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Facilitating the Emergence of Convergent Intraverbals in Children with Autism

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FACILITATING THE EMERGENCE OF CONVERGENT INTRAVERBALS IN CHILDREN WITH AUTISM

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With intraverbal relations, one speaker's verbal behavior controls another speaker's verbal behavior. Convergent intraverbals represent a specific type of intraverbal in which multiple components of one speaker's verbal behavior control a specific verbal response from another speaker (e.g., Speaker 1: what wooly, horned animal lives in the high country? Speaker 2: a mountain goat). Learning intraverbal relations under the control of multiple variables is critical to language, social, and academic development. Sundberg and Sundberg (2011) identified prerequisites that may engender the emergence of novel, convergent intraverbals. We used a multiple-probe design with both nonconcurrent (across participants) and concurrent (across sets of stimuli) components to evaluate the effects of training these prerequisite skills on the emergence of untrained, convergent intraverbals with four children with autism. Participants showed the emergence of novel, convergent intraverbals at mastery levels only after they displayed mastery performance on all of the prerequisite skills identified by Sundberg and Sundberg. We discuss these findings in terms of operant mechanisms that may facilitate the development of generative language.

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LIST OF ABREVIATIONS

DOR	differential Observing Response
VB-MAPP	Verbal Behavior – Milestones Assessment and Placement Program
EESA	Early Echoic Skills Assessment
PPVT-IV	Peabody Picture Vocabulary Test, Fourth Edition (PPVT™-4)
EVT-II	Expressive Vocabulary Test, Second Edition (EVT-2)
CM	centimeters
min	minutes
MTT	multiple-tact
MLT	multiple-listener
IV Categ	intraverbal categorization
LCD	listener compound discrimination
s	seconds
IOA	interobserver agreement
VR2	variable ratio 2
PD	progressive delay
RT	remedial trial

INTRODUCTION

Language plays a strong role in the educational experience of typically developing children and is an important indicator of a child's cognitive development and academic success (Nelson, Nygren, Walker, & Panoscha, 2006). Deficits in language skills are the basis for a number of disorders and dysfunctions, including autism, learning and intellectual disability, illiteracy, aggressive and self-injurious behavior, defiance, and antisocial behavior (Sundberg & Michael, 2001).

Behavior analysts are interested in the environmental conditions that foster language development, and more specifically, the environmental antecedents, consequences, and setting events that are functionally related to language development (Bijou, 1993). Verbal behavior, as described by Skinner (1957), focuses on functional relations between certain responses and environmental variables. Skinner defines verbal behavior as a response that is acquired and maintained through the mediation of the behavior of another person. He "emphasizes the individual speaker and, whether recognized by the user or not, specifies behavior shaped and maintained by mediated consequences" (Skinner, 1957, p.2).

In *Verbal Behavi*or, Skinner (1957) described a series of verbal operants that differed from one another in terms of their functional properties (e.g., the mand "toy" evoked by deprivation from access to play materials and reinforced by the delivery of a preferred toy). The fifth verbal operant described by Skinner (1957), the *intraverbal,* is under the control of a stimulus that does not have point-to-point correspondence to the verbal response (i.e., the antecedent stimulus and the verbal response do not match) and produces generalized conditioned reinforcement. An example of intraverbal behavior is the response "Six o'clock" to the question "What time is it?", that then produces the generalized reinforcing consequences "Thank you." According to Sundberg and Sundberg (2011), most of a person's daily verbal interaction involves intraverbal relations. Intraverbal behavior is also strongly required in the school environment in the form of answering questions, telling stories, solving problems, describing events, and engaging in social reciprocal interaction with peers. Therefore, a weak intraverbal repertoire may negatively impact academic achievement and social-skills development.

The difficulty or complexity of intraverbal interactions can range from simple to advanced and can be of infinite number (Sundberg & Sundberg, 2011). Early intraverbal skills are fairly simple and commonly observed in children around 1 ½ to 2 years old. Around this age, children start learning songs (e.g., after the parent says “The itsy bitsy…”, the child says “spider”), providing sounds that animals make (e.g., “The cow says…” “moo"), and completing reinforcing phrases (e.g., "Ready, set…” “go"). By age two, typically-developing children learn to respond to their names and simple word-word associations (e.g., "Socks and …” “shoes"). Their conversation skills are not yet established, but they already possess a strong listener and speaker vocabulary as well as echoic, mand, and tact repertoires. Language quickly develops between the ages of two and three and consists mostly of intraverbal responses. According to Sundberg and Sundberg (2011), whereas early intraverbal interactions observed in typically developing children tend to be simple, they are the foundation for advanced intraverbal behavior.

One of the challenges involved in the development of advanced intraverbals is the fact that intraverbals are often controlled by multiple verbal antecedent stimuli (Sundberg & Sundberg, 2011). Michael, Palmer, and Sundberg (2011) suggested that outside the analog environment of experimental conditions, verbal responses are the product of many variables that interact with one another. Michael et al. described two primary types of multiple control: *divergent control* and *convergent control*. With divergent multiple control, a unique or singular antecedent variable evokes several verbal responses. For example, when presented with the instruction "Tell me some fruits," one could respond correctly with "banana, strawberry, and grape" or with “orange, blueberry, and mango”. In this example, the single verbal antecedent stimulus "fruits” provided divergent control for several verbal responses. Conversely, in convergent control, two or more antecedent variables evoke a single correct response. For example, when presented with the instruction "Tell me a fruit that is red", one could respond correctly with a single word, "strawberry." In this example, the single response was under the convergent control of the verbal antecedent stimuli "fruit" and "red." The errors produced when an individual responds to some but not all of the functional antecedent stimuli relevant to the emission of a multiply-controlled correct response leads to rote intraverbal responding and has been referred to as *stimulus overselectivity* (Lovaas, Koegel, & Schreibman, 1979; Lovaas, Schreibman, Koegel, & Rehm, 1971) or *restricted stimulus control* (Dube & McIlvane, 1999). For example, the child who responds “John” to both “What is your first name?” and “What is your last name?” demonstrates stimulus overselectivity by attending only to the stimulus “name” and not to the other relevant stimuli (i.e., “first” and “last”).

Several studies have implemented procedures to overcome restricted stimulus control during the teaching of convergent intraverbal relations. For example, Braam and Poling (1983) used a delayed prompting procedure to transfer control from nonverbal stimuli (pictures) to verbal stimuli (signs) to teach intraverbal classification (i.e., *school things*, *school do*, *school people* vs. *home things*, *home do*, *home people*) to two 17-year-olds with hearing impairment and intellectual disability. Intraverbal responding was brought under control of two distinct verbal antecedent stimuli (e.g., "school” vs. “home” and “things” versus “do” versus “people”) for both participants. Other studies have shown the efficacy of including a differential observing response (DOR) to ensure that participants are attending to the relevant features of the antecedent vocal stimulus. For example, in a study by Kisamore, Karsten, Mann, and Conde (2013), a differential observing response (DOR), in which the experimenter prompted the participant to repeat the complete antecedent stimulus (e.g., "Name the same as tall. You say it."), was effective in teaching conditional discrimination of antonym and synonym relations for four of six typically developing preschoolers included in their study.

More recently, Kisamore, Karsten, and Mann (2016) compared the effects of trial-and-error training, DOR, and DOR plus trial-blocking procedures to teach conditional discrimination of intraverbal responses to seven children between 4 and 18 years old diagnosed with autism spectrum disorder. During the trial-and-error training, the experimenter provided praise and a tangible item following a correct response and re-presented the discriminative stimulus followed by the controlling prompt at a 0-s delay following incorrect responses. During the DOR procedure, the experimenter presented the antecedent stimulus (e.g., "What’s an animal that’s red?"), prompted the child to emit the DOR (e.g., "Say animal red"), waited for the participant to emit the DOR, and re-presented the antecedent stimulus. The experimenter implemented the DOR plus trial blocking for participants who did not reach mastery levels with the trial-and-error or DOR procedures. For the trial-blocking component, the experimenter presented 20 consecutive trials for each target and then systematically faded to irregular block sizes. The results indicated that, although some participants acquired at least one set of targets with the trial-and-error procedure, most participants required additional procedures (e.g., DOR, DOR plus trial-blocking) in order to acquire intraverbals involving conditional discrimination.

The aforementioned studies showed that children with autism can learn intraverbals involving multiple control via direct training methods (i.e., differential reinforcement combined with other procedures). However, during typical social and educational interactions, children are routinely asked to produce novel, conditional intraverbals without ever receiving direct training for those specific intraverbal responses. In fact, the frequency with which children are asked to produce novel verbal responses to multiple, novel verbal stimuli during routine conversation would make it unwieldy to build a child’s intraverbal repertoire through direct reinforcement of each potential target response. In addition, children with autism present with language delays that, in most cases, require intensive intervention for prolonged periods (LeBlanc, Esch, Sidener, & Firth, 2006; Roane, Fisher, & Carr, 2016). Hence, it is critically important that behavior analysts discover the variables that facilitate the emergence of novel, untrained intraverbal skills in children with autism, because the incorporation of those variables into early intervention programs would greatly increase the effectiveness and efficiency of programs designed to build intraverbal competencies in children with autism.

Several investigators have demonstrated the emergence of simple intraverbals in children with typical development and in participants with autism (e.g., Grannan, & Rehfeldt, 2012; Miguel, Pettursdottir, & Carr, 2005; Petursdottir, & Haflidadottir, 2009). De Souza and Rehfeldt (2013) demonstrated the emergence of simple intraverbals in three young adults with intellectual disabilities after conditional discrimination training using printed words. In Study 1, after the participants learned to write dictated word via modeling, error correction, and reinforcement, they also demonstrated emergence of oral spelling skills without direct instruction. In Study 2, the investigators showed that participants learned to vocally spell and list synonyms (without direct instruction) after they received direct training to match printed words to their printed synonyms. These studies represent important advances in our understanding of the emergence of intraverbal behavior in children, but additional research is warranted to understand the emergence of more complex intraverbals under multiple control in order to further our knowledge of advanced language development.

Sundberg and Sundberg (2011) suggested that there are several prerequisites when training advanced intraverbals, specifically, when training intraverbals under convergent control. First, when training intraverbals involving a set of stimuli (e.g., red, yellow, green, fruits, and vegetables), the tact and listener repertoire of all individual targets should be well established, discriminated, and generalized in the child's repertoire. Second, all individual targets should be evoked under divergent control (e.g., "Tell me some vegetables" versus "Tell me some fruits"). Finally, the child should be able to respond as a listener when the target is presented in a conditional discrimination task (e.g., "Touch the fruit that is yellow" versus "Touch the vegetable that is yellow”). Evaluating the prerequisites that are necessary for the emergence of untrained, multiply-controlled intraverbals is important for all children, but it is particularly important for children with autism because they often fail to respond correctly under conditions that require convergent stimulus control (Sundberg & Sundberg, 2011). Therefore, our goal for this study was to evaluate if the specific prerequisite skills hypothesized by Sundberg and Sundberg (2011) would facilitate the acquisition and emergence of novel, complex convergent intraverbals in children with autism.

CHAPTER 1: METHOD

Participants

Four children from 4 to 5 years old diagnosed with autism and attending the university-based center participated (see Table 1). All participants could follow simple instructions, tact pictures of various items and their features, and respond to simple intraverbal questions (e.g., "Where do you wash your hands?"). To be included in the study, participants had to (a) reliably echo words when prompted by the experimenter (e.g., say "cookie"); (b) demonstrate simple intraverbal responses (e.g., respond to questions such as "What do you wash?") and intraverbal categorization responses (e.g., "What are some colors?"); and (c) demonstrate restricted stimulus control when asked questions involving multiple components (e.g., "What animal has a long neck?" versus "What animal moves real slow?").

Table 1: Participants Demographics. Participants ages, gender, and language assessment scores. Total possible point on the VB-MAPP Intraverbal Subtest is 80 points, and 10 points for Group 7 and Group 8 each. The total possible score on the EESA is 100. The mean score for standard score on the PPVT-4 and EVT-2 is 100 with a standard deviation of 15.

	Scores					
	VB-MAPP Intraverbal Subtest					
Participants	Total Score	Group 7	Group 8	EESA	PPVT-4	EVT-2
James (male, 5 years)	54	5	3	100	96	94
Thomas (male, 4 years 10 mo.)	50	4	1	99.5	96	92
Kelly (female, 5 years 6 mo.)	56	5	2	100	88	97
William (male, 5 years 2 mo.)	56	4	4	100	86	89

Setting and Materials

We conducted sessions in a quiet area in the child's session room. The room was equipped with a table, chairs for the participant and experimenter, data sheets, leisure items and edibles that were used as reinforcers, and 13- by 10-cm picture cards that were used during sessions. We selected preferred items and edibles by asking the participant what he or she would like to work for on a regular basis prior to and during sessions. We conducted one to six sessions, two to five times per week. Sessions lasted from 5 to 20 min. We provided a break every time the child requested.

