier 1: 0 Tier 2: 0 Post: 0
Multi-word combinations (LS)	Pre: 0 Tier 1: -- Tier 2: -- Post: --	Pre: 0 Tier 1: -- Tier 2: -- Post: 33	Pre: 6 Tier 1: 17 Tier 2: 11 Post: 23	Pre: 0 Tier 1: 5 Tier 2: 3 Post: 25
Agent-action combinations (parent questionnaire)	Pre: 0 Tier 1: -- Tier 2: -- Post: 3	Pre: 1 Tier 1: -- Tier 2: -- Post: 0	Pre: 0 Tier 1: -- Tier 2: -- Post: 0	Pre: 0 Tier 1: -- Tier 2: -- Post: --
Multi-word combinations (parent questionnaire)	Pre: 0 Post: --	Pre: 4 Post: 25	Pre: 11 Post: 22	Pre: 3 Post: --
PEEPS PCC (total consonants)	Pre: (46%) 19 --	Pre: (56.1%) 23 Post: (73.2%) 30	Pre: (68.3%) 28 Post: (90.2%) 37	Pre: (48.8%) 20 Post: (95.1%) 39

Note. Pre=pre-intervention. Post=post-intervention. LS=Language Sample. NDW=number of different words. PEEPS=Profiles of Early Expressive Phonological Skills. PCC=Percent Consonants Correct.

Procedural Fidelity

Table 10 indicates the exact percentage sessions in which PF and IOA for PF was measured for each participant for probe and instructional procedures across baseline and intervention conditions. PF for probe trials assessing production of trained and untrained agent-action combinations during baseline and intervention was 100% across all participants. Average PF measured for instructional trials during teaching sessions in the intervention condition was 98% (range 86-100%) for Participant 1, 98% for Participant 2 (range 88-100%), 96% for Participant 3 (86-100%), and 98% for Participant 4 (96-100%). Average IOA for PF data was 97% for Participant 1 (range 95-100%), 98% for Participant 2 (range 94-100%), 98% for Participant 3 (range 94-100%) and 96% for Participant 4 (range 90-100%).

Table 8. *Interobserver Agreement and Procedural Fidelity Data Means and Ranges*

Participant	P1	P2	P3	P4
		Interobserver Agreement		
Collected IOA (Baseline)	42.5%	34%	37%	42.3%
Agent-action combinations	100%	100%	100%	100%
Collected IOA (Intervention)	33.3%	33.3%	66.6%	77.7%
Agent-action combinations	100%	100%	100%	100%
		Procedural Fidelity		
Collected PF (Baseline)	33.3%	33.3%	33.3%	33.3%
Agent-action probes	100%	100%	100%	100%
Collected PF (Intervention)	35.7%	34%	36%	34%
Agent-action probes	100%	100%	100%	100%
Collected PF (Intervention)	34.5%	34.5%	37.5%	37%
Instructional trials	98% (86-100)	98% (88-100)	96% (86-100)	98% (96-100)
		IOA for Procedural Fidelity		
Collected PF (Baseline)	100%	100%	50%	50%
Agent-action probes	100%	100%	100%	100%
Collected PF (Intervention)	38.5%	40%	35%	33.3%
Agent-action probes	100%	100%	100%	100%
Collected PF (Intervention)	36.7%	38.5%	40%	40%
Instructional trials	97% (95-100)	98% (94-100)	98% (94-100)	96% (90-100)

Note. IOA=Interobserver agreement. PF=procedural fidelity. Means reported with ranges in parentheses.

CHAPTER IV

DISCUSSION

The purpose of this study was to examine the effects of language matrix training on the production of trained agent-action combinations and generalization to untrained agent-action combinations for young children with DS. Results from this study suggest that language-matrix training delivered using a DTT instructional format with a CTD prompting procedure and incorporating the use of an SGD as a response mode was an effective method for increasing the production of trained combinations for all four participants. Three of four participants completed three planned tiers of the multiple probe design. These three participants demonstrated modest and somewhat variable increases in the production of untrained combinations, suggesting that language matrix training may be an effective method for teaching young children with DS the rule for combination agents and actions together (*recombinative generalization*). Variability in the number of combinations trained before *recombinative generalization* was observed suggests that individual child characteristics and planned variations in teaching procedures may have affected generalization outcomes. The effects of systematic, iterative adjustments in instructional procedures on the outcomes for individual participants are discussed below.

Participant 1

The initial proposed primary dependent variable for Participant 1 was a measure of untrained combinations. The primary dependent variable was changed to more proximal measure of trained combinations due to continued low and variable responding on the measure of untrained combinations. Additional discrimination training was conducted to teach Participant 1 to attend to and discriminate between both components in agent-action combinations. Participant 1's production of agent-action combinations after adding a probe measure of trained combinations and additional discrimination training indicated that the language matrix training approach with systematic instructional strategies was effective for increasing production of trained combinations. The minimal evidence of generalization to untrained agent-action combinations suggested the need for further discrimination training to promote generalization.

Participant 2

Three modifications to the experimental design and instructional procedures were made for Participant 2. First, the size of the first language submatrix (Submatrix A) was reduced from 4 x 4 to 3 x 3. Second, the measure of trained agent-action combinations was added as the primary dependent variable in Tier 1; untrained combinations were measured less frequently (every fourth session) after this measure was added. Third, additional discrimination training was conducted with the first three agent-action combinations mastered after Participant 2 mastered these combinations in the instructional sessions but still did not reach criterion for production of trained combination in Tier 1.

Following these three modifications, Participant 2 met criterion for trained combinations in Tier 1; the level of untrained combinations also increased. Participant 2 produced 2 untrained combinations during baseline for Tier 2, and reached criterion for both trained and untrained combinations in three consecutive sessions after intervention was introduced. She produced a total of 8 untrained combinations during baseline for Tier 3, suggesting that *recombinative generalization* was emerging before instruction on additional combinations. Similarly to Tier 2, after intervention began, Participant 2 reached criterion for both trained and untrained combinations within three sessions. These results suggest the additional discrimination training in Tier 1 may have been the critical element that facilitated the emergence of untrained combinations during baseline in Tiers 2 and 3. It may have also contributed to Participant 2 meeting criterion for both trained and untrained combinations with minimal direct instruction training in Tiers 2 and 3.

