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ARTICLE

Teaching multiply-controlled tacting to children with autism

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ABSTRACT
Responding accurately to questions is a fundamental skill, currently under researched in the applied field. The present paper reports the results of a multiple-baseline design across stimulus sets to establish multiply controlled tacting to verbal ("What is it?" "What does it say?" "What color?" "What number?") and nonverbal visual stimuli (colored objects, animals, and numbers). Two preschool children with autism were taught first to echo, then to tact, using matched autoclitic frames (e.g., "It's a spoon," "It's a cat," "It says meow," "Color red," "Number three") to the verbal antecedent to establish generalized responding under multiple control. Following intervention, responding of both children generalized to novel members of the stimulus classes, and for one child, to a novel stimulus class. Question discrimination skills thus developed as a generalized response class under multiple sources of control, irrespective of the particular stimuli.

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Autoclitic frames; question discrimination; multiple verbal control; tact; intraverbal

In the course of typical language development, the ability to respond verbally under multiple stimulus control begins early, as vocal topographies are first established by the social community. Thus, even in its earliest forms, verbal behavior typically occurs under multiple sources of stimulus control (Michael et al., 2011). For example, when a toddler first learns to mand for specific items, the item is nearly always present, often accompanied by a verbal antecedent ("What do you want?"), suggesting that specific vocal topographies may come to be acquired and eventually emitted under multiple motivational (mand), nonverbal (tact), and verbal (intraverbal) control (Miguel, 2017) from early childhood. Responding under multiple control in the tact relation typically appears before the age of two (Blank et al., 1978a, 1978b; Brown, 1973), as the social community establishes novel vocal topographies regarding the identity names and properties of items (e.g., colors, shapes, actions, names of people) in the presence of both nonverbal and verbal antecedent stimuli (e.g., questions).

Skinner's (1957) analysis of multiple verbal control, subsequently elaborated by Michael et al. (2011), describes two types of verbal stimulus control: (1) *convergent* verbal control, in which a single verbal response occurs as a function of more than one variable, and (2) *divergent* verbal control, in which a single variable increases the strength of more than one related verbal response. For example, in a child with an elementary tact repertoire (including identity names, colors, and shapes), when the parent holds up

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a blue ball and asks "What color is it?" two subsets of divergently controlled verbal responses are assumed to increase in probability. The verbal stimulus "Color" increases the momentary response strength of a variety of intraverbal relations related to color names. Contact with the nonverbal stimulus (the ball), on the other hand, raises the strength of previously established tact relations; in this case, regarding the identity, the shape, the size, and the properties, respectively.

According to Skinner's account of multiple control, the only response in this case that can be emitted under both sources of stimulus control (verbal and nonverbal) is "Blue." Hence, the response "Blue" is said to occur under the convergent control of both verbal and nonverbal variables (Michael et al., 2011). "Blue" is thus the strongest of the various responses that are fluctuating in strength at that moment, because of its multiple sources of strength (Michael et al., 2011). Similarly, when the parent asks in relation to the same blue ball "What is it?" the child would say "Ball," and when the parent asks "What shape is it?" the child would respond "Round," provided the specific tacts have previously been acquired in the context of these verbal antecedents.

In children with autism, the ability to respond differentially to questions can be significantly impaired (Howlin, 1982). Unfortunately, the ability to discriminate questions to visual stimuli has received limited attention both by published Early Intensive Behavioral Intervention manuals (Leaf & McEachin, 1999; Lovaas, 2003; Sundberg & Partington, 1998; Taylor & McDonough, 1996) and applied research. The research which has been conducted on question discrimination has focused largely on either establishing (a) responding to *Wh* and *How* questions with respect to complex visual stimuli (Krantz et al., 1981), (b) specific intraverbal responses to questions regarding the class, features or functions of items (e.g., DeSouza et al., 2019; Ingvarsson et al., 2016; Jahr, 2001), or (c) a combination of these elements (e.g., "What's an animal that's red?"; e.g., Kisamore et al., 2016) through the use of echoic to intraverbal, tact to intraverbal prompt transfer procedures, multiple exemplars, blocked trials and discrimination training (see Stauch et al., 2017 for a review).

In some of these studies, children are taught to echo aspects of the verbal antecedent to facilitate discrimination. For example, Krantz et al. (1981) established discrimination of *Wh* and *How* questions (what, why, and how) in relation to pictures of scenes from magazines through echoic and thematic prompts and by requiring children to answer by using a full sentence that formally matched aspects of the verbal antecedent ("What is the boy doing?" "The boy is eating"). Similarly, Jahr (2001) taught intraverbal responding to mixed *Wh* questions by requiring children to answer with a sentence that was structurally similar (i.e., contained the same words) to the question. When asked "What do you like to eat?" vs "What do you like to drink?" children were taught to say "I like to eat X" vs "I like to drink Y." Provided the actual name of the item was in the children's verbal repertoire, and the target response was emitted in a full sentence that matched the question, children showed discriminated responding to novel questions. Kisamore et al. (2016) taught specific intraverbal responses to multi-component questions (e.g., "What's an animal that's red?" vs "What's a vehicle that's red?" vs "What's an animal that's yellow?") by requiring children to repeat critical parts of verbal antecedents followed by the specific target response (e.g., saying "Animal red [parrot]" when asked "What's an animal that's red?").

Jahr (2001) suggested that generalized discriminative responding occurred because the answers taught were "emitted in a full sentence and there [was] structural correspondence between the question and the answer in each single exemplar and across exemplars within a class of questions" (Jahr, 2001, p. 421). Similarly, Krantz et al. (1981) proposed that teaching children to employ a full sentence matching the verbal antecedent facilitated discrimination, because the full sentence functioned as a response chain "in which the question prompted an initial part of the answer, and the first part of the answer prompted the remainder" (Krantz et al., 1981, p. 283). Collectively, the results of these studies highlight the effectiveness of teaching children to emit, as part of the target response, a phrase, clause or sentence that partly matches the verbal antecedent, which may exert intraverbal control over subsequent parts of the response to facilitate intraverbal discriminations.

Such phrases, clauses, sentence structures, or incomplete intraverbal chains that "combine with responses appropriate to a specific situation" (Skinner, 1957, p. 336) can be defined as autoclitic frames: "verbal operants consisting of alternating fixed and variable elements controlled by some feature common to all cases" (Palmer, 2007, p. 169). The unique aspect of an autoclitic frame is that the terms are intraverbally related with one another, with the fixed terms participating in exerting additional control over the subsequent variable terms (e.g., "Look at the X" "It's a Y") in a given context. In other words, saying one term will increase the likelihood of saying the other participating members of the frame. The function of an autoclitic frame is the form, the structural regularity, evoked by the intraverbal relation between the participating members of the frame and the effect that this has on the listener (Palmer, 2007). The emission of a frame in a relevant context is also an example of multiply controlled verbal behavior (Palmer, 2016).