We included two sets of picture cards per participant, except for James who moved away before the completion of the second set (see Table 2). Set B for William was slightly modified because he responded correctly to the probe question “A tool used for scooping is a __” during probe sessions. There were four targets (e.g., zebra, emu) per set. Each target was defined by one of two primary classes hereafter referred to as Class 1 (e.g., mammals and birds) and by one of two secondary classes hereafter referred to as Class 2 (e.g., savanna and rain forest). Therefore, each target in a set overlapped with other targets by either Class 1 (e.g., zebra and gorilla are both mammals) or Class 2 (e.g., zebra and emu are both from the savanna) resulting in two overlapping features between classes. There were no overlapping classes or functions between sets. We counterbalanced each set across participants, that way no set was targeted first or second more than twice across participants. We counterbalanced the sets to ensure that the outcomes of the study were due to the effect of the independent variable and not due to a special characteristic of the stimulus set (e.g., set A is less complex that Set B).

Table 2: Target Stimuli. Individual targets for training Set A and training Set B. Each target overlaps with other targets by either a Class 1 or Class 2.

	Class 1			
	Set A (Animal Type)		Set B (Object Type)	
Class 2	Mammals	Birds	Utensils	Tools
Set A (Animal Bio)				
Savanna	Zebra	Emu		
Rain Forest	Gorilla	Toucan		
Set B (Object Function)				
Scooping			Spoon	Shovel
Cutting			Knife	Saw
Set B-modified[a]				
Spreading			Spatula	Trowel
Cutting			Knife	Saw

Experimental Design

We used a nonconcurrent multiple-probe design (Horner & Baer, 1978) across participants for one set with an embedded concurrent multiple-probe design across two sets for participants to evaluate the effects of the independent variable on the emergence of convergent intraverbals. We first implemented convergent-intraverbal probes with the first participant across both sets of stimuli to evaluate the levels of correct intraverbal responses prior to any training. After the initial probe, the first participant began training with the first set of stimuli while the second set was periodically probed for the emergence of intraverbals (i.e., probes of second set occurred concurrently to probes of the training set). Once the first participant performed to criteria during intraverbal probes for the first set, we initiated training for the second set of stimuli with the first participant, and probe sessions for all sets of stimuli for the second participant. We continued this process of initiating training across sets and participants until all participants performed to criteria for both sets of stimuli. The order in which each set was trained was randomized and counterbalanced per participant. In other words, the first participant initiated training for Set A, whereas the second participant initiated training for Set B.

Dependent Variables and Response Measurement

The primary dependent variable included the percentage of trials with correct convergent intraverbals. We defined a convergent intraverbal as a correct vocal response (e.g., "zebra") to a discriminative stimulus involving the Class 1 and the Class 2 of a specific exemplar (e.g., "A mammal from the savanna is a___"; see Table 3 for a description of target and discriminative stimuli). We scored a trial as correct if the participant provided an exemplar from the stimulus set within 5 s from the presentation of the discriminative stimulus. Because the purpose of this study was to investigate the effects of prerequisite skills involving a specific set of stimuli on the emergence of convergent intraverbals related to the same set of stimuli, the experimenter recorded all intraverbals emitted by the participant, but only intraverbals within the stimulus set were recorded as correct responses (Kisamore, Carr, & LeBlanc, 2011).

Table 3: Discriminative Stimuli. Examples of discriminative stimuli for convergent intraverbal probes and all prerequisite skill sessions.

	Set A		
	Target (e.g., zebra)	Class 1 (e.g., Mammals)	Class 2 (e.g., Savanna)
Probe	A [Class 1] from the [Class 2] is a....		
MTT	Name it	It is a ….	It is from the....
MLT	Point to the [target].	Point to all [Class 1].	Point to all from the [Class 2].
IV Categ		Tell me some [Class 1].	Tell me some things from the [Class 2].
LCD	Point to the [Class 1] from the [Class 2].		

Secondary dependent variables included the percentage of correct responses during multiple-tact (MTT), multiple-listener (MLT), intraverbal categorization, and listener compound discrimination (LCD) phases, and the percentage of trials with a DOR during listener compound discrimination (LCD) and intraverbal probe sessions. During MTT, we scored a trial as correct if the participant responded within 5 s of each discriminative stimulus for the following: (a) the tact of target (i.e. name the exemplar depicted in the picture card [e.g., said “zebra” in response to “Name it”]); (b) the tact of Class 1 associated with the exemplar depicted in the picture card (e.g., said “mammal” in response to “It’s a __”); and (c) the tact of Class 2 of the exemplar depicted in the picture card (e.g., said “savanna” in response to “It’s from the__”). During MLT, we scored a listener response correct if the participant independently pointed to all specified picture cards within 5 s of the presentation of the discriminative stimulus (e.g., “Point to all mammals”). We scored an intraverbal categorization trial correct if the participant provided a vocal response that contained multiple exemplars in response to a discriminative stimulus regarding the Class 1 or Class 2 of items (e.g., "Tell me some mammals” and “Tell me some things from the savanna”). A trial was scored as correct if the participant provided all two targets from the Class 1 of the stimulus set (e.g., zebra and gorilla for mammals) and all two targets from Class 2 of the stimulus set (e.g., zebra and emu for savanna) within 10 s from the presentation of the discriminative stimulus with no more than 5 s between the emission of each exemplar (Sauter, LeBlanc, Jay, Goldsmith, & Carr, 2011) and no more than 5 s between the discriminative stimulus and the emission of the first response. During LCD, we scored a response correct if the participant independently pointed to the specified picture card within 5 s of the presentation of the discriminative stimulus (e.g., "Point to the mammal from the rain forest"). A DOR was defined as a vocal response that matched the Class 1 and Class 2 described in the discriminative stimulus (e.g., "bird from rain forest"), and emitted within 5 s of the discriminative stimulus. We collected data on DOR because DOR's have been used in other studies to teach intraverbals under convergent control (e.g., Kisamore, Karsten, & Mann, 2016). We intended to use a similar procedure in case participants did not demonstrate the emergence of convergent intraverbal to criteria levels after the last prerequisite skill phase. If this was the case, the DOR data collected during probe sessions would serve as baseline data.

Interobserver Agreement and Procedural Integrity

Interobserver agreement (IOA) was recorded by a trained observer who scored data independently for at least 32% of all probe, baseline, and training sessions for all participants. We scored an agreement each time the experimenter and the observer both recorded the same response for a trial. We calculated IOA on a trial-by-trial basis by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100%. The mean percentage and range of IOA across sessions for each participant was 99% (range, 92% to 100%) for James, 97% (range, 75% to 100%) for Thomas, 99% (range, 83% to 100%) for Kelly, and 96% (range, 75% to 100%) for William.

Procedural integrity was recorded by an independent observer according to a procedural integrity checklist for at least 32% of all probe, baseline, and training sessions for all participants.

We calculated procedural integrity by recording if the experimenter performed the steps for each trial. A trial was scored incorrect if the experimenter made an error in any of the steps for that trial. Steps recorded were: (a) correct presentation of probe instructions and probe practice (for probe sessions only), (b) correct presentation of the antecedent stimulus, (c) correct presentation of programmed prompts, and (c) correct presentation of consequences. The mean percentage and ranges of procedural reliability across sessions for each participant was 99% (range, 92% to 100%) for James, 98% (range, 85% to 100%) for Thomas, 99% (range, 92% to 100%) for Kelly, and 99% (range, 92% to 100%) for William.

Procedures

Language Assessment

We conducted two standardized language assessments prior to the beginning of the study to obtain information relevant to participant language skills (similar to those included in Kisamore, Karsten, & Mann, 2016). The Peabody Picture Vocabulary Test–Fourth Edition (PPVT-IV; Dunn & Dunn, 2007) and the Expressive Vocabulary Test – Second Edition (EVT-II; Williams, 2007) were conducted to gain information about the receptive (i.e., listener) and expressive (i.e., tact) scores, respectively.

Inclusion Criteria Assessment

We conducted the *Early Echoic Skills Assessment (EESA*; Esch, 2008) to assess participants' ability to echo single and multiple words. Echoic prompts were used during training of prerequisite skills to evoke correct responses; therefore, being able to echo the experimenter's echoic prompt was an inclusion criteria for the current study. Participants presented the inclusion criteria if they scored at least 85 out of 100 possible points. In addition, we conducted the *Intraverbal Subtest* (Sundberg and Sundberg, 2011) to evaluate participants' intraverbal repertoire. The Intraverbal Subtest is an 80-item assessment with tasks ranging from simple intraverbals (e.g., “A kitty says…”) to advanced intraverbals involving verbal conditional discrimination (e.g., “Why do people wear glasses?”). We sought to identify participants who were able to correctly respond to simple intraverbals and intraverbal categorization questions (e.g., “Tell me some number”) but demonstrated restricted stimulus control when asked questions involving multiple components (e.g., “What color is your shirt?”). Participants presented the inclusion criteria if they scored at least 50 but not more than 70 out of 80 possible points and responded correctly to at least two intraverbal categorization questions.

Convergent Intraverbal Probe

We conducted convergent-intraverbal probe sessions prior to and following each prerequisite skill training to test for the emergence of convergent intraverbals. At the beginning of each session, the experimenter secured the participant’s attending and said: “I am going to ask you some questions. I will not tell you if you are right or wrong, but I want you to do your best. If I tell you a fruit that is red is an ___, you can say ‘Apple.’ Now it’s your turn: A fruit that is red is an ___.” We started the probe with a practice trial to ensure that errors were not due to failure to understand the task. The experimenter then started the probe session by presenting a discriminative stimulus involving Class 1 and Class 2 of targets (e.g., “A bird from the rain forest is a___”). The experimenter moved to the next trial after the participant provided a response (correct or incorrect) or 5 s had elapsed without any response. There were no programed consequences for correct or incorrect responses. However, appropriate session behavior (e.g., attending, quiet hands, attempting to respond to questions), for which correct responding was reinforced with praise and an edible or a preferred item, were interspersed on a VR 2 schedule in attempt to maintain overall responding. We presented each discriminative stimulus three times for a total of 12 trials per session. Mastery criteria was 92% or more of correct intraverbals across two consecutive probe sessions.

Prerequisite Skills Sequence

We implemented a sequence of prerequisite skill phases until participants demonstrated mastery performance during convergent intraverbal probes (Table 4). We conducted baseline sessions for each prerequisite skill followed by training sessions if the participant emitted less than 92% correct responses during baseline sessions for that prerequisite skill phase. The sequence progressed as follows: (a) MTT, (b) MLT, (c) intraverbal categorization, and (d) LCD. According to Petursdottir and Carr (2011), some evidence suggests that training tacts before listener responding may be more effective for skill acquisition programs addressing different responses. Therefore, we decided to implement MTT before the MLT. The order of the remaining procedures followed the sequence of prerequisites suggested by Sundberg and Sundberg (2011). Each prerequisite skill phase was preceded by convergent intraverbal probes. If at any point in the study the participant performed with 92% correct or higher during convergent intraverbal probes for a stimulus set, the experimenter conducted baseline sessions of the remaining prerequisite skills and terminated training for that specific set.

Table 4: Prerequisite Skills Sequence. List of all prerequisite skills and sequence of implementation. Intraverbal probe was conducted before the beginning and after mastery of each prerequisite skill.

Procedure	Type of Control	Type of Response	Prompt Strategy	Discriminative Stimulus (e.g.)
Intraverbal Probe	Convergent	Speaker	None	"A Mammal from the Savanna is a___"
1. Multiple-Tact (MTT)	Simple	Speaker	Echoic	"Name it" "It is a __" "It's from the ___"
2. Multiple-Listener (MLT)	Simple/ Divergent	Listener	Point	"Point to the Zebra" "Point to all Mammals" "Point to all from the Savanna"
3. Intraverbal Categorization	Divergent	Speaker	Picture	"Tell me some Mammals" "Tell me some things from the Savanna"
4. Listener Compound Discrimination (LCD)	Convergent	Listener	Point	"Point to the Mammal from the Savanna"

MTT. MTT was conducted to teach the participants all tacts related to the probe stimuli (similar to Grannan & Rehfeldt, 2012). MTT consisted of four conditions: (a) tact of target baseline, (b) tact of target training, (c) MTT baseline, and (d) MTT training. For all phases, we presented each target three times for a total of 12 trials per session. During MTT, we considered a trial correct if the participant correctly tacted all components within that trial.