Participants 3 and 4

All modifications for Participants 3 and 4 took place before baseline began in Tier 1 and were informed by iterative adaptions with Participants 1 and 2. Intervention for both participants was conducted with the smaller language matrix used with Participant 2 (Submatrix A was reduced from 4 x 4 to 3 x 3). Discrimination training was implemented concurrently for the first three agent-action combinations in each submatrix (combinations were never taught in isolation). Probe data collection for trained and untrained agent-action combinations was interspersed with instructional trials after the first three agent-action combinations were produced at criterion levels. Both Participants 3 and 4 reached criterion on trained combinations in each of the three tiers of intervention after four combinations were taught with discrimination training. Participant 3 did not produce any untrained combinations in baseline for Tiers 1, 2, or 3. The level of untrained combinations increased in each tier of intervention; she met mastery criterion for untrained combinations in Tier 3.

A similar pattern of results was observed for Participant 4 for trained combinations. Upon the introduction of intervention in each tier, there was an increase in level of trained combinations with a stable pattern of data. Participant 4 met criterion for trained combinations in three consecutive sessions in each tier. Participant 4 did not produce any untrained combinations in Tier 1. In Tier 2, he produced only 1 combination and in Tier 3 he produced a total of 2 combinations during two probes for untrained combinations. These results indicate that language matrix training was an effective method for increasing production of trained combinations for both Participants 3 and 4, but the procedures had somewhat variable effects on production of untrained combinations. The sources of variability between the two participants are not immediately apparent, however Participant 3 had a slightly higher expressive language age equivalent on the PLS-5 (30 months) than Participant 4 (27 months). Although neither participant produced agent-action combinations prior to intervention, Participant 3 produced more multi-word combinations (she produced 11 multi-word combinations per parent questionnaire and 6 multi-word combinations on the LS) prior intervention than Participant 4 (he produced 3 multi-word combinations per parent questionnaire and did not produce any multi-word combinations on the LS).

Across all participants, discrimination training appears to have been an essential instructional component for promoting generalization. Potentially teaching a smaller number of initial combinations and interspersing probes for trained and untrained combinations also contributed to more rapid generalization to untrained combinations for Participants 3 and 4. The specific number of agent-action combinations that must trained to criterion before *recombinative generalization* emerges may vary across children even when smaller submatrices, more discrimination training, and interspersed probes are implemented in the language matrix training protocol.

Implications for Practice

The pattern of results across participants emphasizes the importance of a multi-element intervention when teaching challenging language skills to young children with DS. The planned elements of the instructional procedure were selected based on evidence of the effectiveness of these components for teaching language to children with limited communication skills. These included: a) matrix organization of the training of agent-action combinations, b) systematic DTT instruction using CTD prompts, c) use of a programmed SGD as both a child response mode and modeling and error correction platform, d) modeling the stimulus for production of agent-action responses using concrete objects and observable actions. Further, iterative adaptations to instructional procedures were made based on participants' responses to the planned procedures and these adaptations are of particular clinical importance.

Teaching pre-requisite skills and structuring teaching sessions. Prior to teaching children with DS using a language matrix training approach, it is critical to teach or establish pre-requisite skills for learning efficiently in DTT instruction. These skills include: sitting, attending to the stimuli, and responding to prompts during instructional trials. It is important to structure the session to support motivation and responding and to set clear behavioral expectations. For example, the number of trials that individual children can complete before becoming frustrated with the task or engaging in challenging behavior may vary across children and may change from session to session over the course of the intervention. It is critical for the instructor to pay attention to the child's behavior to determine developmentally appropriate behavioral expectations for each session and to structure access to reinforcers to maintain optimal performance. It may be necessary to use a token economy system to indicate the number of responses required before the participant is able to take a short break from the instructional trials.

Young children with DS may engage in challenging behavior to escape or avoid tasks. Instructors should use antecedent modifications (token economy charts, environmental arrangements, frequent preference assessments, breaks contingent on appropriate behavior) to minimize the occurrence of challenging behavior. If challenging behavior does occur, it is important to identify and consistently use functionally appropriate consequences to minimize these behaviors over time. Finally, it may be important to teach the child how to respond to instructional trials by practicing with an easier expressive task (e.g., identifying agents or action in isolation) before teaching a more complex communication response (two-word combinations). Using both antecedent- and consequence-based strategies, teaching the child the format of the session, and providing pre-teaching with less challenging expressive skills may result in more efficient and rapid learning of agent-action combinations using a language matrix training approach.

Combining treatment approaches. The overall goal of speech, language, and communication intervention is to promote functional, spontaneous, linguistically diverse and increasingly complex language in naturally occurring environments and interactions over time (Schreibman et al., 2015). Language matrix training using DTT may contribute to this by providing foundational training for both specific language skills and learning related behaviors that improve responding in natural contexts. It is critical that DTT instructional procedures are paired with naturalistic teaching to transfer newly learned skills and behaviors to play, routine, or conversation-based interactions, to accelerate learning and use of language and communication skills, and to teach the use of these skills in the context of functional communication. Overall, effective DTT instruction paired with naturalistic instruction may be key to maximizing the effects of early language intervention with this population.

Incorporating augmentative modes into treatment. Incorporating an augmentative mode of communication into language matrix training for young children with DS may have a number of benefits. The unique learning-related difficulties (constraints on auditory working memory, resistance to directions provided by adults, limited speech intelligibility; Fidler et al., 2005; Kent & Vorperian, 2003) and difficulties learning and producing expressive language (Abbeduto et al., 2007) that characterize many children with DS suggest that instruction may be more effective using an AAC mode as a teaching support. An alternative mode may be especially important when a complex communication response is required (producing two-word combinations) and this response requires accessing both auditory memory and intelligible speech.