Capitalizing on the potential intraverbal properties of autoclitic frames and procedural strategies from prior research on echoing parts of the verbal antecedent (Jahr, 2001; Kisamore et al., 2016; Krantz et al., 1981), we sought to establish generalized multiply-controlled tacting under the control of both verbal (the questions) and nonverbal stimuli (pictures of animals, colored numbers, and colored objects) with two young children diagnosed with autism spectrum disorder (ASD) who responded under nonverbal stimulus control only (i.e., saying the name of the item regardless of the question). To overcome the problem, the children were taught to emit the target response within an autoclitic frame ("*It's a* [cat]" "*Color* [green]" "*It says* [meow]" "*Number* [four]") matching the verbal antecedent stimulus ("What is it?" "What color?" "What does it say?" "What number?"). We applied this procedure with respect to members of one set of visual stimuli and tested for generalization on novel members of the same set to assess within-class generalization. In addition, probes on novel stimulus sets were conducted throughout the study to test across-class generalization. The overall aim was to establish tacting under multiple echoic, intraverbal, and nonverbal control as a generalized skill, irrespective of the specific exemplars, in children whose responding was under restricted nonverbal stimulus control.

Method

Participants

Sarah (3 years of age) and Richard (4.6 years of age) were two British children who had received a diagnosis of ASD from the National Health Service multidisciplinary disability

team and had an Educational Health and Care Plan (EHCP) in compliance with UK educational regulations. Both children had been enrolled in a privately funded ABA home-based program since the age of two, could produce two-word echoic responses, and had a verbal repertoire of more than 300 element tacts.

On the VB-MAPP, Sarah fully completed Level 1 and demonstrated several Level 2 skills, including social and group skills, for a total score of 92. She did not achieve any milestone at Level 3. On the intraverbal assessment, she achieved 9/10 for Group 1, 2/10 for Group 2, and 0/10 for Group 3. Given her young age, Sarah had not yet been taught any listener or speaker skills in relation to printed numbers.

On the VB-MAPP, Richard scored at Level 1 and at Level 2 across most domains and at Level 3 for some academic skills, for a total score of 102. On the intraverbal assessment, Richard's scores were 10/10 for Group 1, 4/10 for Group 2, 2/10 for Group 3, and 0/10 for Group 4. He had also begun to work on listener and intraverbal responses by feature, function, and class. In the context of a comprehensive evaluation of his verbal, social, and communication skills, it became apparent that Richard made consistent and recurrent verbal discrimination errors. For example, when asked "What is a cat?" Richard would say "Meow," when asked "What is he drinking?" on a picture of a boy drinking juice, he would say "Cup." Despite having mastered several intraverbal responses regarding the category, function, and feature, he failed to respond discriminatively when those same verbal antecedents were presented in conjunction with the related nonverbal stimulus. For example, when presented with a picture of a cat and asked the questions "What is it?" "What color?" "What does it say?" "What is a cat?" "What does it have?" Richard generally answered with the name of the item, regardless of the question posed. When asked "What does a cat say?" he would say "Meow," but if the word "Cat" was omitted from the question (i.e., "What does it say?"), he would say the name of the animal in the picture (i.e., "Cat"). He would at times say the category word "Animal," but only if the instructor presented the verbal instruction as a fill-in sentence (i.e., "A cat is an . . . "). However, if one did not say "An" in the verbal antecedent but said "A cat is . . . " he would generally reply "Meow" instead. It was clear throughout the assessment, that Richard had learned to answer specific questions intraverbally, but when the questions related to the same concepts were asked in the presence of the relevant nonverbal stimulus, he simply gave the name of the item, irrespective of the question posed.

Setting and materials

All experimental sessions took place in the participants' homes in a dedicated teaching room. The instructor and the child sat opposite each other at a table.

Table 1 shows the stimulus sets used during all phases of the experiment. A random number and sequence generator program (www.textmechanic.com) produced the necessary randomization of verbal and nonverbal stimuli positions for each block of trials in every session, for a total of 1680 different combinations. Because it was not possible to test all the combinations, the positions of the visual stimuli were randomized, as was which of the two verbal stimuli was presented for each of the visual stimuli for a total of 20 trials per session per set (40 trials for the combined teaching and novel sets).

Table 1. Experimental verbal antecedents and visual stimuli for each experimental phase and trials per session

Set number	Set name	Visual stimuli	Verbal antecedents	Experimental phase (trials)
1	Number component	8 white cards (7 cm x 10 cm) with black printed numbers 1-8	What number?	Step 2 Autoclitic tact
2	Color component	6 swatches (8.89 cm x 12 cm) in Blue, yellow, red, green, pink, brown	What color?	Step 2 Autoclitic tact
3	Colored numbers teaching	16 white cards (7 cm x 10 cm) with printed numbers 2, 3,5 7 each in blue, yellow, red, green	What number? What color?	Baseline 1 (20) Step 3 Discrimination
4	Colored numbers novel	16 white cards (7 cm x 10 cm) with printed numbers 1, 4, 6, 8 each in blue, yellow, red, green	What number? What color?	Baseline 1 (20) Baseline 2 (20) Follow up (20)
5	Animal teaching	4 photographic cards: Dog, cat, mouse, lion	What is it? What does it say?	Baseline 1 (20) Step 2 Autoclitic Tact Step 3 Discrimination
6	Animal novel	4 photographic cards: Cow, horse, sheep, frog	What is it? What does it say?	Baseline 1 (20) Baseline 2 (20) Follow up (20)
7	Animal Color Sound novel	8 photographic cards of new representations of Set 5 and 6 animals in Set 2 colors	What is? What color? What does it say?	Probes (24)
8	Objects teaching	8 everyday object cards: Car, spoon, knife, plate, block, tissue, bag, necklace in Set 2 colors (except pink and brown)	What is it? What color?	Baseline 1 (20) Step 2 Autoclitic Tact Step 3 Discrimination Probes (20)
9	Objects novel	8 everyday object cards: Cup, hat, fork, pen, brush, key, shoe, book in all Set 2 colors	What is it? What color?	Baseline 1 (20) Baseline 2 (20) Follow up (20) Probes (20)

Response definition and measurement

The primary dependent variable was the percentage of correct, unprompted, multiply-controlled tacts, defined as verbal responses that matched both the verbal antecedent and the visual stimulus, within 2 s of instruction delivery, irrespective of whether the response was emitted within an autoclitic frame. Additional data were taken on a secondary dependent variable: the independent use of matched autoclitic frames, before, during, and following intervention. This was defined as the child independently saying "Color [color name]" to the verbal antecedent "What color?" "Number [number name]" to "What number?" "It's a [animal name]" or "It's a [object name] to "What is it?" and "It says [sound]" to "What does it say?" This measure was taken on each trial, whether responding on the primary dependent variable (the multiply controlled tact) was correct or incorrect.