Target Baseline. We taught the tact of the target first because it is common that children learn to tact a particular stimulus before they learn to tact the category and features of the item (Sundberg, 2008). Every training trial started with the experimenter presenting one picture card at a time and the discriminative stimulus “Name it.” Following a correct or incorrect response, or if 5 s had elapsed without a response, the experimenter moved to the next trial.

Target training. Every training trial started with the experimenter presenting one picture card at a time and the discriminative stimulus “Name it.” Across all training, the experimenter implemented a progressive delay (PD; i.e., 0 s, 1 s, 2 s, 3 s, 4 s, and 5 s) to an echoic prompt (similar to that included in Miguel & Kobari-Wright, 2013). For sessions with a 0-s prompt delay, the experimenter presented the picture card followed by the discriminative stimulus and then immediately provided the echoic prompt (e.g., “gorilla”). For sessions on 1-s PD, the experimenter presented the picture card followed by the discriminative stimulus and after 1 s provided the model prompt. The experimenter repeated the same procedures for the remaining intervals of the prompt delay procedure. The criterion for increasing the delay for the model prompt was 92% or higher of correct independent or prompted tacts at each delay level for two consecutive sessions. Contingent on three consecutive errors within a session, the experimenter moved back to the previous prompt-delay level. For all trials, correct independent tacts were followed by praise and an edible or a preferred item. We concluded training if a participant reached mastery criteria (i.e., two consecutive session at or above 92% correct) at any prompt delay. Correct prompted tacts were followed by praise only, except during 0-s PD, in which prompted tacts were followed by praise and an edible or a preferred item. Incorrect tacts resulted in a correction procedure during which the experimenter re-presented the trial, modeled the correct tact on a 0-s PD until a correct prompted tact was emitted, and then moved to the next trial. Praise was delivered for correct prompted tacts during the correction procedure. A remedial trial procedure was implemented for Thomas to improve acquisition during training. Following the error correction procedure, the experimenter re-presented the trial (i.e., showed the participant the target card and said "Name it") and waited for an independent correct response. If the participant responded incorrectly or did not respond within the specified prompt delay, the experimenter prompted the response and re-presented the trial. The experimenter repeated the error correction procedure until the participant responded correctly to the remedial trial or up to five times. Only the first presentation of the target during a given trial counted for data collection purposes. Praise only was delivered for correct independent tacts during the remedial trial procedure.

Target, Class 1, and Class 2 baseline. Each trial consisted of three parts: a target tact (e.g., "Name it"), a Class 1 tact (e.g., "It's a___"), and a Class 2 tact (e.g., "It's from the ___"). Whereas we always presented the target tact question first, we randomized the order of the Class 1 and Class 2 questions. At the beginning of the trial, the experimenter presented a picture card of the target (e.g., emu) and said "Name it." Following any vocal response or 5 s since the presentation of the target tact question, the experimenter initiated the second part of the trial by presenting either a Class 1 or a Class 2 task. After a correct class tact or 5 s of no responding since the presentation of the Class 1 or Class 2 discriminative stimulus, the experimenter initiated the third part of the trial by presenting the remaining task different (i.e., if the previous task consisted of a Class 1 tact, then the third part of the trial consisted of a Class 2 tact and vice-versa).

Class 1 and Class 2 training. Training of Class 1 and Class 2 tacts started only after the participant reached mastery on tact of targets. Every training trial started with the experimenter presenting one picture card at a time and the discriminative stimulus “Name it” (i.e., the target tact question). If the participant responded incorrectly or did not respond within 5 s of the discriminative stimulus, the experimenter modeled the correct response and waited for the participant to repeat. Independent and prompted tacts were followed by praise only. We implemented a 5 s PD to the first part of the trial because we assumed that participants already had the tact of the target in their repertoires as verified by their performance during target training. During the second part of the trial, the experimenter presented either a Class 1 or a Class 2 task while holding up the picture card in front of the participant, and implemented the prompt on the specified delay. During teaching of Class 1 and Class 2 tacts the experimenter prompted the participant to repeat the entire discriminative stimulus plus the correct response to increase discrimination of the antecedent stimulus. In other words, the experimenter would first say “It is from the __” and, on the specified prompt delay or following an incorrect response, provide the prompt “It is from the savanna.” If the participant provided a correct response before the echoic prompt but did not repeat the entire discriminative stimulus (e.g., “savanna”), the experimenter said “You can also say ‘It is from the savanna,’” but did not request the participant to echo the statement. A trial was considered correct even if the participant did not repeat the entire discriminative stimulus. Training started with a 0-s PD to the model prompt and progressed according to the procedure described in the target training section. Correct tact trials resulted in praise, edible or a preferred item, and incorrect tacts resulted in the correction procedure described earlier. A remedial trial procedure was implemented for James and Thomas to improve acquisition during training. Following the error correction procedure of the specific task (i.e., target, Class 1, or Class 2), the experimenter finished the trial and re-presented it in the same sequence that it was presented the first time (e.g., target, Class 2, and Class 1) and waited for an independent correct response. If the participant responded incorrectly or did not respond within the specified prompt delay, the experimenter prompted the response and re-presented the trial. The experimenter repeated the error correction procedure until the participant responded correctly to the remedial trial or up to five times. Only the first presentation of the target, Class 1, and Class 2 during a given trial counted for data collection purposes. Praise only was delivered for correct independent tacts during the remedial trial procedure.

MLT. MLT was implemented to ensure that participants could respond as a listener to all aspects of the stimuli as suggested by Sundberg and Sundberg (2011). MLT consisted of two conditions: (a) MLT baseline and (b) MLT training.

Baseline. During baseline, the experimenter (a) placed all four picture cards on the table in front of the child, (b) randomized and counterbalanced the positions prior to sessions to ensure that each exemplar was presented an equal number of times in each position, and (c) delivered the discriminative stimulus "Point to ___” (e.g., “Point to the emu” [target]; “Point to all mammals” [Class 1]; “Point to all from the savanna” [Class 2]). Trials were randomized and counterbalanced before every session. There were no programed consequences for correct or incorrect responses. However, appropriate session behavior (e.g., attending, quiet hands, attempting to respond to questions), for which correct responding was reinforced with praise and an edible or a preferred item, were interspersed on a VR 2 schedule in attempt to maintain overall responding. There were a total of four targets, two Class 1, and two Class 2 discriminative stimuli that were presented three times each for a total of 24 trials per session. Mastery criteria was 92% or more of correct listener responses across two consecutive sessions.

Training. Every training trial started with the experimenter (a) placing all four picture cards on the table in front of the child, (b) randomizing and counterbalancing the positions prior to sessions to ensure that each exemplar was presented an equal number of times in each position, and (c) presenting the target discriminative stimulus “Point to the___.” During training, the experimenter implemented a progressive delay (i.e., 0 s, 1 s, 2 s, 3 s, 4 s, 5 s) to a point prompt (similar to that included in Miguel & Kobari-Wright, 2013). For sessions with a 0-s PD, the experimenter placed all four picture cards on the table followed by the discriminative stimulus and immediately provided the point prompt (i.e., experimenter pointed to the correct picture card). For sessions on 1-s PD, the experimenter placed the pictures cards on the table followed by the discriminative stimulus and after 1 s provided the point prompt. The experimenter repeated the same procedures for the remaining delays of the PD procedure. The criterion for increasing the delay for the model prompt was 92% or higher of correct independent or prompted responses at each delay level for two consecutive sessions. Contingent on three consecutive errors within a session, the experimenter moved back to the previous prompt delay level. We concluded training if participant reached mastery criteria (i.e., two consecutive session at or above 92% correct) at any prompt delay. For all trials, correct independent responses were followed by praise and an edible or preferred item. Correct prompted responses were followed by praise only. Incorrect responses resulted in a correction procedure during which the experimenter re-presented the trial, pointed to the correct picture card on a 0-s PD until a correct prompted response was emitted, and then moved to the next trial. Praise only was delivered for correct prompted responses during the correction procedure. A remedial trial procedure was implemented for Thomas to improve acquisition during training. Following the error correction procedure, the experimenter shuffled the cards on the table, re-presented the discriminative stimulus, and waited for an independent correct response. If the participant responded incorrectly or did not respond within the specified prompt delay, the experimenter prompted the response and re-presented the trial. The experimenter repeated the error correction procedure until the participant responded correctly to the remedial trial or up to five times. Only the first presentation during a given trial counted for data collection purposes. Praise only was delivered for correct independent tacts during the remedial trial procedure. Because MLT was comprised of an extensive number of trials per session (24 trials), we initiated training with the tasks that we observed to be below criteria during MLT baseline. That is, a within session analysis demonstrated that during baseline of both Set A and Set B, Thomas responded to criteria for Class 2 but not for target and Class 1; therefore, we started training for the target and Class 1 only. Once Thomas responded to criteria for trials involving the target and Class 1, we introduced Class 2 and continued with training until Thomas reached mastery criteria across target, Class 1, and Class 2. Mastery criteria was 92% or more of correct listener responses across two consecutive sessions.

Intraverbal categorization. Intraverbal categorization was implemented to ensure that participants could provide multiple responses to categorization questions as suggested by Sundberg and Sundberg (2011). Intraverbal categorization consisted of two conditions: (a) baseline and (b) intraverbal categorization training.

Baseline. Procedures were similar to those described by Miguel, Pettursdottir, and Carr (2005). During baseline, the experimenter presented the target discriminative stimulus “Tell me some ___ (e.g., mammals).” Trials were randomized and presented three times in the same session. There were no programed consequences for correct or incorrect responses. However, appropriate session behavior (e.g., attending, quiet hands, attempting to respond to questions), for which correct responding was reinforced with praise and an edible or a preferred item, were interspersed on a VR 2 schedule in attempt to maintain overall responding. There were a total of two Class-1 and two Class-2 discriminative stimuli that were presented three times each for a total of 12 trials per session. Mastery criterion was 92% or more of correct intraverbal categorization responses across two consecutive sessions.

Training. The trial started with the experimenter presenting the target discriminative stimulus (e.g., “Tell me some things from the savanna [Class 2]”) to the participant. During training, the experimenter started with a 0-s PD to a picture prompt and 5 s to a model prompt, and upon mastering, moved to a 5-s PD to a picture prompt followed by a 5-s PD to a model prompt. For sessions with a 0-s PD, the experimenter presented the discriminative stimulus (e.g., “Tell me some mammals”) and immediately provided the picture prompt (i.e., picture cards of mammals). If the participant tacted the first picture (e.g., zebra), the experimenter presented the second picture (e.g., gorilla). For sessions on 5-s PD, the experimenter presented the discriminative stimulus and waited 5 s for a correct response. If the participant did not respond within 5 s, the experimenter followed the prompt procedure described above. At any PD, if the participant did not tact the picture within 5 s of its presentation, the experimenter then presented a model prompt (e.g., “Say gorilla”) up to five times until the participant repeated it. The criterion for increasing the delay from 0 s to 5 s to the picture prompt was 92% or higher of correct prompted responses for two consecutive sessions. Contingent on three consecutive errors within a session, the experimenter moved back to the previous PD level. If the participant emitted an incorrect intraverbal categorization, the experimenter said “A [target] is not a ___ (e.g., mammal)” and implemented a correction procedure during which the experimenter re-presented the trial, presented the picture prompt on a 0-s PD until a correct prompted response was emitted, and then moved to the next trial. If the participant repeated a previously emitted correct target the experimenter said, “You already said __ (e.g., gorilla [target])” and allowed 5 s for a different response. If the participant did not provide an additional response within 5 s, the experimenter presented a picture prompt. The experimenter terminated the trial when the participant emitted all targets (prompted or unprompted) from the stimulus set. For all trials, correct independent responses were followed by praise and an edible or a preferred item. Correct prompted responses were followed by praise only. A trial was considered correct if the participant responded independently with all exemplars from the stimulus set. Mastery criterion was 92% or more of correct intraverbal categorization responses across two consecutive sessions.

Listener conditional discrimination (LCD). LCD was implemented to facilitate the emergence of intraverbal responses under multiple control as suggested by Sundberg and Sundberg (2011). LCD phase consisted of two conditions: (a) LCD baseline and (b) LCD training.