If the child has an existing AAC mode for communication, it is essential to teach production of more advanced early syntax skills through modeling and responding using the child's mode. If a child's primary mode of communication is speech, an AAC mode may still be an important instructional support. The function of the AAC may vary based on the characteristics of individual children with DS. For example, when children are highly unintelligible or do not respond consistently when asked to produce spoken language, an AAC provides an alternative non-speech response that can be prompted effectively when eliciting an oral verbal response is not possible. Thus, a prompting procedure, such as the CTD procedure used in this study, would generally not be as effective if used with a spoken mode because a controlling prompt is not possible in speech responses. Lower tech options such as picture cards that the child could combine on a sentence strip or manual signs could also be used. The support provided by alternative modes may be faded over time as speech articulation or responses to prompting improve and the individual requires less support to produce spoken word combinations.

The SGD used in this study was a unique AAC mode because it provided a visual symbol and written word as well as produced a phonologically consistent model when the child activated each icon. Although the exact role of the SGD in prompting *recombinative generalization* is not yet clear and may vary for each participant, it is possible that the SGD plays an important role in changing the overall intelligibility of speech sounds over time. In this study, Participants 2, 3, and 4 were able to produce more speech sounds following the language matrix training intervention as assessed by the PEEPS (Williams & Stoel-Gammon, 2014). This finding is similar to increases in productive language found with minimally verbal children with ASD when the intervention included an SGD (Kasari et al., 2014), suggesting that incorporating an SGD into an intervention may have long-term effects that affect overall spoken language abilities.

Discrimination training. Incorporating discrimination training early in a language matrix training approach to intervention may be essential to generalized responding. Production of trained combinations during probes improved for Participants 1 and 2 after discrimination training was conducted with a larger set of agent-action combinations. The results for Participants 3 and 4 further support this recommendation. Discrimination training was conducted with sets of three agent-action combinations and as each set was mastered, one new combination was intermixed with the previously mastered combinations to create a set of four. The contrast between the previous combinations taught with the addition of a new combination appeared to accelerate the generalization process for Participants 3 and 4. For example, the first three combinations that were taught to Participant 4 in Tier 3 were: “zebra riding”, “zebra climbing”, and “cheetah climbing.” When “cheetah riding” was introduced, contrast introduced in the intermixed instructional trials with previously mastered combinations may have cued the child to pay closer attention to <u>both</u> the agent and the action which, in turn, may have increased the overall efficiency of instruction (fewer combinations were needed to be directly taught before the child was able to produce untrained combinations because he was now attending both agents and actions). Additionally, the participant may have been more motivated to respond when probe trials were interspersed in the instructional session and these trials included agent-action combinations that he already knew and had been reinforced for producing in previous sessions.

Limitations

Although results from this study demonstrated the effectiveness of the language matrix training intervention, limitations of the study must be considered in the interpretations of these results. First, although the study was planned as four concurrent replications of a multiple probe design within participants, the study as implemented had several design limitations. The final design included three replications within individual participants and three replications across participants. Although most aspects of the instructional procedure were identical across Participants 2, 3 and 4 (i.e., DTT instruction, the CTD prompting procedure, and language matrix training using the reduced 5x5 matrix), the process of discrimination training differed for Participant 2 compared to Participants 3 and 4.

A second limitation was that the method for measuring trained combinations differed for Participant 2 because of the way agent-action combinations were systematically introduced and trained to criterion. Probes for trained combinations for Participant 2 were conducted with agent-action combinations that had been previously trained and mastered, but were no longer being directly taught during intervention. Probes for Participants 3 and 4 were conducted with agent-action combinations that had been mastered, but were still being taught (reinforced) in teaching sessions as new combinations were added. When the first set of three combinations was mastered, a new combination was added and the four combinations were intermixed across teaching trials; measurement of trained combinations was conducted with the three mastered combinations. It is possible that rapid response to the intervention for the final two participants might have been affected by the ongoing training with the agent-action combinations while they were being measured in the probes of trained combinations.

A third limitation is the amount of time between baseline measurement and measurement during intervention for Participants 3 and 4. After intervention began, measurement for each participant began only after the first three combinations were taught to criterion (5 consecutive independent responses) during the teaching phase in each tier. This was a relatively small number of sessions for Participant 3 (10 in Tier 1; 5 in Tier 2; 4 in Tier 3), but more sessions for Participant 4 (27 in Tier 1; 12 in Tier 2; 10 in Tier 3) because Participant 4 made slower progress during the instructional sessions. Given that baseline levels of responding remained low across the three tiers of intervention for both participants, it is unlikely that changes observed during intervention were the result of time or outside learning.

Finally, intervention for all four participants was conducted by the same researcher. It is possible that the results of this study would vary with a different implementer who was not as highly skilled and experienced. Finally, the language samples that were added at the end of each tier for Participants 3 and 4 were conducted by the researcher. Although questions related to the language samples was exploratory, these results would be clearer to interpret if the language samples had been completed by an assessor who was not involved in the intervention.

Future Directions

First, although the results for the three participants who completed the study are promising, it is essential that the procedures be replicated by researchers not involved in developing the protocol. It is especially important to replicate the procedures as implemented for Participants 3 and 4, which appeared to be relatively more effective. Future studies should explore components of the discrimination training process including the optimal number of combinations taught and the inclusion of previously mastered combinations as part of discrimination training when new combinations are added.

Second, the potential for the language matrix training intervention to leverage changes in the complexity of communication for children with DS language should be explored. Participants 3 and 4 demonstrated changes in their functional language during intervention and at post intervention. For both participants, the number of spontaneous multi-word combinations increased in the naturalistic language sample measured at the end of each tier. Additionally, parent reports post-intervention suggested that all four participants were producing two-word combinations functionally throughout the day and that participants were producing different types of two-word combinations (e.g., action-object: “brush teeth”, action-location: “go bath” and agent-action: “mommy drive”), unconventional combinations (e.g., “I teeth” meaning “I need to brush my teeth”). Parents of Participants 2 and 3 also reported changes in longer multi-word combinations (e.g., “I need to go potty”, “I don’t want to”). Although changes in the types of two-word combinations produced and overall complexity of communication varied across participants, there was some indication that generalized changes might have occurred for all four participants. Future studies of language matrix training should include more frequent and blinded measurement of generalization to conversational contexts to fully analyze generalization from training and to identify potential pivotal changes in language production. Given the importance of effective early language intervention for children with DS, determining how a language matrix training approach can be included in a comprehensive language intervention to support transition to syntax is critical.