In *Baseline 1, Discrimination* (Step 3), *Baseline 2, Follow up*, and *Probe* sessions, correct responses were defined as multiply-controlled tacts in which the response matched both the verbal antecedent and the visual stimulus, with or without a frame, and occurred within 2 s of the delivery of the instruction. Table 2 shows correct and incorrect response definitions with respect to Animal vs Sound, for illustration, though

the same response definition criteria applied to Object vs Color and Number vs Color. For the objects, a correct response was defined as saying the object name, with or without a frame ("Car" or "It's a car") to the verbal antecedent "What is it?" The color response was defined as saying the color name, with or without a frame ("Red" or "Color red") to the verbal antecedent "What color?" For the colored numbers, a correct response was defined as saying the number name, with or without a frame ("Two" or "Number two") to the verbal antecedent "What number?" The color response was the same as for the Object vs Color.

In *Echoic* (Step 1) sessions, a correct response was defined as echoing all parts of the target verbal stimulus with clear articulation within 2 s from the delivery of the instruction (e.g., repeating "It's a cat" to the instruction "Say 'it's cat'"). An incorrect response was defined as echoing only a part of the verbal stimulus (e.g., saying "Cat" to the instruction "Say 'it's a cat'"). In *Autoclitic tact* (Step 2) sessions, a correct response was defined as emitting the target tact to the visual stimulus, within an autoclitic frame matching the verbal antecedent. For example, upon presentation of the picture of a cat and the verbal antecedent "What is it?" the correct response was "It's a cat." Similarly, upon presentation of the picture of a cat and the verbal antecedent "What does it say?" the correct response was "It says meow." An incorrect response was defined as: (1) omitting the frame but tacting the nonverbal stimulus correctly (e.g., saying "Cat"), (2) tacting the nonverbal stimulus incorrectly with or without a frame (e.g., "Dog" or "It's a dog"), (3) saying the frame only ("It's a"), or (4) any response before the verbal antecedent had been delivered.

Interobserver agreement and treatment integrity

A second independent observer was either present in the room or watched a video of the session for 100% of pre-assessment trials, 50% of teaching sessions, and 100% of *Baseline 1, Baseline 2*, and *Probe* sessions. Interobserver agreement (IOA) was collected on correct responding, errors, and independent use of the autoclitic frame. On each trial, the experimenter and observer noted if the response was either correct, incorrect, or prompted, and if a matched autoclitic frame had been emitted. IOA was calculated by

Table 2. Definitions of correct and incorrect responses to the verbal antecedent (VA) "What is it?" and "What it say?", and the visual stimulus (VS) cat.

			Type	What does it say?	What is it?
Animal vs Sound 	*Correct*		Matched VA & VS	"Meow", "It says meow"	"Cat", "It's a cat"
	Incorrect	1	Discrimination error (Unmatched VA & matched VS)	"Cat", "It says cat", "It's a cat"	"Meow", "It's a meow", "It says meow"
		2	Tact error (Matched VA & unmatched VS)	"Woof", "It says woof"	"Dog", "It's a dog"
		3	Combined response	"Meow cat", "Cat meow"	"Meow cat", "Cat meow"
		4	Anticipatory response	Any responding prior to VA	Any responding prior to VA

Note. Verbal Antecedent (VA). Visual Stimulus (VS).

dividing the number of agreements for each trial by the total number of trials and converting the result to a percentage. For Sarah, IOA was 97.5% (range 95 to 100%) and for Richard 95% (range 92% to 100%).

For treatment integrity, a trial was scored as correct if the instructor engaged in all of the following steps: (a) presented verbal and nonverbal stimuli in accordance with the prescribed randomized order; (b) presented tokens in accordance with the prescribed production and exchange schedule; (c) presented verbal and nonverbal antecedent stimuli correctly and according to the specified phase; (d) allowed the child the specified time to respond after presenting the verbal antecedent; (e) presented programmed prompts for the specified phase; (f) presented transfer trials after a prompted trial; (g) did not provide any feedback during *Baseline 1, Baseline 2, Follow up*, and *Probe* sessions. A trial was scored incorrectly if an error was made in any of the steps. The number of correctly conducted trials was divided by the total number of trials, and the result was converted to a percentage. Treatment integrity was 100% for Sarah and 98.5% (range 97% to 100%) for Richard.

Element tact pre-assessment

The purpose of the pre-assessment was to evaluate whether the children could produce the relevant animal sounds intraverbally and tact the elements of the compound stimuli that would be presented in the experiment proper. All sets were employed in this phase, except for Sets 3 and 4 (colored numbers teaching and colored numbers novel sets). Sarah was not tested on any sets that involved numbers (Set 1). Each stimulus card was presented only once, in isolation, with the corresponding verbal antecedent. For example, the experimenter held up a color swatch and asked the question "What color?" To animal cards and objects, children were asked "What is it?" For the animal sounds, children were asked "What does a [animal name] say?" in the absence of the relevant visual stimulus. Both children correctly tacted all presented stimuli and emitted the target intraverbal sounds; no stimulus replacement was necessary. There were no programmed consequences for either correct or incorrect responding.

To ensure children's collaboration, maintenance tasks were interspersed every one or two consecutive target trials. Tokens were delivered on maintenance tasks only, according to the children's current schedule for such skills: variable ratio (VR) 3 token production (3 responses, on average, to produce a token) and fixed ratio (FR) 5 exchange production (5 tokens to produce exchange opportunities) for Sarah, and VR 4 token production and FR 8 for exchange production for Richard. Upon meeting the exchange production schedule, experimental stimuli were removed and a tray or a box containing children's personal reinforcers was presented; children manded or picked up their preferred item and consumed the reinforcer. If a toy or iPad was chosen, consumption was roughly 30 s. Food was placed in a small Tupperware box, which the children could open; once the food was consumed, the box was removed and another piece of food was placed inside, ready for the next exchange period.

Procedures

Overview

A multiple-baseline design across stimulus sets with additional probes was employed. Children completed baseline assessments (*Baseline 1*) on all sets upon which the three-

step teaching intervention would be subsequently introduced. The teaching intervention was introduced on one stimulus set, while the second stimulus set remained on baseline (no teaching). After mastery had been achieved on the first set, intervention was introduced with respect to the second set.