Baseline. During baseline, the experimenter (a) placed all four picture cards on the table in front of the child, (b) randomized and counterbalanced the positions prior to sessions to ensure that each exemplar was presented an equal number of times in each position (i.e., first, second, third, fourth), and (c) presented the target discriminative stimulus (e.g., "Point to the mammal [Class 1] from the rain forest [Class 2]"). There were no programmed consequences for correct or incorrect responses. However, appropriate session behavior (e.g., attending, quiet hands, attempting to respond to questions), for which correct responding was reinforced with praise and an edible or a preferred item, were interspersed on a VR 2 schedule in attempt to maintain overall responding. Each target was presented three times for a total of 12 trials per session. Mastery criteria was 92% or more of correct intraverbals across two consecutive sessions.

Training. LCD training was implemented in the same manner as in the MLT phase described above except that there were four targets that were presented four times for a total of 12 trials. A remedial trial procedure was implemented for James in the same manner as described in the MLT phase to improve acquisition during training.

CHAPTER 2: RESULTS

Across-Participant Analysis

Figure 1 depicts the performance of all four participants during intraverbal probe sessions for the first set. We introduced training on (a) Set A first for James and William and (b) Set B first for Thomas and Kelly. We selected this order using randomization with counterbalancing across pairs of participants. All participants performed with zero levels of correct intraverbals during pretraining probe sessions. After MTT, correct intraverbals increased to 8% (one correct trial) for all participants. MLT had minimal effects on the level of correct intraverbals emitted by James and Thomas. James performed with the same levels of correct intraverbals whereas levels of correct intraverbal decreased to zero for Thomas. Kelly and Thomas demonstrated moderate increases in the levels of correct intraverbal. Kelly responded correctly to 33% of the trials whereas Thomas responded correctly to 50% of the trials. After the intraverbal categorization phase, the levels of correct intraverbals slightly increased for James and William who responded correctly to 25% and 17% of the trials, respectively. Kelly's performance increased to 50% of correct intraverbals whereas Thomas' performance remained the same. All four participants responded to criteria only after the LCD phase. James, Thomas, and Kelly responded with 92% accuracy during both intraverbal probe sessions, and William responded with 100% accuracy during both intraverbal probe sessions.

The bars denote the percentage of trials in which participants emitted a correct unprompted DOR. James emitted a DOR on 8% of trials after intraverbal categorization training, and 100% and 83% during the last two intraverbal sessions during which he demonstrated mastery performance. Thomas first emitted DORs after intraverbal categorization training on 17% of the trials. Thomas' percentage of trials with DOR during the last two probe sessions were 17% and 33%, respectively. Kelly did not emit DOR in any of the probe sessions. William was the only participant who emitted a DOR during pretraining sessions. William emitted a DOR on

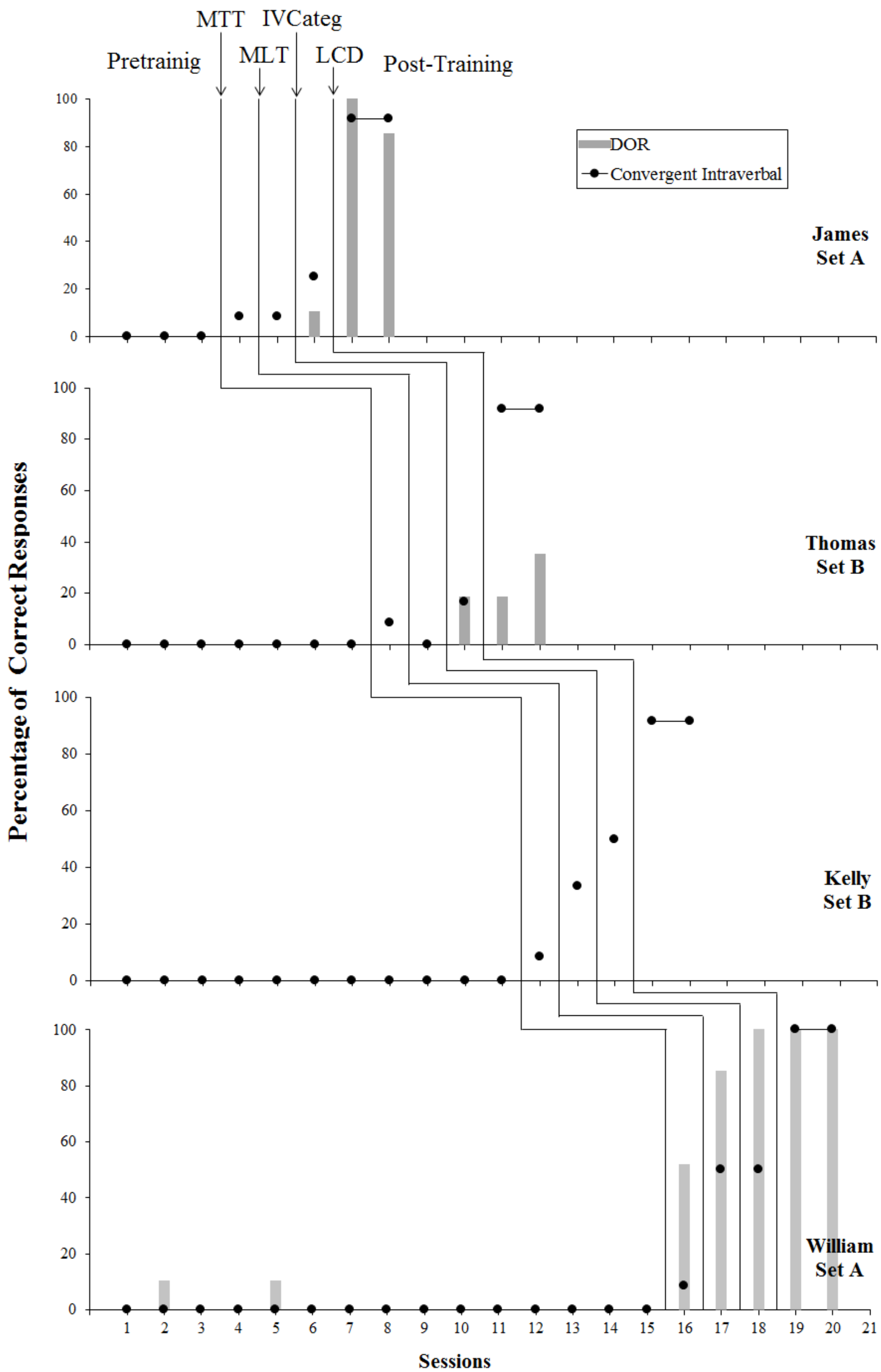

Figure 1: Convergent intraverbal probe across participants. Percentage of correct convergent intraverbals during probe sessions for the first training set across participants. Arrows indicate when each prerequisite skill phase occurred. MTT = Multiple-Tact; MLT = Multiple Listener; IV Categ = Intraverbal Categorization; LCD = Listener Compound Discrimination; DOR = Differential Observing Response.

8% of two sessions. When training started, William emitted DOR during 50% of trials after MTT, 83% of trials after MLT, and 100% of trials after intraverbal categorization and LCD.

Within-Participant Analysis

Figures 2 through 11 demonstrate the performance during intraverbal probes and training phases for Sets A and B for Thomas, Kelly, and William, and the training data for Set A for James[1]. During the initial training sessions of all procedures, participants did not have a chance to emit independent responses because the controlling prompt was always provided at a 0-s PD for two sessions. Therefore, no data point is depicted because the data paths denote the percentage of correct independent responses.

James. Figure 2 shows James's performance during all training phases for Set A. During baseline sessions of tact of target, James responded correctly to 50% of trials for all sessions. Following two sessions at a 0-s PD, the prompt delay procedure was introduced and a steady increase in performance to criterion levels was observed. We then introduced MTT (i.e., tact of Class 1 and Class 2). During baseline sessions, James responded with 100% accuracy for the tact of the target, with a mean of 22% accuracy (range, 16% to 25%) for Class 1, and with 41% accuracy during all sessions for tact of Class 2. During the training phase of MTT, we implemented a progressive prompt delay for the tact of Class 1 and Class 2 while the tact of the target was under a 5-s delay. James demonstrated 100% accuracy for the tact of the target for all sessions during training of Class 1 and Class 2. His performance during MTT of Class 1 and Class 2 was variable but he reached criteria after we added remedial trials. The next phase was MLT. James responded with 100% accuracy during two consecutive sessions and therefore did not require training for this phase. James responded with 0% accuracy across all baseline sessions during intraverbal categorization. After the two initial training sessions on 0-s prompt delay to a

[1] Intraverbal probe data and training data of Sets B are not reported for James because he moved away before training of the second set started.

picture prompt, James readily acquired the targets and demonstrated performance criteria. The last procedural phase was LCD. James mean correct responses during baseline was 50% (range, 42% to 67%). His performance after the initial 0-s delay sessions was variable with a decreasing trend. Performance recovered and James met criteria after we added remedial trials.

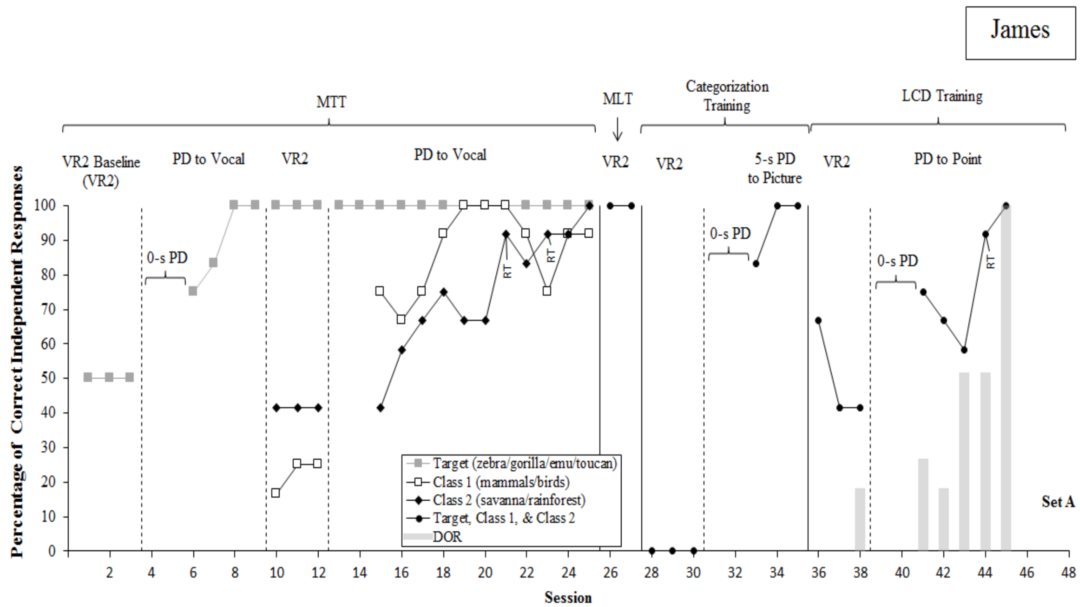

Figure 2: James' training data. This figures shows James' performance during all prerequisite skills for Set A. The 0-s PD bracket represents sessions with 0-s PD. No data points are depicted for these sessions because participants did not have the opportunity to respond independently. VR2 = Variable ratio 2; MTT = Multiple-Tact phase; MLT = Multiple Listener phase; LCD = Listener Conditional Discrimination phase; DOR = Differential observing response; PD = Progressive delay; RT = Remedial trial.

Thomas. Figure 3 depicts the data for Thomas' performance during intraverbal probes for both sets. His correct responses during the initial probe sessions for Set A (second training set) was at zero levels. Thomas responded with higher levels of correct responding after MTT for Set A relative to the levels of correct responding after MTT or Set B. His performance during probe sessions of Set A was 25% of correct responses after MTT, and 50% of correct responses after MLT and intraverbal categorization training. Thomas demonstrated criteria performance only after LCD; that is, he responded with 92% and 100% accuracy during the last two intraverbal probe sessions. Thomas' levels of trials with DOR during Set A increased relative to Set B. DORs were observed on 8% of the trials after intraverbal categorization training, and in 50% and 83% of trials after LCD training.