Conclusions

Results of this study demonstrated that language matrix training can be effective for increasing productions of trained and untrained agent-action combinations in young children with DS. These results suggest that children with DS can acquire underlying rules for combining words (*recombinative generalization).* Findings from this study replicate previous research indicating that language matrix training is an effective method for teaching two-word combinations (action-object, object-location) to children with developmental and intellectual delays using spoken modes (Ezell & Goldstein, 1989; Goldstein & Brown, 1987; Goldstein & Mousetis, 1989; Mineo & Goldstein, 1990) and AAC modes (Light, et al., 1990; Naoi, et al., 2006). This study extends previous research by focusing on agent-action combinations as a gateway to early syntactic development, including young children with DS with robust vocabularies who are ready to learn these combinations, and incorporating an SGD as an augmentative teaching support. Results from this study also suggest that learning from DTT procedures in a structured environment can result in generalization to a more natural communication context, but further evidence supporting these findings is needed. Teaching a core set of two-word combinations using a language matrix training approach resulted in production of novel two-word combinations and possibly may facilitate production of different types of two-word combinations without directly teaching these skills. Future replication studies should focus on identifying optimal discrimination training techniques, incorporating familiar implementers (e.g. parents, teachers), and include more frequent measurement of language use in naturalistic and functional contexts.

References

Abbeduto, L., Warren, S. F., & Conners, F. A. (2007). Language development in Down syndrome from the prelinguistic period to the acquisition of literacy. *Mental Retardation and Developmental Disabilities Research Reviews, 13*, 247-261.

Adamson, L. B., Bakeman, R., Deckner, D. F., & Romski, M. (2009). Joint engagement and the emergence of language in children with autism and Down syndrome. *Journal of Autism and Developmental Disorders*, *39*, 84–96.

Adamson, L. B., Chance, S. E., Wetherby, A., Warren, S., & Reichle, J. (1998). Coordinating attention to people, objects, and language. *Transitions in prelinguistic communication*, *7*, 15-37.

Ayres, K., & Ledford, J. R. (2014). Dependent measures and measurement systems. *Single case research methodology: Applications in special education and behavioral sciences*, 124-153.

Bauer, S. M., & Jones, E. A. (2015). Requesting and verbal imitation intervention for infants with Down syndrome: generalization, intelligibility, and problem solving. *Journal of Developmental and Physical Disabilities*, *27*, 37–66.

Bauer, S. M., Jones, E. A., & Feeley, K. M. (2014). Teaching responses to questions to young children with Down syndrome. *Behavioral Interventions*, *29*, 36–49.

Berglund, E., Eriksson, M., & Johansson, I. (2001). Parental reports of spoken language skills in children with Down syndrome. *Journal of Speech, Language, and Hearing Research*, *44*, 179–191.

Byrne, A., Buckley, S., MacDonald, J., & Bird, G. (1995). Investigating the literacy, language and memory skills of children with Down syndrome. *Down Syndrome Research and Practice*, *3*, 53-58.

Camarata, S., Yoder, P., & Camarata, M. (2006). Simultaneous treatment of grammatical and speech-comprehensibility deficits in children with Down syndrome. *Down Syndrome Research and Practice, 11*, 9-17.

Carlesimo, G. A., Marotta, L., & Vicari, S. (1997). Long-term memory in mental retardation: evidence for a specific impairment in subjects with Down's syndrome. *Neuropsychologia*, *35*, 71-79.

Chapman, R. S., Schwartz, S. E., & Bird, E. K. R. (1991). Language skills of children and adolescents with Down syndrome: I. Comprehension. *Journal of Speech, Language, and Hearing Research*, *34*, 1106-1120.

DeLeon, I. G., & Iwata, B. A. (1996). Evaluation of a multiple-stimulus presentation format for assessing reinforce preferences. *Journal of Applied Behavior Analysis*, *29*, 519-533.

Dunst, C. J. (1998). Sensorimotor development and developmental disabilities. *Handbook of mental retardation and development*, 135-182.

Eadie, P. A., Fey, M. E., Douglas, J. M., & Parsons, C. L. (2002). Profiles of grammatical morphology and sentence imitation in children with specific language impairment and Down syndrome. *Journal of Speech, Language, and Hearing Research*, *45*, 720.

Feeley, K. M., Jones, E. A., Blackburn, C., & Bauer, S. (2011). Advancing imitation and requesting skills in toddlers with Down syndrome. *Research in Developmental Disabilities*, *32*, 2415–2430.

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., & Reznick, J. S. (2014). *MacArthur-Bates Communicative Development Inventories: user's guide and technical manual*. PB Brookes.

Fey, M., Warren, S. F., Brady, N., Bredin-Oja, S., Fairchild, M., Sokol, S., & Yoder, P. (2006). Early effects of responsivity education/prelinguistic milieu teaching. *Journal of Speech, Language, and Hearing Research, 49*, 526-547.

Fidler, D. J. (2005). The emerging Down syndrome behavioral phenotype in early childhood: Implications for practice. *Infants & Young Children*, *18*, 86–103.

Fidler, D. J. (2006). The emergence of a syndrome-specific personality profile in young children with Down syndrome. *Down syndrome: Neurobehavioral specificity*, 139-152.

Fidler, D. J., Hepburn, S. L., Mankin, G., & Rogers, S. J. (2005). Praxis skills in young children with Down syndrome, other developmental disabilities, and typically developing children. *American Journal of Occupational Therapy*, *59*, 129-138.

Gast, D. L., Lloyd, B. P., & Ledford, J. R. (2018). Multiple baseline and multiple probe designs. In *Single case research methodology* (pp. 239-281). Routledge.

Ledford, J.R., Lane, J.D., & Gast, D.L. (2018). Dependent variables, measurement, & reliability. *Single case research methodology* (pp. 97-132). Routledge.

Gibbs, M. V., & Thorpe, J. G. (1983). Personality stereotype of noninstitutionalized Down syndrome children. *American Journal of Mental Deficiency*.

Goldstein, H., Angelo, D., & Mousetis, L. (1987). Acquisition and extension of syntactic repertoires by severely mentally retarded youth. *Research in developmental disabilities*, *8*, 549-574.