Figure 1 provides an illustration of the general sequence with respect to Animal vs Sound. In Step 1 (*Echoic*), children were taught to echo the relevant autoclitic frames (e.g., "It's a cat" "It says meow") in the absence of visual stimuli. In Step 2 (*Autoclitic tact*), children were taught to produce the relevant tacts within the previously established autoclitic frames when answering the relevant question ("What is it?" "What does it say?") in a simultaneous simple discrimination arrangement. The same question was asked across multiple exemplars of the same stimulus class (e.g., animal teaching set). In Step 3 (*Discrimination*), the two questions related to the visual stimuli were randomly rotated (e.g., "What is it?" vs "What does it say?") in a conditional discrimination arrangement. Following mastery of Step 3, responding was tested again on novel stimuli within the target stimulus class (e.g., animal novel set) in a return to baseline (*Baseline 2*) phase, and subsequently for *Follow up* sessions on all teaching and novel sets. Additionally, *Probe* sessions were arranged throughout the study on two additional stimulus sets upon which no teaching was introduced. Each session lasted approximately 10 to 20 minutes. Children participated in one to two sessions per day, four to five days a week.

Baseline 1 sessions

Stimuli were presented on the table in a horizontal array of four items, with the array changing after five trials. Five verbal antecedents for the four visual stimuli were presented. Figure 2 provides an example of three randomized blocks of trials with 5 questions per block for each stimulus set. After laying out the four visual stimuli, the instructor pointed to one card, presented the target verbal antecedent, and waited 2 s for the child to respond. Once the trial block was completed, stimuli were removed and replaced by four new ones.

As in the pre-assessment, there were no programmed consequences for either correct or incorrect responding. To ensure children's collaboration, maintenance tasks were interspersed every one or two consecutive target trials, as previously described. Both children were tested on a different stimulus set each morning or afternoon, to ensure that baseline assessments did not take too much time away from their ABA-home based intervention. Both received baseline assessment with respect to the animal teaching set (Set 5) and the animal novel set (Set 6). Because Sarah was three years old and did not have any verbal behavior with respect to printed numbers, she did not receive baseline measures on the colored numbers sets (Set 3 & Set 4). Instead, she underwent baseline assessments on the objects teaching set (Set 8) and the objects novel set (Set 9). Richard underwent baseline assessments on the colored numbers teaching set (Set 3) and the colored numbers novel set (Set 4).

Teaching intervention sessions

Step 1: echoic. The purpose of this phase was to increase the intraverbal control between the participating fixed and variable terms of the relevant autoclitic frame. Our expectation was that saying the fixed frame (e.g., "It's a" "Number" "Color" "It says") would increase the

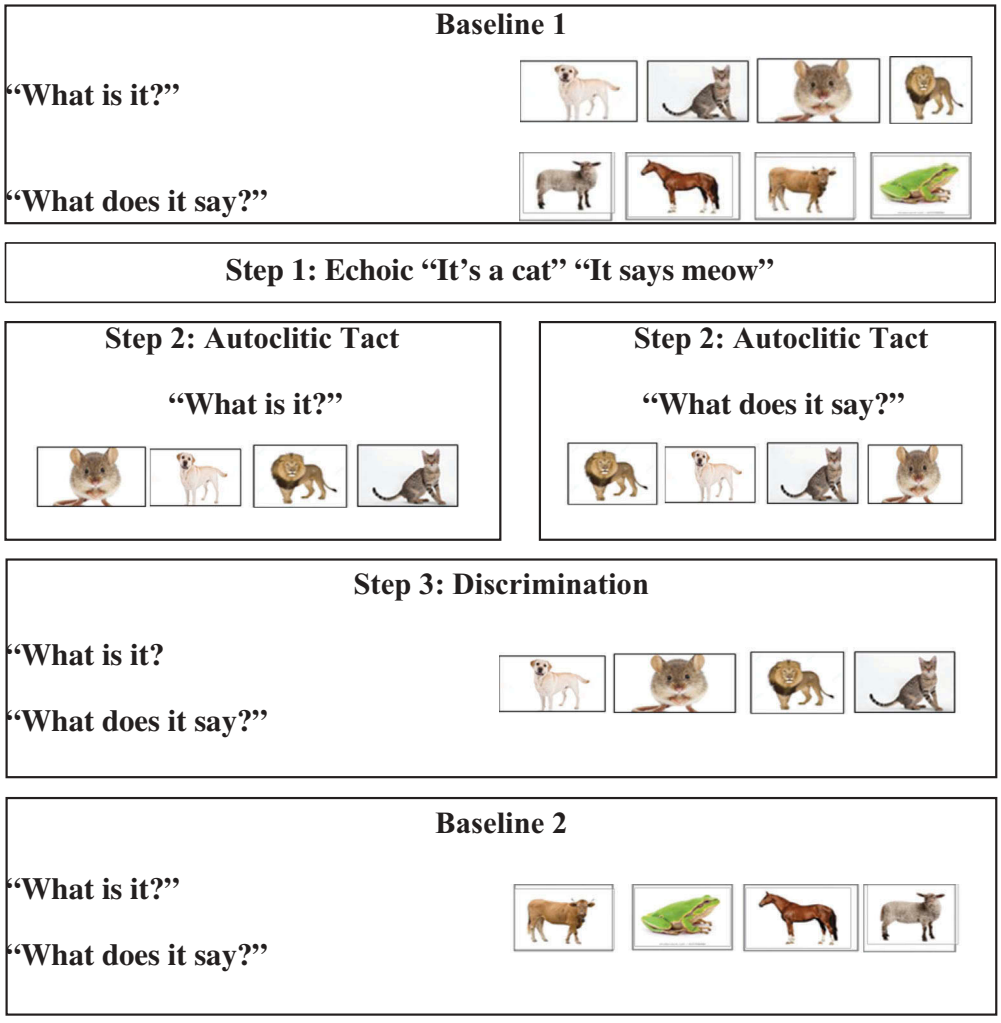

Figure 1. Teaching sequence for animal versus sound as an example. [To view this figure in color, please see the online version of this journal].

likelihood of saying the variable names (e.g., "Cat" "Three" "Green" "Meow") in the subsequent experimental phases because of a history of reinforcement for having produced these terms together in this phase. An additional objective was to ensure that the children could pronounce the relevant vocal stimuli with clear articulation.