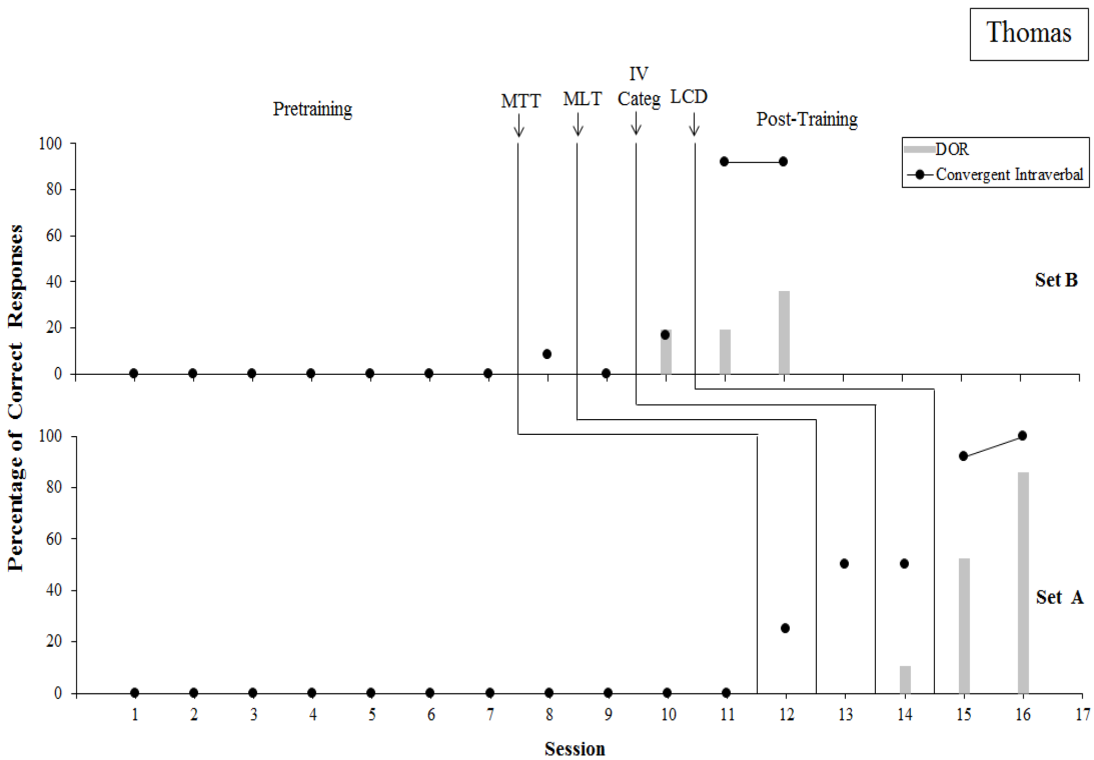

Figure 3: Thomas' convergent intraverbal probes. Percentage of correct convergent intraverbals during probe sessions across sets for Thomas. Arrows indicate when each procedural phase occurred. MTT = Multiple-Tact phase; MLT = Multiple Listener phase; IV Categ = Intraverbal Categorization phase; LCD = Listener Conditional Discrimination phase; DOR = Differential observing response.

Thomas' performance during training of the first set (Set B) is showed on Figure 4. Thomas responded with a mean of 69% accuracy (range, 58% to 75%) during the first baseline. Following the 0-s prompt delay sessions, we implemented a progressive prompt delay to a vocal prompt. His performance was stable for several sessions and no improvement was observed on the level of correct responding relative to baseline. We then added remedial trials to the prompt delay procedure. Within four sessions, Thomas reached mastery criteria for the tact of targets. During the second baseline, Thomas responded to criteria for the tact of targets and with a mean of 15% accuracy (range, 8% to 16%) for the tact of Class 1 and a mean of 22% accuracy (range, 17% to 25%) for the tact of Class 2. Following the initial two sessions at a 0-s delay to vocal prompt, Thomas quickly reached mastery criteria for tact of both Class 1 and Class 2. Next, we implemented baseline sessions of MLT. Thomas responded with 83% accuracy across all three baseline sessions and, therefore, training was implemented. Thomas was the only participant who did not respond to criteria during MLT baseline sessions. After the two initial 0-s prompt delay sessions, we implemented the progressive prompt delay to point. Thomas performance was variable and did not improve. Following a decreasing trend, we added remedial trials to the prompt delay procedure and observed an increase in the levels of correct responding to mastery after three sessions. During baseline sessions of intraverbal categorization, Thomas responded with a mean of 39% accuracy (range, 33% to 42%). We then implemented two sessions with a 0-s prompt delay to a picture prompt with a 5-s prompt delay to a vocal prompt. After these two sessions, we implemented a 5-s prompt delay to pictures with a 5-s prompt delay to vocal prompt. Thomas readily demonstrated mastery criteria to intraverbal categorization. Finally, we implemented the LCD phase. During baseline, Thomas responded with a mean of 58% accuracy (range, 50% to 67%). Following the initial 0-s delay sessions, we implemented a progressive prompt delay to a point prompt and Thomas acquired the skills within six sessions.

Figure 4 depicts Thomas' performance during training of the second stimulus set (Set A). Thomas' performance during training of Set A was similar to his performance during training of Set B in that direct training was required for all procedural phases. During the first baseline of MTT, Thomas responded with 17% accuracy across all sessions. After the initial sessions at a 0-s prompt delay, we implemented the progressive prompt delay to vocal model. Thomas' performance improved relative to baseline within a few sessions but it remained stable at a mean

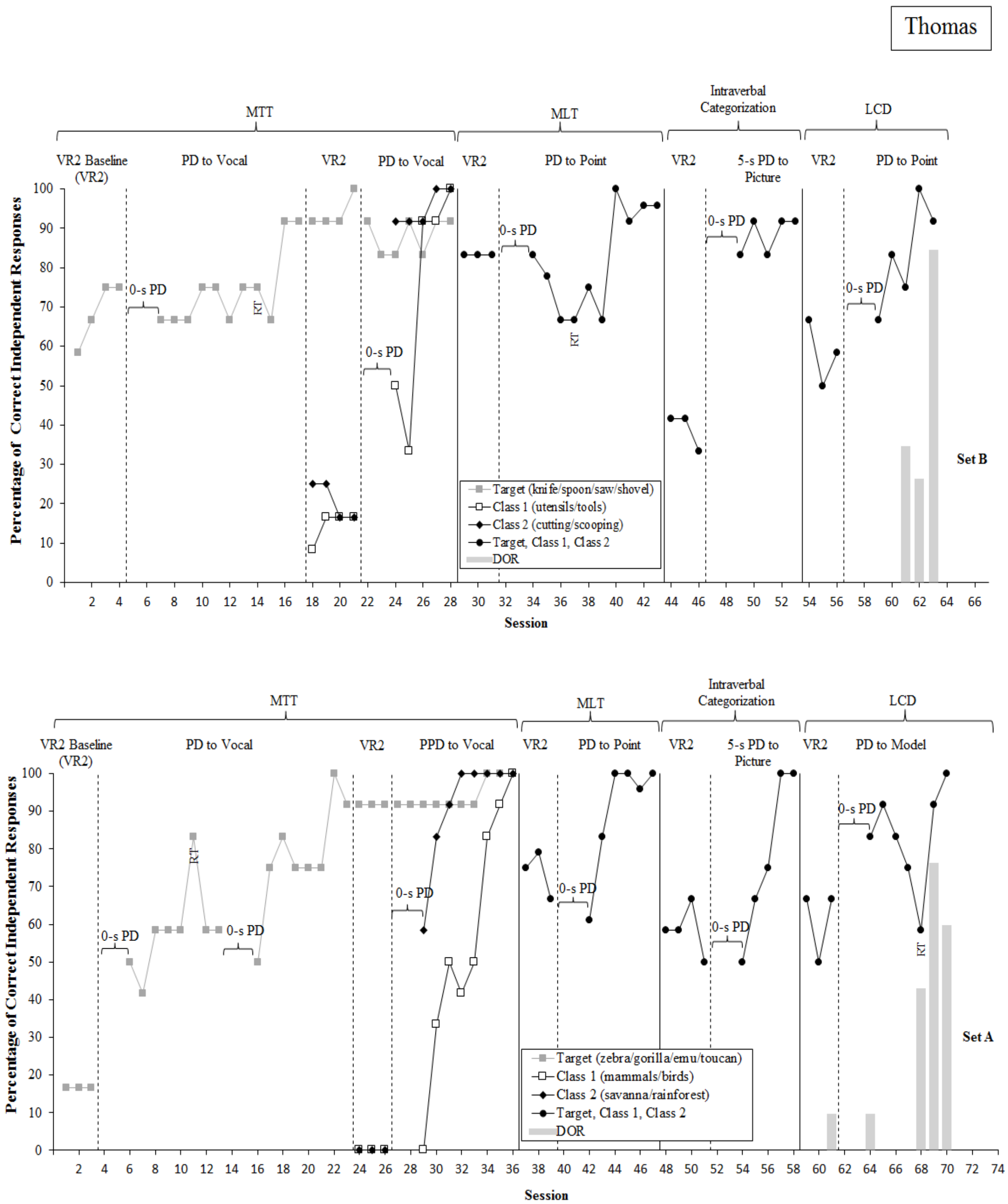

Figure 4: Thomas' training data. Thomas' performance during all prerequisite skills for Sets B and A. The 0-s PD bracket represents sessions with 0-s PD. No data points are depicted for these sessions because participants did not have the opportunity to respond independently. VR2 = Variable ratio 2; MTT = Multiple-Tact phase; MLT = Multiple Listener phase; LCD = Listener Conditional Discrimination phase; DOR = Differential observing response; PD = Progressive delay; RT = Remedial trial.

of 60% (range, 50% to 83%) for several sessions. We added remedial trials to the prompt delay procedure but no significant change was observed. A within session analysis showed that Thomas' errors involved exclusively two stimuli (i.e., toucan and emu), therefore, we implemented a second series of 0-s prompt delay to a vocal model. Thomas' performance improved and he reached mastery criteria after eight sessions following the second 0-s prompt sessions. We then implemented baseline for the tact of targets, Class 1, and Class 2. Thomas responded with 92% accuracy for tact of target during all sessions, and with 0% accuracy for the tact of both Class 1 and Class 2. Following the two sessions at a 0-s prompt delay, the data demonstrated a steady increase in the levels of correct responses for the tact of Class 1 and Class 2 up to mastery criteria levels. Next, we implemented MLT. Thomas responded with 74% accuracy (range, 67% to 79%) during baseline sessions. During training, Thomas demonstrated performance criteria after six sessions following the two sessions at a 0-s prompt delay. During the intraverbal categorization baseline, Thomas responded with 58% accuracy (range, 50% to 67%). Following the sessions at 0-s delay, the data demonstrated a steady increase to mastery criteria levels. Thomas' correct responses were at a mean of 61% (range, 50% to 67%) during baseline. Thomas' performance was variable at the initial stage of training. After the 0-s delay sessions, his performance increased to criteria levels followed by a decreasing trend to 58% accuracy. We introduced remedial trials and Thomas quickly mastered this skill.

Kelly. Figure 5 shows Kelly's performance during intraverbal probes for her second training set (i.e., Set A). As observed during probe session of Set B, Kelly responded with 0% accuracy during all pretraining sessions. Kelly's correct responses increased to 50% after MTT, and to 67% after MLT. Differently to what was observed during training of Set B, Kelly demonstrated the emergence of intraverbal responses after the intraverbal categorization phase with 100% accuracy across two sessions. Kelly did not emit DORs during probe sessions of Set A.