Goldstein, H. (1983). Recombinative generalization: Relationships between environmental conditions and the linguistic repertoires of language learners. *Analysis and Intervention in Developmental Disabilities*, *3*, 279-293.

Goldstein, H. (1985). Enhancing language generalization using matrix and stimulus equivalence training. In S. Warren & A. Rogers-Warren (Eds.), Teaching functional language (pp. 225- 249). Baltimore, MD: University Park Press.

Hodapp, R.M., & DesJardin, J. L. (2002). Genetic etiologies of mental retardation: Issues for interventions and interventionists. *Journal of Devlopmental and Physical Disabilities, 14,* 323-338.

Hodapp, R. M., Leckman, J. F., Dykens, E. M., Sparrow, S. S., Zelinsky, D. G., & Ort, S. I. (1992). K-ABC profiles in children with fragile X syndrome, Down syndrome, and nonspecific mental retardation. *American Journal on Mental Retardation*.

Hodapp, R. M., & Ly, T. M. (2003). Visual processing strengths in Down syndrome: a case for reading instruction. *Visual information processing*, 155-169.

Iverson, J. M., Longobardi, E., & Caselli, M. C. (2003). Relationship between gestures and words in children with Down's syndrome and typically developing children in the early stages of communicative development. *International Journal of Language & Communication Disorders*, *38*, 179–197.

Jarrold, C., Baddeley, A. D., & Hewes, A. K. (1999). Genetically dissociated components of working memory: evidence from Downs and Williams syndrome. *Neuropsychologia*, *37*, 637-651.

Kaiser, A. P. & Roberts, M. Y. (2013). Parent-implemented Enhanced Milieu Teaching with preschool children with intellectual disabilities. *Journal of Speech, Language, and Hearing Research, 56,* 295-309.

Kasari, C., & Freeman, S. F. (2001). Task-related social behavior in children with Down syndrome. *American Journal on Mental Retardation*, *106*, 253–264.

Kasari, C., Kaiser, A., Goods, K., Nietfeld, J., Mathy, P., Landa, R., … Almirall, D. (2014). Communication interventions for minimally verbal children with autism: a sequential multiple assignment randomized trial. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*, 635–646.

Kent, R. D., Vorperian, H. K., Kent, J. F., & Duffy, J. R. (2003). Voice dysfunction in dysarthria: application of the Multi-Dimensional Voice Program™. *Journal of communication Disorders*, *36*, 281-306.

Light, P., Watson, J., & Remington, B. (1990). Beyond the single sign: the significance of sign order in a matrix-based approach to teaching productive sign combinations. *Mental Handicap Research*, *3*, 161-178.

Miller, J. F., Leavitt, L. A., & Leddy, M. G. (Eds.). (1999). *Improving the communication of people with Down syndrome*. Paul H. Brookes Pub.

Miller, J. F., Sedey, A. L., & Miolo, G. (1995). Validity of parent report measures of vocabulary development for children with Down syndrome. *Journal of Speech, Language, and Hearing Research*, *38*, 1037-1044.

Mineo, B. A., & Goldstein, H. (1990). Generalized learning of Receptive and Expressive action-object responses by language-delayed. *Journal of Speech and Hearing Disorders*, *55*, 665-678.

Naoi, N., Yokoyama, K., & Yamamoto, J. (2006). Matrix training for expressive and receptive two-word utterances in children with autism. Japanese Journal of Special Education, 43, 505-518.

Odom, S. L., Collet-Klingenberg, L., Rogers, S. J., & Hatton, D. D. (2010). Evidence-based practices in interventions for children and youth with autism spectrum disorders. *Preventing school failure: Alternative education for children and youth*, *54*, 275-282.

Ohr, P. S., & Fagen, J. W. (1994). Contingency learning in 9-month-old infants with Down syndrome. *American Journal on Mental Retardation*.

Pitcairn, T. K., & Wishart, J. G. (1994). Reactions of young children with Down's syndrome to an impossible task. *British Journal of Developmental Psychology*, *12*, 485-489.

Remington, B., Watson, J., & Light, P. (1990). Beyond the single sign: A matrix-based approach to teaching productive sign combinations. *Mental Handicap Research*, *3*, 33-50.

Rodgers, C. (1987). Maternal support for the Down's syndrome stereotype: The effect of direct experience of the condition. *Journal of Intellectual Disability Research*, *31*, 271-278.

Rosner, B. A., Hodapp, R. M., Fidler, D. J., Sagun, J. N., & Dykens, E. M. (2004). Social competence in persons with Prader-Willi, Williams and Down's Syndromes. *Journal of Applied Research in Intellectual Disabilities*, *17*, 209-217.

Rogers, S. J., & Vismara, L. A. (2008). Evidence-based comprehensive treatments for early autism. *Journal of Clinical Child & Adolescent Psychology*, *37*, 8-38.

Ruskin, E. M., Mundy, P., Kasari, C., & Sigman, M. (1994). Object mastery motivation of children with Down syndrome. *American Journal on Mental Retardation*.

Schreibman, L., Dawson, G., Stahmer, A. C., Landa, R., Rogers, S. J., McGee, G. G., ... & McNerney, E. (2015). Naturalistic developmental behavioral interventions: Empirically validated treatments for autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *45*, 2411-2428.

Schroeder, C. M., Schuster, J. W., & Hemmeter, M. L. (1998). Efficiency in programming for generalization: Comparison of two methods for teaching expressive labeling to preschoolers with developmental delays. *Journal of Developmental and Physical Disabilities*, *10*, 109–131.

Sigman, M., Ruskin, E., Arbelle, S., Corona, R., Dissanayake, C., Espinosa, M., ... & Robinson, B. F. (1999). Continuity and change in the social competence of children with autism, Down syndrome, and developmental delays. *Monographs of the society for research in child development*, i-139.

Slonims, V., McConachie, H., & Abbeduto, L. (2006). Analysis of mother-infant interaction in infants with Down syndrome and typically developing infants. *American Journal on Mental Retardation*, *111*, 273–289.