The instructor and the child sat opposite each other. The instructor said, "We are going to repeat some words" and then proceeded to deliver the instruction (e.g., "Say 'It's a [animal name]'"). Blocks of frames (e.g., "Its' a [animal name] and "It says [animal sound]") were presented in separate and counterbalanced blocks of trials, rather than interspersed with one another. If the child correctly echoed all parts of the verbal antecedent, a token was delivered. If the child echoed only one part of the verbal stimulus, the trial was presented again with a pause in between the target words, so that the child could echo the first words (e.g., "It's a"), after which the subsequent word

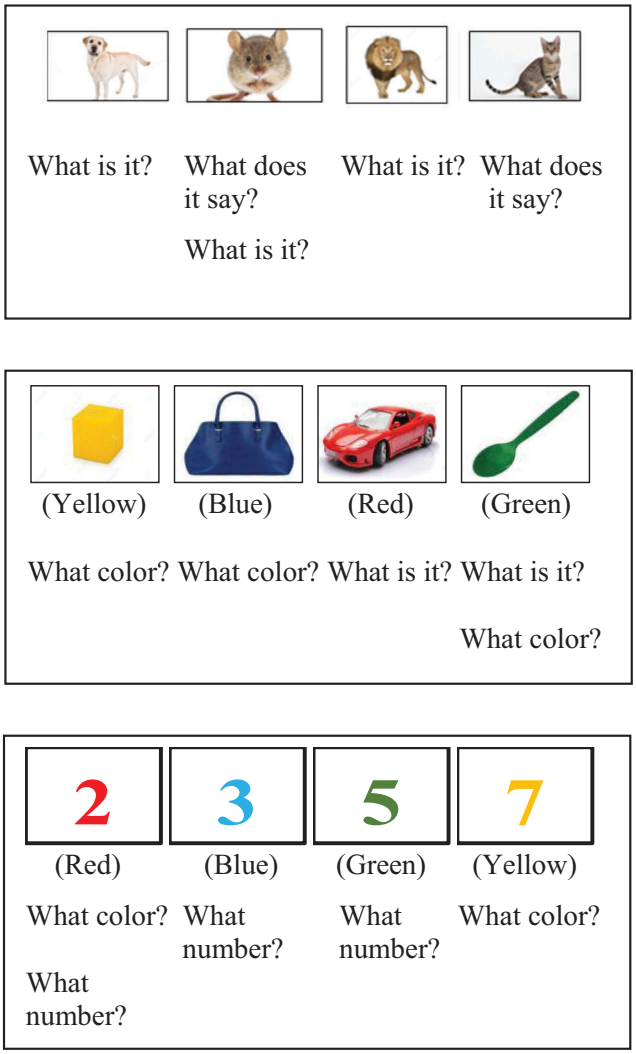

Figure 2. Example of three randomized blocks of trials with 5 questions per block for each stimulus set.

was presented (e.g., "Cat"). No reinforcement was given on these trials. Following echoing the second word, a transfer trial was immediately delivered in which the target verbal stimulus (e.g., "It's a cat") was presented. If the child echoed all parts, a token was delivered, and a new verbal stimulus presented. Mastery criterion was set at 100% for two consecutive sessions.

Both children received teaching on the animal name and animal sound frames. The autoclitic frames were "It's a [animal name]," (e.g., "It's a cat") and "It says [animal sound]," (e.g., "It says meow"). Only the animal names and sounds related to the animal teaching set (Set 5) were targeted; animal names and sounds corresponding to the stimuli in the animal novel set (Set 6) were not. Each session consisted of a minimum of 16 trials.

Sarah received echoic teaching on the frames that were relevant to Object vs Color intervention, for which the fixed terms were "It's a" and the name of the objects that made

up the object teaching set (e.g., "It's a car"), and "Color" and the names of four colors that made up Set 2 (red, blue, yellow, green, but not on pink and brown). A minimum of 12 trials per session were conducted. Richard received echoic teaching on the frames that were relevant to the Number vs Color intervention. For him, the target echoics were also the names of four colors that made up Set 2 (red, blue, yellow, green, but not pink or brown) and "Number [number name]," (e.g., "Number two"). Only the names of the Set 3 numbers (2, 3, 5, 7) were targeted. The other numbers names (1, 4, 6, 8), linked to novel stimuli (Set 4), were not. Each session consisted of a minimum of 16 trials.

Step 2: autoclitic tact. The aim of this phase was to teach children to produce the element tact within an autoclitic frame in which the fixed part matched the verbal antecedent stimulus. In other words, we taught children to emit the relevant tacts as the variable elements of a frame of which the fixed aspects were, for example, the words "It's" or "It says" and word order (i.e., saying "It's a" before the name tact, saying "It says" before the sound tact). There were two types of trial blocks in this step, which were conducted separately and were counterbalanced each day. In each block, responses to only one question were targeted.

Stimuli were presented in a simultaneous simple-discrimination arrangement during which the instructor laid out four visual stimuli in a horizontal array on the table. On the very first trial of the first session for this step, the instructor pointed to one visual stimulus, gave the verbal antecedent (e.g., "What is it?"), and immediately provided the full verbal prompt "It's a [animal name]" (e.g., "It's a cat"). If the child echoed the response correctly, a transfer trial was presented, in which the instructor re-presented the verbal antecedent for that visual stimulus and waited 2 s. If on the transfer trial, the child engaged in the target autoclitic tact (saying "It's a cat"), a token was given and a new trial on a new visual stimulus commenced. The instructor pointed to another visual stimulus, presented the relevant verbal antecedent, and waited for 2 s for the response to occur. If the child responded correctly, a token was given.

A least-to-most prompting approach was used to correct any errors. We report here only the correction procedures that were necessary, based on children's errors (Errors 1 and 4; see Table 2). If a frame omission occurred (Error 1), the instructor presented the verbal antecedent again and waited for 2 s. If the child omitted the frame a second time, a "frame prompt" was used on the third trial, whereby the instructor re-presented the verbal antecedent and gave only the fixed term of the frame (e.g., "It's a … "). If the child emitted the target response (e.g., "It's a cat") subsequent to the frame prompt, a transfer trial was presented. If on the transfer trial, the child did not emit the target response and once again provided only the element tact without the frame, the instructor presented the verbal antecedent again, followed by a full verbal prompt ("It's a cat") and another transfer trial. Any response that had been immediately preceded by a frame prompt or a full verbal prompt did not receive reinforcement and was always immediately followed by a transfer trial. If the child responded correctly on the transfer trial, a token was given.

If the child responded prior to the verbal antecedent (Error 4), the instructor presented the verbal antecedent while pointing to the visual stimulus and waited 2 s for the response to occur. If a frame omission error (Error 1) occurred at this point, the previously described error correction procedure followed; if the response was correct,

a token was given. The same procedure was used for each block of trials. A minimum of 24 trials per session were conducted. Mastery criterion was set at 100% of teaching trials for two consecutive sessions.

Both children received the Animal vs Sound intervention, with respect to the animal teaching set (Set 5). The same visual stimuli from this set were used for both the "What is it?" and "What does it say?" question blocks. Sarah received Object vs Color intervention, during which the object teaching set (Set 8) was used for the trial blocks corresponding to the "What is it?" question and the color component set (Set 2) was used for the "What color?" question blocks. In the object name trial blocks, the objects were laid on the table, the verbal antecedent was "What is it?" In the color trial blocks, four color swatches (red, blue, yellow, green, but not pink or brown) from the color component set (Set 2) were targeted, the verbal antecedent was "What color?" Richard received intervention on Number vs Color, during which the number component set (Set 1) and four color swatches (red, blue, yellow, green, but not pink or brown) from the color component set (Set 2) were used. In the number trial blocks, only four (2, 3, 5, 7) of the eight black and white numbers belonging to the number component set (Set 1) were presented. The verbal antecedent was "What number?" No teaching was given on the numbers that made up the colored numbers novel set (Set 4). The color trial blocks were the same as previously described for Sarah.