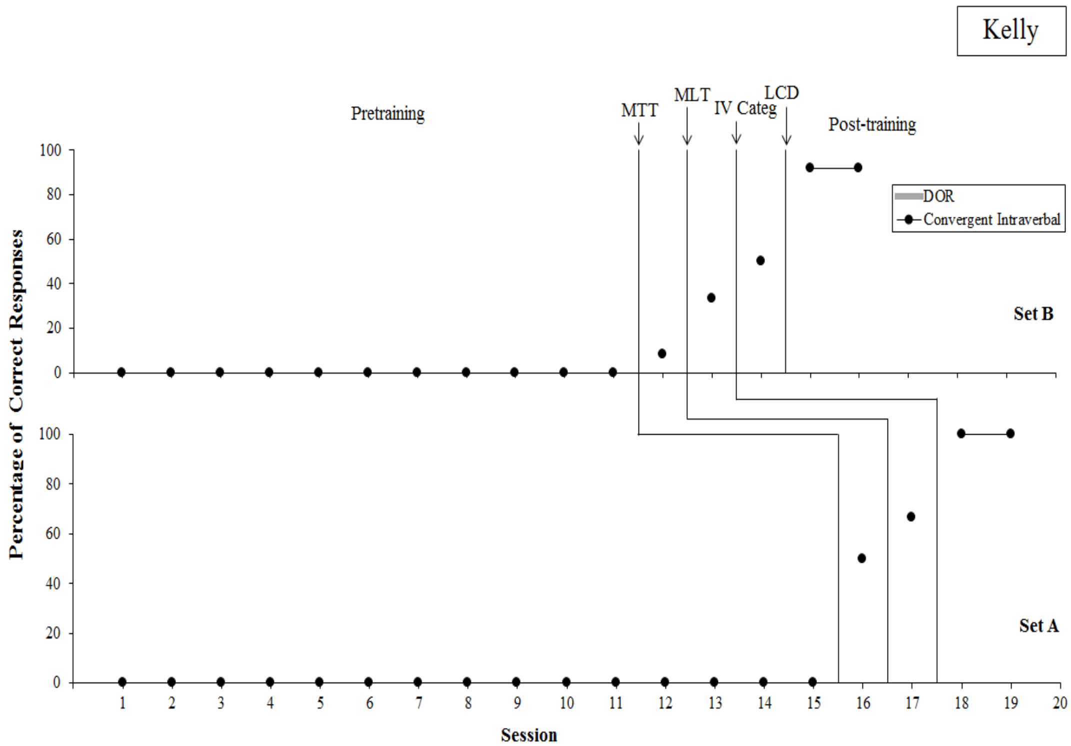

Figure 5: Kelly's convergent intraverbal probes. Percentage of correct convergent intraverbals during probe sessions across sets for Thomas and Kelly. Arrows indicate when each procedural phase occurred. MTT = Multiple-Tact phase; MLT = Multiple Listener phase; IV Categ = Intraverbal Categorization phase; LCD = Listener Conditional Discrimination phase; DOR = Differential observing response.

Figure 6 depicts Kelly's performance throughout all training phases for Set B. During the first baseline phase of MTT, Kelly responded with 50% accuracy across all three sessions. After the two sessions in which a vocal prompt was delivered at a 0-s delay, Kelly demonstrated a steady increase in correct tacts of target. Kelly required eight training sessions to demonstrate performance criteria for this skill. During the second baseline phase in which the tacts of target, Class 1, and Class 2 were presented, Kelly responded with 100% accuracy for the tact of the target, with 0% accuracy for all sessions of Class 1 tacts, and with a mean of 72% accuracy (range, 66% to 75%) for Class 2 tacts. Kelly responded to criteria for the tact of targets throughout all training sessions. After the initial two sessions at a 0-s delay, she rapidly acquired the tacts of Class 1 and Class 2 and reached mastery criteria within seven training sessions. Following mastery of MTT, Kelly was able to respond to criteria during baseline sessions for all subsequent procedures. Although Kelly did not undergo direct training during MLT, intraverbal categorization, and LCD, she was not able to demonstrate the emergence of convergent intraverbal until she was exposed to the all procedural phases.

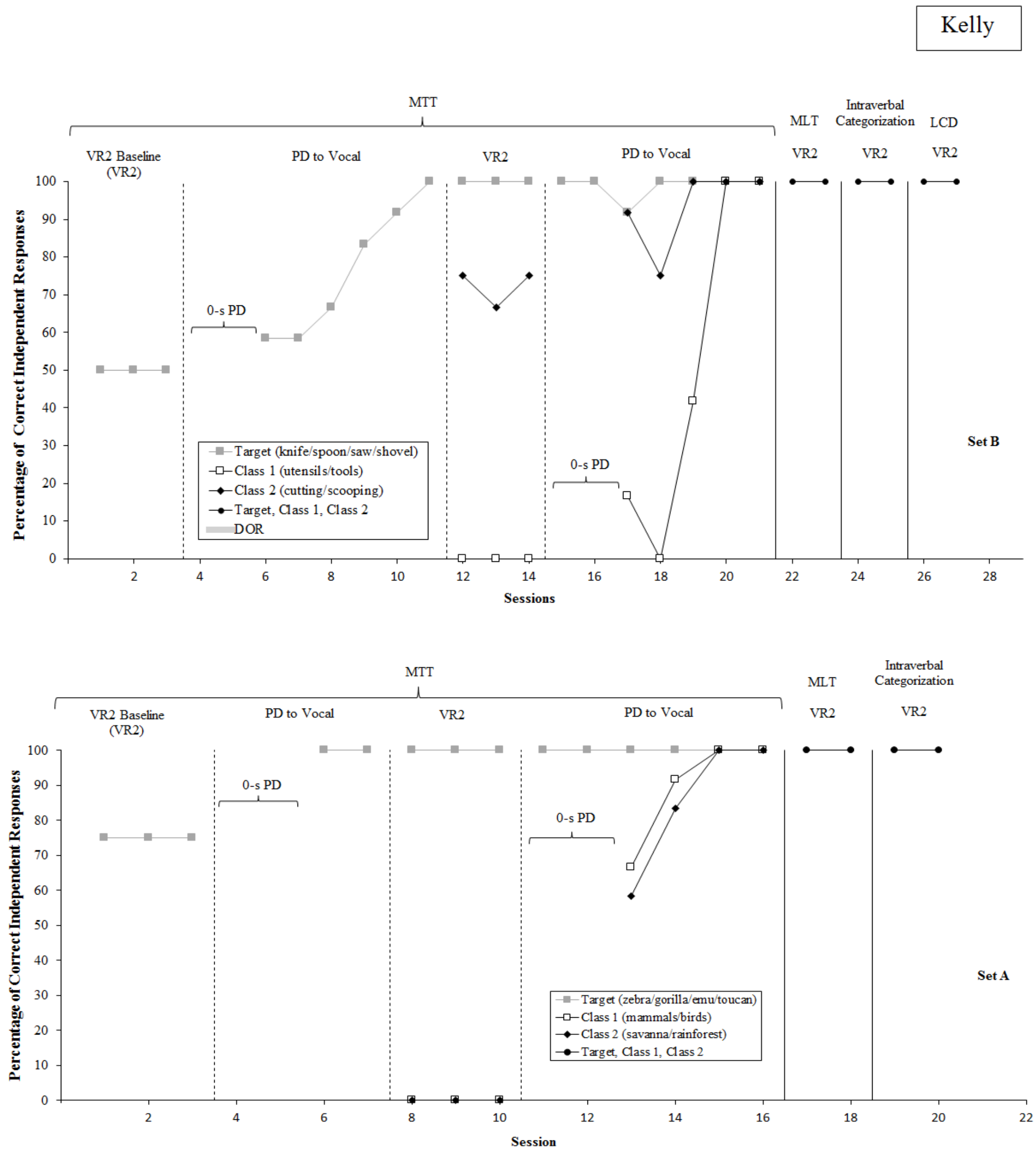

Figure 6: Kelly's training data. Kelly's performance during all prerequisite skills for Sets B and A. The 0-s PD bracket represents sessions with 0-s PD. No data points are depicted for these sessions because participants did not have the opportunity to respond independently. VR2 = Variable ratio 2; MTT = Multiple-Tact phase; MLT = Multiple Listener phase; LCD = Listener Conditional Discrimination phase; DOR = Differential observing response; PPD = Progressive delay; RT = Remedial trial.

Kelly's performance throughout all procedural phases during training of Set A is also shown on Figure 6. During baseline of target, Kelly responded with 75% accuracy for all three sessions; that is, Kelly responded correctly to the tact of gorilla, zebra, and emu. Kelly reached mastery criteria for tact of targets immediately after the initial sessions at a 0-s delay and responded with 100% accuracy during all subsequent MTT sessions. Correct tacts of Class 1 and Class 2 were at zero levels during the second baseline phase. After the initial 0-s delay sessions, Kelly's levels of correct responses increased and reached mastery criteria within four sessions. As observed during training of Set B, Kelly responded to criteria during baseline sessions of MLT and intraverbal categorization and did not required direct training. LCD phase is not depicted because Kelly demonstrated the emergence of convergent intraverbals after exposure to intraverbal categorization.

William. Figure 7 shows the performance of William during probe sessions across Sets A and B-modified. William responded with low levels of correct responses during pretraining. In contrast to his performance during probe session of Set A, William responded with 42% accuracy after MTT, and 8% accuracy after both MLT and Intraverbal Categorization. William demonstrated mastery criteria only after LCD phase. William emitted lower levels of DOR's during probes sessions of Set B-modified when compared to probe sessions of Set A. William did not emit DORs during pretraining probe sessions. He emitted a correct DOR on 25% of intraverbal probe trials after MTT, on 17% of trials after MLT, on 0% of the trials after Intraverbal Categorization, and 58% and 75% of trials during the last two probe sessions after LCD.

Figure 8 depicts the data for all procedure phases for William during training of the first set (Set A). William responded with 50% accuracy during the first baseline of MTT. After the sessions at 0-s delay, William demonstrated increased levels of correct responding and reached mastery criteria of tact of target within four sessions. During the second baseline and throughout

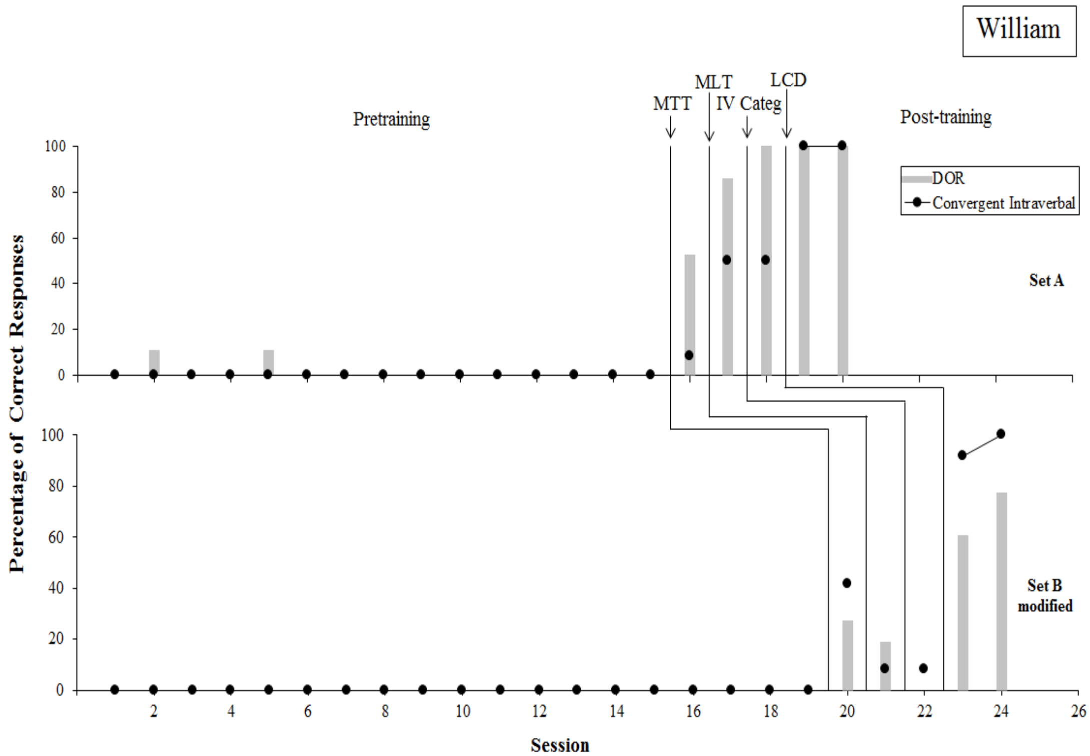

Figure 7: Williams' convergent intraverbal probes. Percentage of correct convergent intraverbals during probe sessions across sets for William. Arrows indicate when each procedural phase occurred. MTT = Multiple-Tact phase; MLT = Multiple Listener phase; IV Categ = Intraverbal Categorization phase; LCD = Listener Conditional Discrimination phase; DOR = Differential observing response.

all sessions of MTT, William responded to criteria to the tact of target. During the second baseline, Thomas responded with 0% accuracy for tact of Class 1 and with a mean of 31% accuracy (range, 8% to 42%) for tact of Class 2. William demonstrated a rapid shift in levels of correct responses after the initial two 0-s delay sessions, but a gradual increase in the levels of correct responses up to mastery. Similarly to James and Kelly, William responded with 100% accuracy during the baseline sessions of MLT. During intraverbal categorization baseline, William responded with 0% accuracy across all baseline sessions. Following two sessions at 0-s delay to a picture prompt, William immediately reached mastery criteria. Finally, during LCD phase, William responded to criteria during baseline.