Smith, T. (2001). Discrete trial training in the treatment of autism. *Focus on Autism and Other Developmental Disabilities*, *16*, 86–92.

Sokol, S. B., & Fey, M. E. (2013). Consonant and syllable complexity of toddlers with Down syndrome and mixed-aetiology developmental delays. *International Journal of Speech-Language Pathology*, *15*, 575–585.

Stoel-Gammon, C. (2001). Down syndrome phonology: Developmental patterns and intervention strategies. *Down Syndrome Research and Practice*, *7*, 93–100.

Striefel, S., Wetherby, B., & Karlan, G. (1978). Developing generalized instruction-following behavior in severely retarded people. *Monograph of the American Association of Mental Deficiency*, 267-326.

Thiemann-Bourque, K. S., Brady, N. C., & Fleming, K. K. (2012). Iconic Play of Preschoolers with Severe Communication Impairments with Autism and Other Developmental Delays: More Similarities than Differences. *Journal of Autism and Developmental Disorders*, *42*, 863–873. http://doi.org/10.1007/s10803-011-1317-7

Uzgiris, I. C., & Hunt, J. (1979). McV. (1975). *Assessment in infancy: Ordinal scales of psychological development*.

Warren, S. F., Fey, M. E., Finestack, L. H., Brady, N. C., Bredin-Oja, S., & Fleming, K. K. (2008). A randomized trial of longitudinal effects of low-intensity responsivity education/Prelinguistic milieu teaching. *Journal of Speech, Language, and Hearing Research, 51*, 451-70.

Wetherby, B., & Striefel, S. (1978). Application of miniature linguistic system or matrix training procedures. *Language intervention strategies*, 319-356.

Windsor, K., Roberts, M. Y., & Kaiser, A. (2012, February). The effects of Enhanced Milieu Teaching on children with Down syndrome. Poster presented at the Conference on Research Innovations in Early Intervention, San Diego.

Windsor, K., & Kaiser, A. P. (2015, November). Systematic review of language & communication interventions in children with Down syndrome. Poster presented at the American Speech-Language-Hearing Association Annual Convention, Denver, Colorado.

Wishart, J. G., & Bower, T. G. (1984). Spatial relations and the object concept: A normative study. *Advances in infancy research*.

Wishart, J. G., & Johnston, F. H. (1990). The effects of experience on attribution of a stereotyped personality to children with Down's syndrome. *Journal of Intellectual Disability Research*, *34*, 409-420.

Wolery, M., Ault, M. J., & Doyle, P. M. (1992). *Teaching students with moderate to severe disabilities: Use of response prompting strategies*. Longman Publishing Group.

Wright, C., Kaiser, A., Reikowsky, D., & Roberts, M. (2013). Effects of a naturalistic sign intervention on expressive language of toddlers with Down syndrome. *Journal of Speech, Language, and Hearing Research, 56,* 994-1008.

Yoder, P., Woynaroski, T., Fey, M., & Warren, S. (2014). Effects of dose frequency of early communication intervention in young children with and without Down syndrome. *American Journal on Intellectual and Developmental Disabilities*, *119*, 17-32.

Yoder, P. J., & Warren, S. F. (1998). Maternal responsivity predicts the pre-linguistic communication intervention that facilitates generalized intentional communication. *Journal of Speech, Language, and Hearing Research*, *41*, 1207-121

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2011). Preschool Language Scales–Fifth Edition (PLS-5). *Bloomington, MN: Pearson. Find this author on*.

Appendix A
Parent Questionnaire for Word Combinations

Below are some examples of types of word combinations that children begin to say together after they have learned to say several words on their own.

Here are some examples of some types of common early combinations:
("mommy drink", "baby sleep", "mommy book", "my toy", "eat pizza", "kick ball", "daddy chair", "mommy purse", "big car", "brown horse", "more milk", "no milk", "hi mommy")

Please list any words that your child says together below:

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____
11. ____
12. ____
13. ____
14. ____
15. ____

Appendix B
Language Sample Protocol

A language sample is a naturalistic adult-child interaction with a specific set of toys to evaluate a child's spontaneous expressive language ability.

Purpose:

1. A language sample accurately captures a child's initiated, unprompted language using a 20-minute language sample.
2. A language sample avoids language-rich verbs and labels that may not occur in the child's natural environment but provides a fun, responsive and engaging environment.
3. The language sample has a standard format so that all children get the same number of supports (Time Delay, Open-ended questions, and Test questions) and a minimum amount of verbal statements (2 per minute) from the adult.
4. The spontaneous use of the IPad during this assessment is important. The therapist should make a statement to the child before the session to set up the expectation as well as model once per toy set.

Materials:
There are 6 toys sets that comprise the language sample: 1. Tea set with babies, 2. Grooming with babies 3. Barn, animals, blocks, 4. Cars with ramp, 5. Dolls with table, chairs, and bed, 5. "Where's Spot" book.

Getting Started Procedures:

1. Have all 6 toy sets available in the room.
   a. Set up toy sets so that they are all in the child's line of sight, but contained to maintain room organization and environmental control
   b. Move through the toy sets playing with each one individually as much as possible, cleaning up a set when you are done with is as much as you can and introducing new sets periodically.
2. Set a timer for **20 minutes**. The timer makes sure we get a 20-minute sample, and can also be referenced to watch your pacing through toy sets.

Communication

3. Be at the child's eye level and in close proximity to the child.
4. Use a warm, positive tone of voice, smile, and engage with the child.
5. Engage with the child and toys.
   a. Imitate the child's play acts.
   b. Introduce at least new play acts
   c. Play with the child naturally, and be as engaging as possible
   d. Encourage the child and praise them for engaging and playing.
6. **Respond to all child communication** (gesture, vocalization, words):
   a. Imitate the child's words
      i. When imitating a word, use a "comment-like" tone rather than a questioning tone (i.e. "train" rather than "train?").

   Note: transcribers use assessor imitations to verify things the child says, so only repeat what you hear.

   a. If the child continues to talk, let the child talk – do not cut the child off mid-statement. Repeat what you remember from the long utterance only. **Do not add in words you think you might have heard**.
   b. Acknowledge nonverbal communication with sounds (e.g., "mhm," "yeah," "uh-huh") but refrain from making too many silly noises (oop! Vroom, numnumnum (eating noise) that the child might begin to over use)
   c. If the child asks a question, respond with a nonverbal gesture (i.e. point or show). If you are not able to answer nonverbally, then use a brief, positive response (i.e., "I don't know"). If a child asks "what is this?" do not label the object.