Step 3: discrimination. At the start of each session, before presenting the visual stimuli on the table, the child was asked to echo the relevant frames for the to-be-presented stimuli once and in random order. These echoic trials functioned as primers with the aim of potentiating intraverbal control between the autoclitic frame fixed and variable terms, potentially reducing the need for prompting during subsequent discrimination trials. Only verbal praise was given at the end of the echoic priming trials, after which discrimination trials commenced. The echoic priming trials were dropped completely after the first discrimination session in which 100% correct responding was met.

Stimulus presentation and randomization for the discrimination trials were the same as during the baseline sessions. Unlike baseline, however, token reinforcement for correct responding was provided. The token reinforcement schedules were FR 1 (token production) and FR 4 (exchange production) for Sarah, and FR 1 (token production) and FR 8 (exchange production) for Richard. If a discrimination error occurred (e.g., saying "It's a cat" when the verbal antecedent was "What does it say?") (Error 1), then the frame prompt described in Step 2 was used. If incorrect responding occurred on the transfer trial following the frame prompt, the instructor simply proceeded to the next stimulus in the sequence. The actual target tact for the presented stimulus (i.e., the animal name or sound) was never prompted in this step. This was because we aimed for the multiply-controlled tact to occur as a result of the stimulus control history established in the prior steps and the independent differential frame use, rather than as a result of full verbal prompting and fading. Any prompted trials were not reinforced. A minimum of 20 trials per session were conducted. Mastery criterion was set at 100% of teaching trials for two consecutive sessions.

Baseline 2 sessions

The aim of this phase was to evaluate changes in multiply-controlled tacting with respect to novel stimuli that had been assessed during *Baseline 1*, but for which no teaching had been

carried out. Both children were tested on the animal novel set (Set 6). Additionally, Sarah was tested on the objects novel set (Set 9) and Richard on the colored numbers novel set (Set 4). Twenty trials per set were delivered. All other procedures were the same as in *Baseline 1*.

Follow up sessions

Follow up trials were conducted every 3 to 10 sessions, in which procedures and stimulus sets were identical to *Baseline 1*.

Probe sessions

Probe trials were conducted throughout the study on stimulus sets for which no intervention was introduced. For both children, probe measures were taken on Set 7 (animal color sound novel); however, for Richard, probe measures were also taken on Set 8 (objects teaching) and Set 9 (objects novel). Procedures for Set 8 and Set 9 were the same as in *Baseline 1*. The procedures were slightly different for Set 7: the three verbal antecedents ("What is it?" "What color?" "What does it say?") were presented consecutively on a single visual stimulus in a successive simple-discrimination arrangement. The instructor laid a single animal picture on the table in front of the child, delivered one of the three verbal antecedents, and waited 2 s for the child to respond. There were no programmed consequences for either correct or incorrect responding; maintenance tasks were interspersed randomly, after one, two, or three verbal antecedents had been delivered. This stimulus presentation change was applied because we wished to explore how children would respond if multiple verbal antecedents, with respect to a single visual stimulus, were presented successively, in a way that more closely resembled day-to-day early verbal interactions.[1]

Results

Both children completed all phases of the experiment in under six weeks and demonstrated generalized multiply-controlled tacting on novel stimuli within established (Sarah) and novel stimulus sets (Richard). Figures 3 and 4 display, for Sarah and Richard respectively, correct responding in relation to the different verbal antecedents for the teaching and novel sets combined into one data path during *Baseline 1* and *Probe* sessions. These figures show data from all experimental phases, including the three teaching intervention steps, to illustrate the changes in responding on the probed sets in relation to the changes in responding during intervention on the teaching sets. Data paths for the intervention steps relate to teaching stimuli only. The *Baseline 2* data path shows responding to novel stimuli only.

During the three *Baseline 1* sessions for Object vs Color, Sarah's accuracy was low (Figure 3, top graph, first panel). There were no non-responses; Sarah provided a response in each of the trials. Her error pattern was very clear: She responded almost exclusively by saying the identity name of the object or the animal (Figure 3, top and middle graph, first panel), irrespective of the verbal antecedent, suggesting that her response was under simple nonverbal stimulus control on most of the 40 baseline trials.

On the *Echoic* teaching step for Object vs Color, one teaching session was required to achieve mastery criterion (Figure 3, top graph, second panel). On the *Autoclitic tact* step (Figure 3, top graph, third panel) errorless performance on producing the color names with the frame "Color" was achieved in six sessions, one session prior to correctly tacting