William

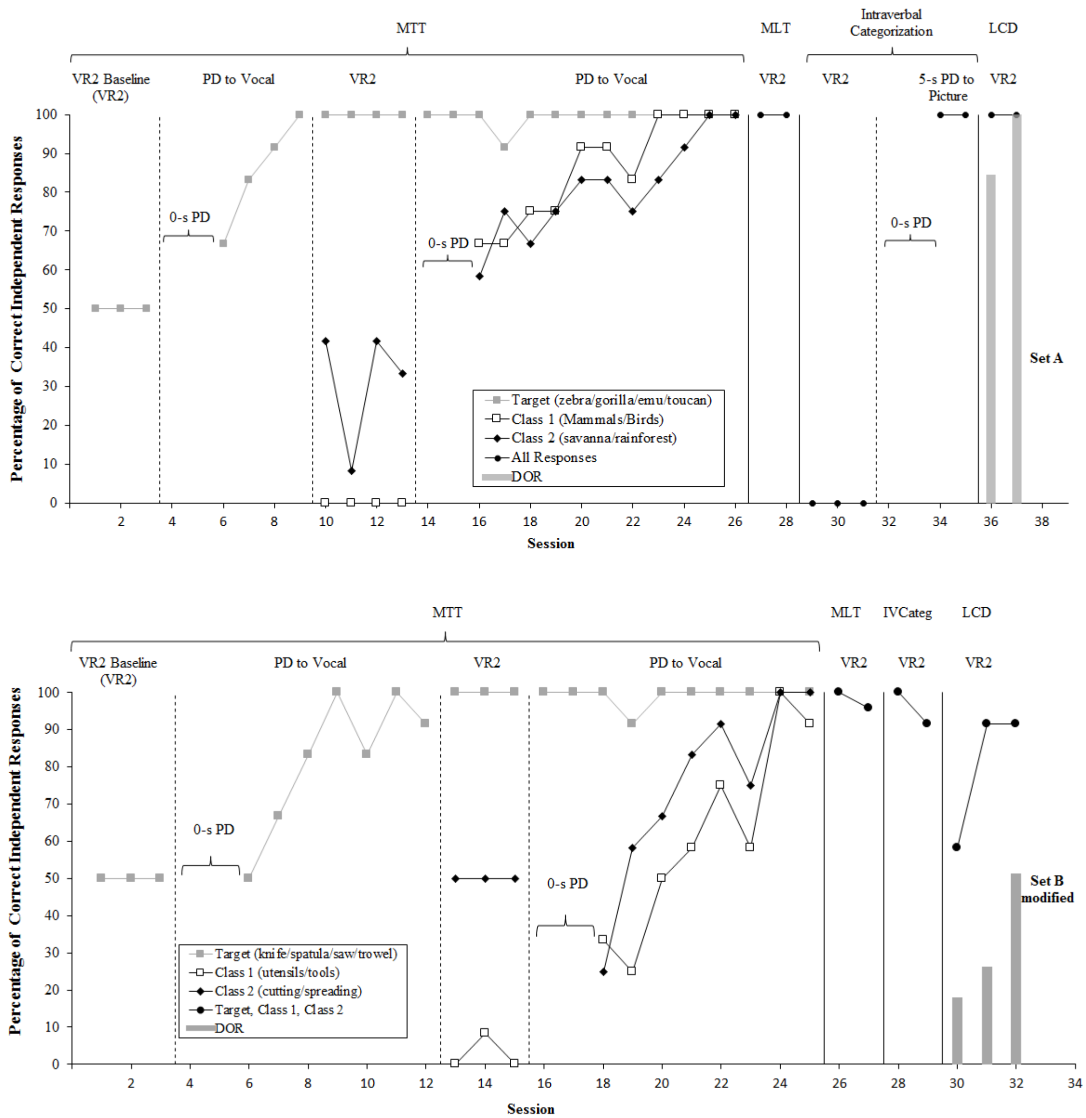

Figure 8: Williams' training data. Wiliams' performance during all prerequisite skills for Sets A and B. The 0-s PD bracket represents sessions with 0-s PD. No data points are depicted for these sessions because participants did not have the opportunity to respond independently. VR2 = Variable ratio 2; MTT = Multiple-Tact phase; MLT = Multiple Listener phase; LCD = Listener Conditional Discrimination phase; DOR = Differential observing response; PPD = Progressive delay; RT = Remedial trial.

Figure 8 also demonstrates William performance throughout all procedural phases during training of Set B-modified. During MTT, William responded with 50% accuracy during baseline sessions of tact of targets. William correctly tacted the knife and the saw on all trials. After two sessions at a 0-s PD, William demonstrated a gradual increase in correct responses and reached mastery criteria within seven training sessions. When we introduced the tact of Class 1 and Class 2, William continued responding with criteria for the tact of the target, but showed low levels of correct responses for Class 1 and Class 2. William responded with a mean of 3% accuracy (range, 0% to 8%) for Class 1 and, 50% accuracy for all sessions for Class 2. His correct responses involved Class 2 of knife and saw (i.e., used for cutting). After the initial 2-s delay session, William responding during the following procedural phases was similar for that observed during training of Set A, except that he responded to criteria during Intraverbal Categorization baseline sessions and therefore did not undergo direct training for this skill.

Skill Acquisition

Figure 9 shows trials to criteria for all prerequisite skill of all participants. For all training set across all participants, MTT was the prerequisite skill with the highest number of trials to criteria. Among the participants, Kelly demonstrated the lowest number of trials to criteria for MTT during training of the second set (i.e., Set A) with 192 trials. Thomas demonstrated the highest number of trials to criteria for MTT during training of the second set (i.e., Set A) with 432 trials.

Of all participants, three performed to criteria during baseline sessions of prerequisite skill phases after MTT for at least one prerequisite skills. When participants responded to criteria for a prerequisite skills, no training was implemented for that specific prerequisite skill. James demonstrated performance criteria during baseline for MLT; Kelly demonstrated performance criteria during baseline for MLT and intraverbal categorization of Sets B and A, and LCD of Set B; and William demonstrated performance criteria for MLT and LCD of Sets A and B, and intraverbal categorization of Set B. Thomas responded below criteria for all baseline sessions across all prerequisite skills.

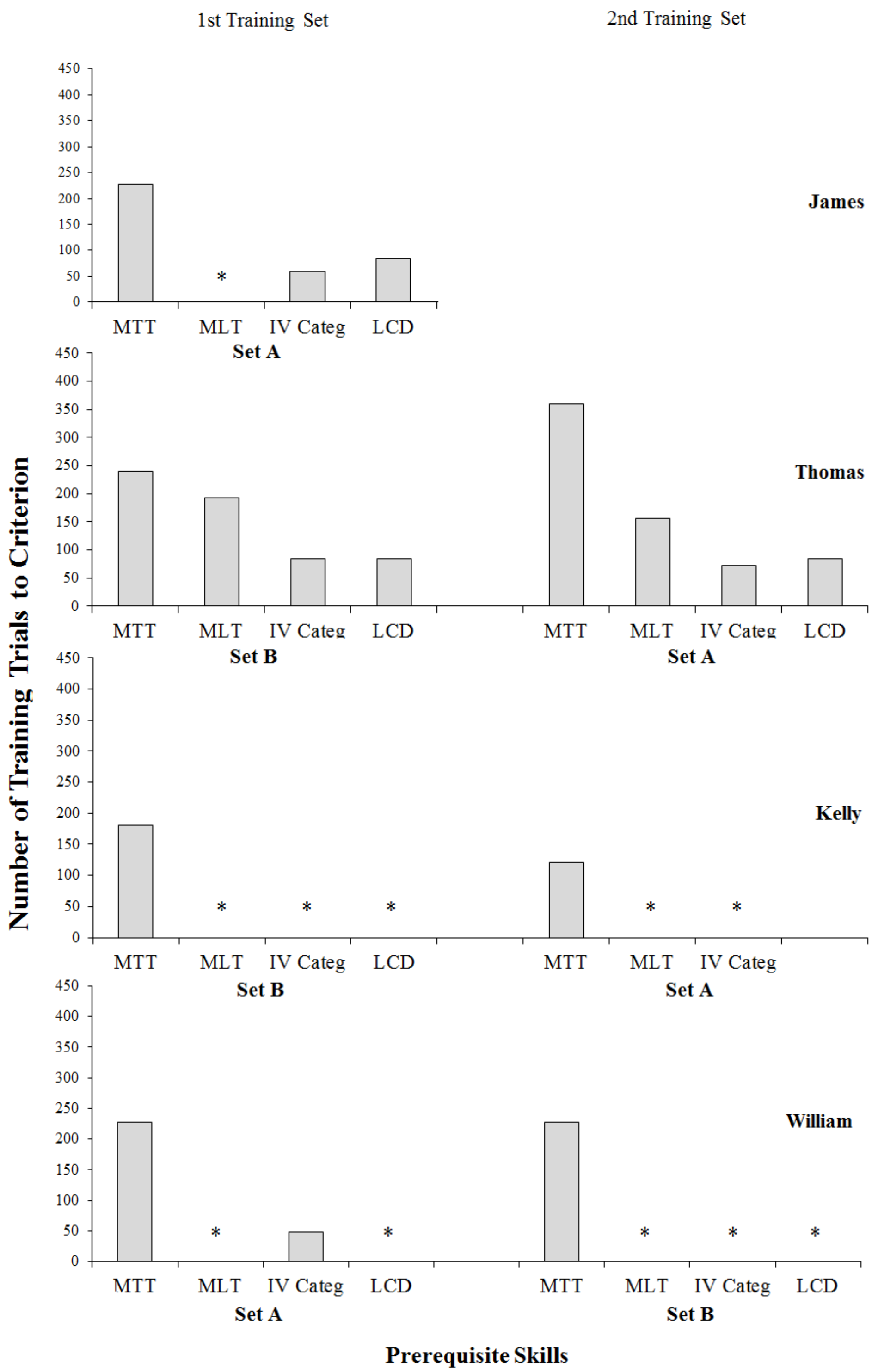

Figure 9: Training trials to criterion. Number of training trials to criteria during all prerequisite skill for all participants. The asterisks denote the phases in which participants responded to criteria during baseline sessions and training was no required. Because of that, no data is depicted for these skills. MTT = Multiple-Tact; MLT = Multiple Listener; IV Categ = Intraverbal Categorization; LCD = Listener Compound Discrimination; DOR = Differential Observing Response.

Although some participants performed to criteria during baseline sessions of prerequisite skills, the emergence of convergent intraverbals were only observed to criteria after baseline sessions of the complete prerequisite skill sequence (except for Kelly during Set A who performed to criteria during convergent intraverbals after baseline sessions of intraverbal categorization).

CHAPTER 3: DISCUSSION

Four children with autism, aged four to five, showed the emergence of convergent intraverbals after receiving training on a sequence of prerequisite skills that Sundberg and Sundberg (2011) suggested would facilitate the acquisition of intraverbals under multiple control. The outcomes of the current study suggest that, whereas training the individual component skills (e.g., MTT, MLT) resulted in mastery performance of those skills, correct convergent intraverbals first emerged (without direct training) for each participant only after they mastered all four component skills: MTT, MLT, intraverbal categorization, and LCD. In addition, we replicated this finding across sets of stimulus with two of the three participants that we exposed to the training sequence a second time with a new set of target stimuli. Thus, in six of seven applications of the training sequence hypothesized to facilitate convergent intraverbal responding, convergent intraverbals emerged at mastery levels without direct training. In the seventh application, convergent intraverbals emerged at mastery levels after the participant learned the first three of the four hypothesized prerequisite skills. Taken together, these results strongly support the hypothesis that this sequence of training represents an effective means of facilitating the emergence of novel, complex intraverbal behavior in young children with autism.

These results extend the literature on the emergence of multiply-controlled intraverbal behavior in several ways. First, prior studies have demonstrated that individuals with typical and atypical development can acquire complex intraverbal responses under the control of multiple conditional and discriminative stimuli via direct training using transfer-of-stimulus-control procedures or prompted DORs (Bramm & Poling, 1989; Kisamore et al., 2013; Kisamore et al., 2016). In addition, previous research has shown that training procedures can be arranged in ways to promote the emergence of simple intraverbal responses in individuals with typical and atypical development (e.g., De Souza & Rehfeldt, 2013; Grannan, & Rehfeldt, 2012; Miguel, Pettursdottir, & Carr, 2005; Petursdottir, & Haflidadottir, 2009). Finally, prior investigations have shown that children with typical development can show the emergence of complex intraverbal responses without direct training (Perez-Gonzalez et al., 2008). However, to our knowledge, the current study is the first to demonstrate that young children with autism can show the emergence of complex intraverbal responses without direct training. This represents a potentially important finding because the emergence of novel, complex intraverbals responses are critical to the development of conversational speech, a skill area that is often markedly impaired in children on the autism spectrum (Goldsmith, LeBlanc, & Sautter, 2007).