2. **Do not** introduce any new content-specific language. You can say things like "this is so fun" "oh wow" and "I like that" or "good job" to praise the child, but never label an object or action you are doing, e.g. "I like this car" or "he's sliding".

Play

3. Let the child choose which toy set he/she wants to play with, and move through all toy sets, playing with each for 3-4 minutes.
   a. If the child **does not** choose a toy set:
      i. pick a toy set, introduce it and begin to play with it
      ii. hand the child part of the toy to play with
      iii. hold up two toys for the child to choose from (remember this is a Time Delay – see below)
      iv. encourage the child to sit and interact with a toy
      v. move the child to the table and help them begin to play
      vi. remove a distracting toy from the room
   b. If the child **chooses** a toy set:
      i. Introduce the toy set with the open-ended question listed
      ii. Engage in play with the child
      iii. Model new play acts as well as imitating what the child is doing
      iv. Praise the child for playing and engaging, ex: "good idea!"
4. The adult must attempt to have the child interact with all of the toy sets:
   a. High priority / preferred toys may be cleaned up and put back in the Language Sample bag/box to help the child move on to a different toy set.
   b. If removing a toy or moving to different toy set causes behavior issues, you may include the toy moving forward, but continue to try to remove and replace it if you can.
   c. Discontinue playing with a toy set if the child loses interest and present a different toy set, but try to play with each toy set for 3-4 minutes to maintain good pacing across all sets
   d. If the child loses interest in the toy sets quickly, some of the toy sets may need to be re-introduced to make it through the 20 minute session.

Things you must do during each toy set

5. Model 4-5 agent-action play actions within the 20-min sample to elicit communication; use least to most prompting to help the child produce a response.
   For each action:
   a. Model action and wait 3s

i. If the child produces the correct response, reinforce and acknowledge with specific praise
ii. If the child produces an incorrect response, or does not respond move to step b)

b. Model action, wait 3s, and say "What do you see?
    i. If the child produces the correct response, reinforce and acknowledge with specific praise
    ii. If the child produces an incorrect response, or does not respond move to step c)
c. Model action and provide a spoken+gesture model for both the agent and action symbols on SGD (e.g., verbally say: "the dog is sitting" and pressed the "dog" and "sitting" symbols on the SGD)

2. **Model at least 2 new play acts per toy set.** If the child will not engage with all of the toy sets, model extra play acts with the toys that the child will use. Otherwise, play with the child naturally.
3. The adult must make at least two statements per minute (one every 30 sec) to maintain engagement. This rate includes the adult's Open-ended, Comments, and Responses to the child's communication. Behavioral or Transition statements do NOT count toward this total. There should never be more than 30 seconds of silence.
    a. Since there are a lot of built in opportunities, this will only occur when you have completed your open questions, comments, and the child is silent for the 30 seconds.
    b. When making these statements:
        i. Use non-specific words you have heard the child use during the Language Sample and limit introducing new vocabulary (e.g. it/that/ those instead of nouns): "wow, look what you did with that!" "That looks like so much fun!" "it went all the way over there"
        ii. Don't finish a statement with a content word that is likely to be imitated/the child has used spontaneously earlier.

Appendix C
Primary Coding Manual

Agent-action combinations

- To count as an agent-action combination, the noun (agent) and the verb (action) must be produced (spoken, AAC) within 5 s of one another.

For each occurrence of an agent-action probe trial:

- The adult should provide the task instruction (What do you see?) OR
- The child initiates an answer before the adult says: “What do you see?” **AND** the adult has begun acting out the action with both the noun (e.g., cat toy) and verb toy (e.g., swing) stimuli placed directly in front of the child.

Spoken combination: Child clearly says both words of combination (e.g., says “cat swinging”) within 5 s of one another.

SGD combination: Child activates both icons on SGD (e.g., presses “cat” and presses “swinging”) within 5 s of each other.

- For any answer provided on the SGD, the child can press an incorrect icon on the SGD and self-correct, but he/she has to end on the correct answer (e.g., presses “elephant”, then presses “cat swinging” for “cat swinging”)
    - She/he **CAN** activate incorrect icon/s between two correct icons as long as she finishes with the correct icon and they are activated within 5s of each other
        - (e.g., presses “cat jumping” then presses “swinging” for “cat swinging”)
    - She/he **CAN** press the icons in the wrong order as long as she presses them within 5s of each other (e.g., presses “swinging cat” for “cat swinging”)
    - She/he **CANNOT** press the correct answer and then press an incorrect answer
        - (e.g., presses “elephant” then presses “cat swinging jumping” for “cat swinging”)

Spoken+SGD combination: Child says part of the combination and activates the SGD for the other part of the combination within 5 s of one another.

Agent/action produced in isolation

Correct SGD agent: Child activates correct agent icon on the SGD when stimuli are in front of the child OR after the adult says: “What did you see?”

Correct SGD action: Child activates correct action icon on the SGD when stimuli are in front of the child OR after the adult says: “What did you see?”

Correct spoken agent: Child verbally says correct agent when stimuli are in front of the child OR after the adult says: “What did you see?”

Correct spoken action: Child verbally says correct action when stimuli are in front of the child OR after the adult says: “What did you see?”

Incorrect answers/non-responses

Error: Child produces an answer but no part of the child’s answer is correct

No response: Child does not speak or activate any icons on the SGD in response to adult saying: “What do you see?”

- If the child does not respond, the adult should re-present the probe trial again at that time or later in the session.