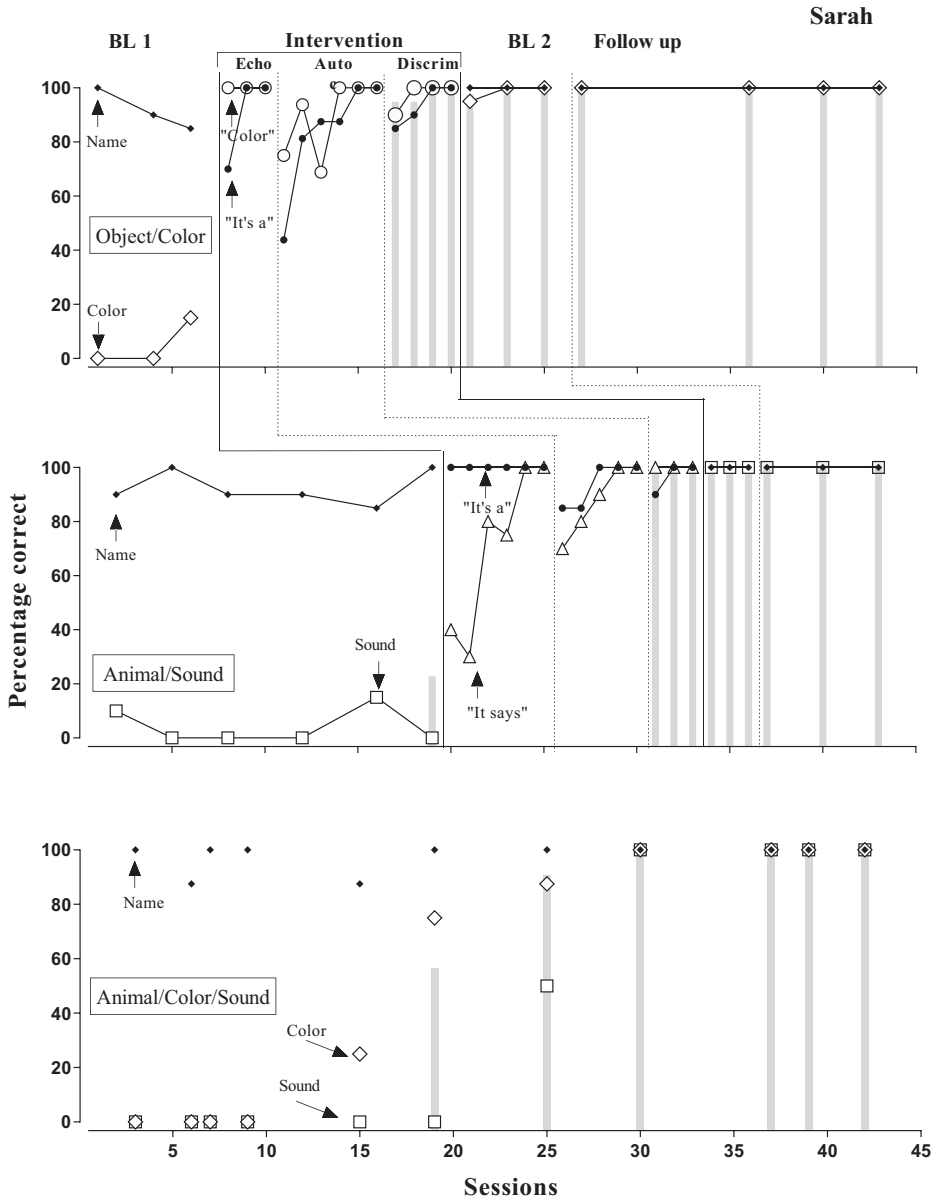

Figure 3. Mean percentage of correct responding to each different verbal antecedent for Sarah. Closed diamonds express correct responses for saying the identity name to the "What is it?" verbal antecedent, open diamonds for the color name to "What color?" and open squares for the sound to "What does it say?" ?" during BL 1 and BL 2 (Baseline 1 and Baseline 2) and follow up. In object vs color (top graph), closed circles show accurate responding during teaching of "It's a [identity name]" in Echo (Echoic Step 1) Autoc (Autoclitic Tact Step 2) and Discrim (Discrimination Step 3). Open circles show correct responding during teaching of "Color [color name]." In animal vs sound (middle graph), open triangles refer to correct responding during teaching of "It says [sound]" in the Echo, Autoc and Discrim Steps. The grey bars show the overall mean percentage of trials in which independent autoclitic frame use was observed.

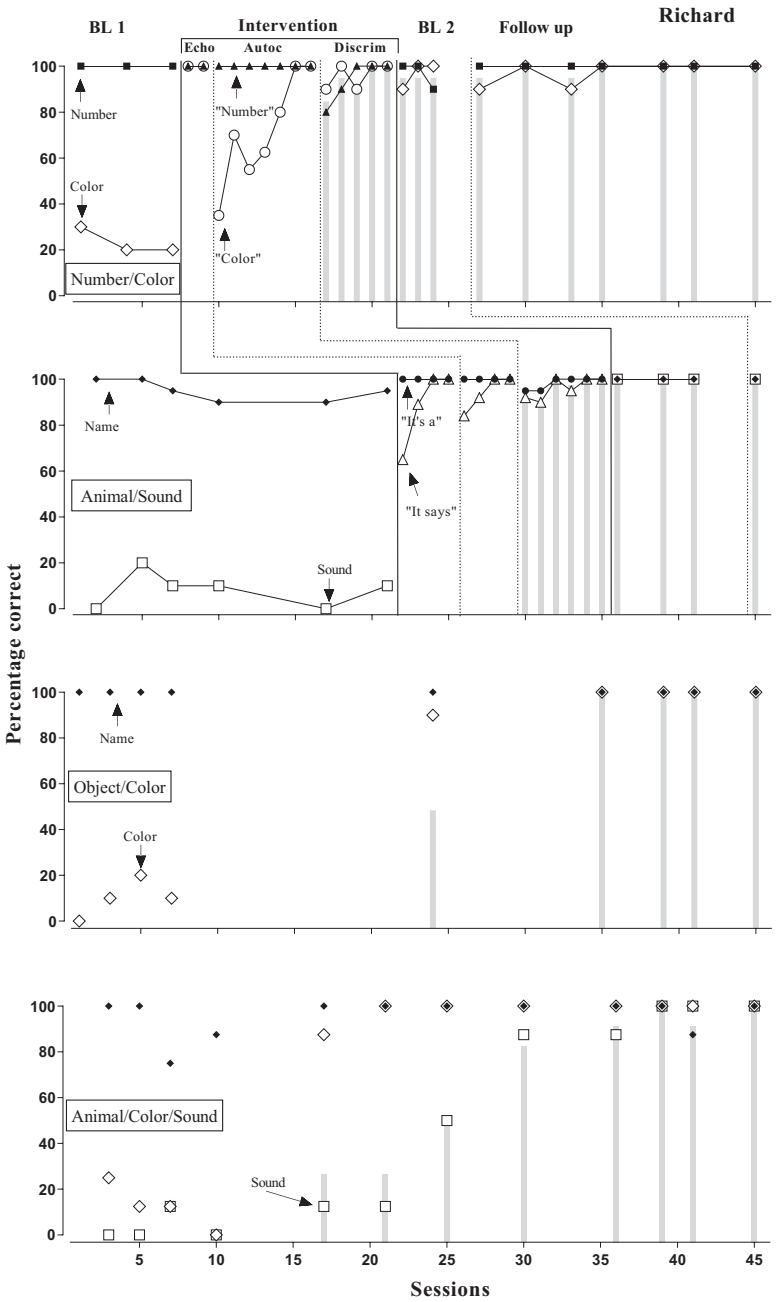

Figure 4. Mean percentage of correct responding to each different verbal antecedent for Richard. Closed squares express correct responses for saying the number name to the "What number?" verbal antecedent, open diamonds for the color name to "What color?" open squares for the sound to "What does it say?" and closed diamonds for the identity name to "What is it?" during BL 1 and BL 2 (Baseline 1 and Baseline 2), and Follow up. In number vs color (top graph), closed triangles show accurate responding during teaching of "Number [number name]," open circles during teaching of "Color [color name]" in Echo (Echoic Step 1), Autoc (Autoclitic Tact Step 2) and Discrim (Discrimination Step 2) for the teaching set only. In animal vs sound (second graph), closed circles express correct responding during teaching of "It's a [identity name]" and open triangles for "It says [sound]" in the Echo, Autoc and Discrim steps. The grey bars show the overall mean percentage of trials in which independent autoclitic frame use was observed.

object names using the "It's a" frame. A level shift in accurate responding was observed on the first session of the *Discrimination* step (Figure 3, top and middle graph, third panel) for both stimulus sets (objects and animals). During this phase, she made two errors on the first session in relation to "What is it?" and one error for "What color?" achieving errorless performance on both verbal antecedents by the third session.