Second, results of the current investigation provide at least some support for the hypothesis that the development of intraverbal behavior follows a general sequence (Poon & Butler, 1972; Sundberg & Sundberg, 2011). That is, we trained four prerequisite skills hypothesized to facilitate the development and emergence of convergent intraverbal responding (Sundberg & Sundberg), and each participants first showed the emergence of the target intraverbals at mastery performance immediately after, and only after, training to mastery performance of the four hypothesized prerequisite skills. Prior research has provided correlation data supporting the notion of a general sequence in the development of intraverbal behavior (Sundberg & Sundberg). The current findings add to those data by providing experimental results demonstrating that training in accordance with the hypothesized sequence of intraverbal development resulted in the emergence of novel intraverbals in children who reportedly had not previously emitted intraverbal behavior at this level of complexity.

It should be noted that one participant, Kelly, showed the emergence of the second set of convergent intraverbal targets after training on just the first three hypothesized prerequisites (MTT, MLT, intraverbal categorization). This finding should not be surprising, as one might expect broader and more rapid generalization from the prerequisites to the target convergent intraverbals following repeated exposure to the training sequence with multiple exemplars, as has been demonstrated with other conditional discriminations (e.g., Saunders & Spradlin, 1990) and emergent relations (e.g., Rose, Souza, & Hanna, 1996). Nevertheless, it is possible that other training procedures, ones not following the hypothesized sequence, would have similarly facilitated the emergence of novel, convergent intraverbals in these children. That is, the current results show that training the hypothesized prerequisite skills proved sufficient for inducing novel and complex emergent stimulus relations in young children with autism, but the results do not demonstrate that training using this specific sequence is necessary for the emergence of such relations. Future research should examine whether the direct training other prerequisite skills or the training of the current prerequisite skills in a different sequence would produce equivalent or better effects relative to the emergence of convergent intraverbals.

Third, the training procedures we used to train each prerequisite skill proved effective in teaching the prerequisite skills to all four participants with little modification (i.e., James and Thomas required the addition of a remedial-trial procedure). The training procedures began with the continuous delivery of the discriminative stimulus (e.g., “Name it”; “Point to zebra”) and a controlling prompt (i.e., an echoic prompt for vocal responses; a point prompt for selection responses). In subsequent sessions, we inserted a progressively increasing delay between the discriminative stimulus and the controlling prompt (and we added the remedial-trial procedure for James and Thomas). Variations of these procedures have proven effective in prior investigations with a variety of target responses (e.g., Grow, Kodak, & Carr, 2014; Kobari-Wright & Miguel, 2014; Reichow & Wolery, 2011). The current results also suggest that these training methods may be useful for promoting emergent responses in addition to the target responses exposed directly to these training procedures.

In MTT, we trained participants to tact the target stimuli (e.g., zebra) as well as two characteristics of the target (e.g., mammal [Class 1] and from the savanna [Class 2]). During MLT, we taught participants to select specific stimuli when we presented the name of the target and their Classes in separated trials (e.g., “Point to the zebra,” “Point to all mammals,” and “Point to all from the savanna"). For intraverbal categorization, we taught participants to emit two intraverbal responses corresponding to Class-1 trials (e.g., "Tell me some mammals," with the correct response being "zebra" and "gorilla" in no specific order) and Class-2 trials (e.g., "Tell me some things from the savanna," with the correct response being "zebra" and "emu"). Finally, during LCD, participants responded as a listener in a conditional discrimination task involving compound stimuli (e.g., "Point to the mammal from the savanna").

We trained the MTT response first. This prerequisite skill required the most trials to produce mastery performance for every participant with every target set. Nevertheless, mastery of this skill alone produced minimal effects on the levels of correct intraverbals of the first training set for all participants (Figure 1). However, we observed higher levels of correct intraverbals following MTT training with the second target set relative to the fist for Kelly, Thomas, and William, the three participants trained on a second set of targets. Moreover, once they mastered the MTT targets, three of the participants (James, Kelly, & William) mastered MLT in baseline without direct training, suggesting that tact training facilitated the emergence of corresponding listener skills, consistent with a number of prior studies (e.g., Delfs, Conine, Frampton, Shilingsburg, & Robinson, 2014; Gilic & Greer, 2011; Miguel, Petursdottir, Carr, & Michael, 2008).

After mastering the MTT skills, Kelly showed mastery performance on each subsequent prerequisite skill during baseline, but she did not show mastery performance on the convergent intraverbal probes until after exposure to each of the prerequisite skills with the first target set or until after exposure to each of the first three prerequisite skills for the second target set. William showed the same response pattern except that he required some training in order to master the intraverbal categorization skills with the first set of targets. The fact that these two participants mastered all (Kelly) or almost all (William) of the prerequisite skills in baseline, but they did not master the convergent intraverbals until after exposure to all (or all but one) of the prerequisite skills, suggest that mere exposure to the prerequisite skill targets facilitated the emergence of the convergent intraverbals for these two participants.

We speculate that following MTT, MLT may have facilitated *naming* (Horne & Lowe, 1997) or *bidirectional naming* (Miguel, 2016) of the target stimuli (i.e., learning to respond in an equivalent manner to corresponding words and pictures). Next, intraverbal categorization may have facilitated functional, stimulus-stimulus relations between the topographically-defined classes (e.g., learning that “zebra” and “gorilla” go together as “mammals”; cf. Miguel, Petursdottir, Carr, & Michael, 2008). Finally, LCD may have facilitated conditional responding based on conjoint membership of a single stimulus in two stimulus classes (i.e., convergent stimulus control). That is, convergent control may be easier to learn first in a listener format (relative to an intraverbal format), because with a listener format the participant has access to some of the controlling stimuli (i.e., the pictures) until the participant emits the convergent response (e.g., all pictures remained present in front of the participants until they selected the picture of a mammal from the Savannah).

Our speculation is partially supported by results from prior investigations. Several studies have addressed the effects of simple tact training on the emergence of other operants, such as mands (e.g., Finn, Miguel, & Ahern, 2012; Nuzzollo-Gomes & Greer, 2004), intraverbals (e.g., Petursdottir, Olafsdottir, & Aradottir, 2008), and listener responding (e.g., Greer, Stolfi, Chavez-Brown, & Rivera-Valdes, 2005; Miguel, & Kobari-Wright, 2013). Studies involving tact and listener responding suggest that conditions can be created in which the acquisition of one response will promote the emergence of the other response (Fiorile & Greer, 2007; Greer, Yaun, & Gautreaux, 2005; Nuzzolo-Gomez & Greer, 2004). In other words, by teaching the tact of a specific target, the participant would demonstrate the emergence of the listener response toward that target without direct training, and vice-versa. The performance of our participants during

MLT following MTT is consistent with studies that demonstrated the emergence of listener responding following tact training.

The effects of MTT on the emergence of untrained intraverbal categorization also have been evaluated by few studies (Miguel, Petursdottir, & Carr, 2005; Partington, & Bailey, 1993). The results of both Miguel et al. (2005) and Partington and Bailey (1993) demonstrated that participants were able to respond with higher levels of correct responding during intraverbal probe sessions relative to baseline sessions. However, with our participants, MTT alone did not result in mastery performance, which required the subsequent addition of a transfer-of-stimulus-control procedure. The current study partially replicated these prior results (Figure 4), in that three of the participants (James, Thomas, and William [first training set]) had low levels of correct responses during the intraverbal categorization baseline and required direct training to master this prerequisite skill.

Fourth, because we collected data on the participant's use of DORs, but we did not specifically prompt the participants' to emit a DOR on each trial, the results provide some data relevant to the role of naming or the naming relation in the development of emergent stimulus relations (Horne & Lowe, 1997). In the applied literature, researchers have prompted or required DORs to overcome stimulus overselectivity in matching-to-sample tasks (Dube & McIlvane, 1999; Fisher, Kodak, & Moore, 2007; Walpole, Roscoe, & Dube, 2007) and to directly train multiply-controlled intraverbals (Kisamore et al., 2016). When DORs are not prompted, they may represent an example of naming or the naming relation (Horne & Lowe).

In the basic and theoretical literature on stimulus class formation, naming is hypothesized to be a higher-order response involving bidirectional stimulus relations between object or events and the speaker and listener responding they engender (Horne & Lowe). For example, when a verbally competent individual sees a picture (e.g., of a zebra), it typically evokes one or more tacts pertaining to relevant stimulus classes (e.g., "zebra", "mammal"), and each tact, in turn, may evoke relevant listener responding, such as identifying other pictures from a common stimulus class (looking at the gorilla because it also is a mammal).

The fact that three of the four participants in the current study displayed DORs without being prompted to do so is at least somewhat consistent with the naming account of emergent stimulus relations. In addition, rates of the DOR appeared to be somewhat correlated with corrected convergent intraverbal responding within those participants that displayed DORs (James, Thomas, and William). That is, these three participants showed near-zero or zero levels of the DOR during pretraining and rates of the DOR generally increased with or following training. However, rates of the DOR across participants showed little to no correlation with correct convergent intraverbals, as evidenced by the fact that all participants showed mastery performance of the convergent intraverbals despite the fact that Kelly showed zero rates, Thomas showed low rates, and James and William showed high rates of the DOR. Taken together, these results do not support the supposition that naming is necessary for the emergence of convergent intraverbals, but it is quite possible that naming facilitated emergent responding for James and William.

One limitation of the current investigation was that we trained the prerequisite skills in a given sequence with each participant (MTT, followed by MLT, then intraverbal categorization, and finally LCD). We chose this sequence based on theoretical framework provided by Sundberg and Sundberg (2011), which provided a conceptually sound rationale for why the sequence of prerequisite skills would facilitate the emergence of convergent verbal responding. However, this limitation leaves open the possibility that had we conducted training only with LCD for an amount of time approximately equal to that spent on all four prerequisite skills, it is possible that convergent intraverbal responding may have similarly emerged at mastery level. Because of this limitation, we are unable to conclude that it is necessary to train each of the prescribed prerequisite skills and to do so in the prescribed sequence to demonstrate the emergence of convergent intraverbals.

Another limitation is that all participants correctly tacted at least one of targets of all sets during baseline sessions. As such, the participants' history of reinforcement with these "known" targets may have influenced their performances of some prerequisite skill (e.g., MLT) and facilitated subsequent performances. However, knowing some of the targets did not influence the pretraining phase of intraverbal probes as demonstrated by zero levels of correct intraverbals before MTT (Figure 1). Future researchers studying convergent intraverbals should select unknown targets or use abstract stimuli to control for the effect of the history of reinforcement.

Finally, we did not conduct baseline sessions of MLT, intraverbal categorization, and LCD before MTT. We omitted these baselines to minimize participants' exposure to the target stimuli. However, without these baselines, we cannot completely rule out the possibility that the participants mastered at least some of the prerequisite skills prior to the study; therefore, conclusions regarding the emergence of untrained responses observed during baseline of prerequisite skills should be made with caution. Future research should conduct baseline sessions of all prerequisite skills before MTT.

The results of the current study demonstrated the emergence of convergent intraverbal in four children with a diagnosis of autism. The current study adds to the literature of skill acquisition because it provides a series of prerequisite skills that, when implemented to criterion in a prescribed sequence, can promote the emergence of intraverbal under multiple control in children with autism.

CONCLUSION

The results of the current study demonstrated the emergence of convergent intraverbal in four children with a diagnosis of autism. Few other studies have addressed issues related to intraverbals under multiple control and demonstrated effective procedures to teach this skill (Braam, & Poling, 1983; Kisamore, & Karsten, 2016; Perez-Gonzalez, & Williams, 2008). The current study adds to the literature of skill acquisition because it provides a series of procedures that, when implemented to criterion, can promote the emergence of intraverbal under multiple control in children with autism.

Differently from the studies above, we sought to teach progressively complex skills involving the same set of stimuli. Our sequence of procedures are consistent to what is commonly observed in clinical practice and followed the skill progression listed in skill assessment tools (Partington, 20006; Sundberg, 2008). Commonly, clinicians first teach children to tact and select objects and pictures of common items. Then, they teach the tact and selection of features of items. Next in the curriculum is intraverbal categorization in which children must provide several responses when presented with a category, feature, or function. Finally, they are required to provide responses under the control of multiple variables.

Expecting that hundreds of relations involving categories, features, and functions be directly taught is unrealistic in the midst of all the other deficits that must be addressed in children with autism. Therefore, understanding the conditions under which verbal behavior emerges without direct training is paramount for increasing efficiency of intervention programs.

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