Appendix D
Training Data from Instructional Sessions Across Participants

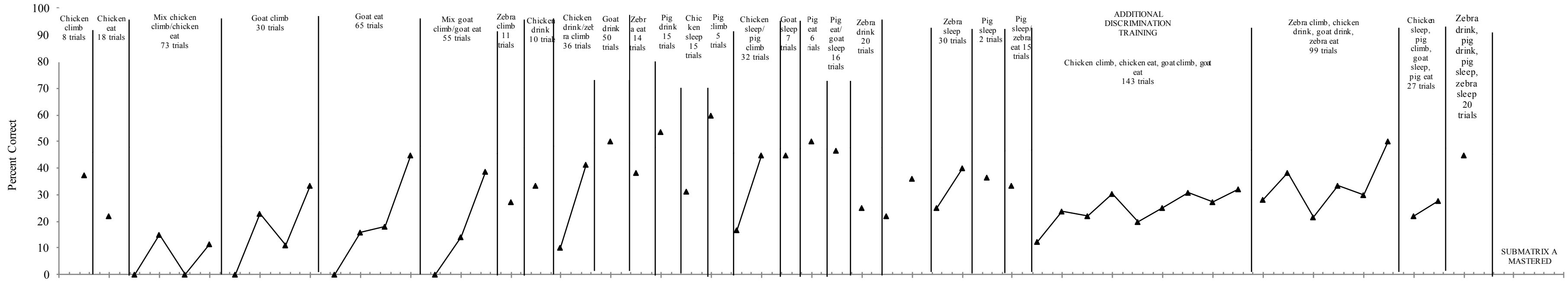

Figure 11. Training data for Participant 1

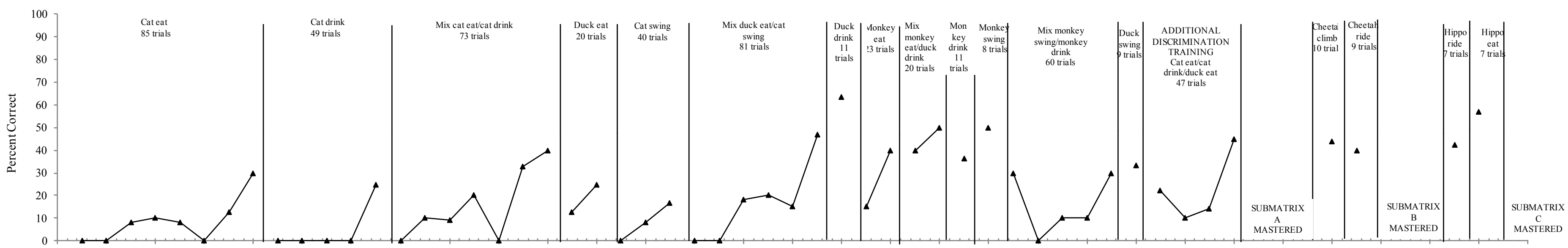

Figure 12. Training data for Participant 2

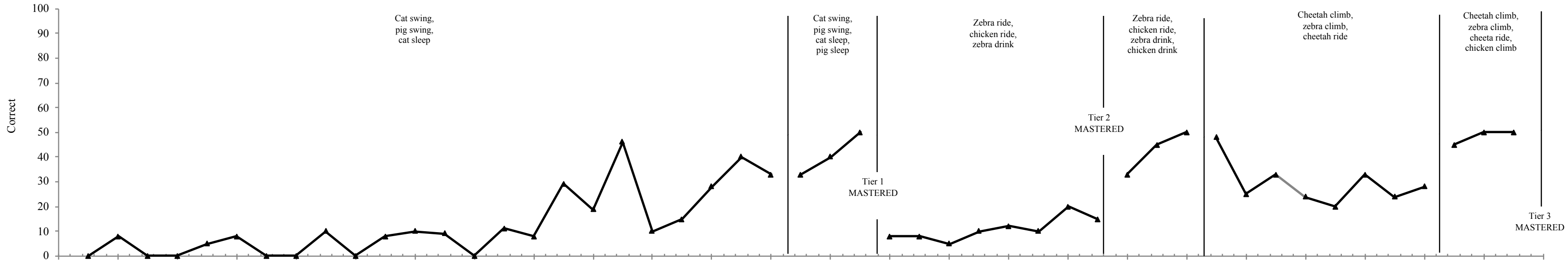

Figure 13. Training data for Participant 3

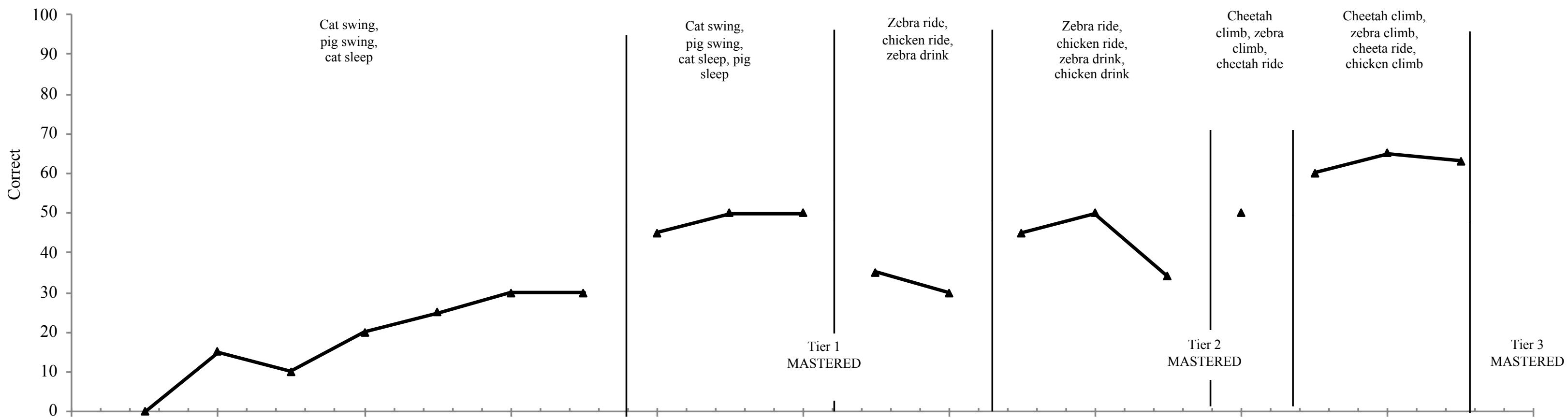

Figure 14. Training data for Participant 4