Generalized multiply-controlled tacting in relation to the taught verbal antecedents and the corresponding property (name or color) is exemplified by the near errorless performance when novel stimuli of the same class, previously tested only in *Baseline 1*, were presented again during *Baseline 2* (Figure 3, top graph, fourth panel). On the first session of *Baseline 2* on novel objects that also included the two untaught colors (pink and brown), near errorless responding was achieved, and generalized use of the "Color" frame was observed with respect to the two new colors. Responding continued error-free during the *Follow up* phase, where the relevant frames accompanied all correct responses. A similar pattern of responding was observed for Animal vs Sound (Figure 3, middle graph).

The bottom graph in Figure 3 illustrates changes in Sarah's responding on novel stimuli which had not received any teaching. On session 19, having shown accurate responding to "What color?" and "What is it?" in the Object vs Color intervention, she responded correctly to the "What color?" question on novel pictures of animals. Error-free responding to "What does it say?" was achieved on session 30, at the end of the *Autoclitic tact* step for Animal vs Sound.

Figure 4 depicts percentage of correct responding relative to the verbal antecedent stimuli for Richard. During *Baseline 1*, with respect to Number vs Color, on some trials, he responded accurately to the "What color?" verbal antecedent. Across all three baseline sessions, correct responding was seen on only 14 of the total 60 color-related trials across the three sessions. On all the remaining *Baseline 1* trials, the number name was emitted. With regard to the teaching intervention steps, several sessions were required to echo the frame "It says" clearly in the *Echoic* step (Figure 4, second graph, second panel) and to tact the color swatches using the color frames in the *Autoclitic tact* step (Figure 4, top graph, third panel). No tact errors were made during this phase (Step 2), but the frame was omitted (e.g., "Green" instead of "Color green"). Following the *Echoic* and *Autoclitic tact* steps, differential responding improved on the first *Discrimination* session (Step 3). During *Baseline 2*, only one error out of the 20 trials occurred in relation to "What color?" (first session), and in relation to "What number?" (third session). It is worth noting that the relevant frame was omitted on both trials with incorrect responding. During *Follow up*, responding was 100%, and frames were used consistently on every trial for the last four sessions.

Like Sarah, a similar pattern of responding was observed for Animal vs Sound (Figure 4, second graph). In addition, generalized responding was observed on the two objects sets (Figure 4, third graph), which had not received any intervention and were tested during *Probe* sessions only throughout the experiment. Responding to the objects teaching and objects novel sets (Set 8 & Set 9) was probed on session 21, following the demonstration of generalized responding on Number vs Color in *Baseline 2*. On this session and thereafter, generalized use of the "Color" frame was observed to the two new colors (pink and brown), which had not been targeted in any of the intervention steps; frame teaching had only been provided to red, blue, yellow, and green with respect to printed numbers.

The bottom graph of Figure 4 depicts changes in responding in relation to the three verbal antecedents on novel animals. On session 17, following mastery of *Echoic* (Step 1) and *Autoclitic tact* (Step 2) and prior to commencing the *Discrimination* (Step 3) in Number vs Color, accurate responding in relation to "What color?" was observed (Figure 4, bottom graph). On session 35 of *Probe* sessions, following acquisition of the frame "It's a" in Animal vs Sound, Richard began saying the frame in response to "What is it?" on the objects. Because there were no probes taken between sessions 21 and 35, however, we are not in a position to ascertain which intervention steps in the Animal vs Sound intervention contributed to this change.

Discussion

The present research explored the effectiveness of a multicomponent procedure to establish generalized multiply-controlled tacting with two children diagnosed with ASD. Prior to the teaching intervention, the children were unable to respond accurately to the verbal antecedents "What color?" "What number?" "What is it?" and "What does it say?" when presented with a compound visual stimulus and responded almost exclusively under restricted nonverbal stimulus control (i.e., saying the name of the item regardless of the question posed). The overall post-intervention results were positive, in that both children responded accurately to the different verbal antecedents with respect to taught and novel nonverbal stimuli, within and across novel stimulus classes.

The present findings build on prior research examining the effects of echoing part of a verbal antecedent and teaching responses within an autoclitic frame on enhancing intraverbal stimulus control (Jahr, 2001; Kisamore et al., 2016; Krantz et al., 1981) and overcoming restricted stimulus control. Our focus was not on establishing specific intraverbal responses, as in prior research, but rather on establishing a general relation between specific verbal antecedents and a class of nonverbal stimuli (e.g., identity, color, sound). In other words, we aimed to establish *generalized* answering to specific questions, irrespective of the nonverbal exemplars presented. First, we aimed to establish a history of intraverbal control between a critical fixed term and the related class of variable terms through *Echoic* teaching (Step 1). Second, in a simultaneous simple discrimination arrangement, the production of the previously echoed frames was brought under the control of the verbal antecedent, with the variable terms being the tacts related to the visual stimuli (Step 2). Finally, differential frame use and accurate discrimination to both verbal and nonverbal stimuli was established in a conditional discrimination arrangement (Step 3). Following the three-step teaching intervention, multiply-controlled tacting in relation to novel exemplars of the taught stimulus class and novel classes was demonstrated.

Some recent studies (e.g., DeSouza et al., 2019; Kisamore et al., 2016) on intraverbal conditional discriminations have conceptualized the echoing of the verbal antecedent establishing differential control over the response as a differential observing response (DOR) procedure, in that it ensures contact with the salient aspects of the controlling stimulus. In the present study, the child saying "It's a," "It says," "Number," and "Color," in response to the verbal antecedent is partly an echoic and, as such, is a demonstration of contact with the critical verbal stimulus, thereby satisfying the definition of a DOR. We would take the explanation for our findings a step further from a descriptive account,

however, by offering a potential analysis of the additional controlling function of the response product of the echoic on subsequent responses.

In the present study, during the teaching intervention steps, a history of emitting tacts as the variable elements of an autoclitic frame may have been established, with the critical term (e.g., "It's a") being the fixed part. The emission of a matched frame was taught under the relevant verbal stimulus (e.g., "What is it?"). It is important to point out that we refer to autoclitic frames as a type of intraverbal relation: two or more fixed and variable terms that occur together through a history of contiguous usage (Palmer, 2007). Any time two or more fixed and variable terms are regularly emitted together, as in our case "It's a Y," "Color X," or "It says Z," intraverbal control is likely to be involved, meeting the definition of an autoclitic frame in both form (structural regularity) and function (intraverbal relation). We would suggest that, in our case, the verbal antecedent may have set the occasion for the emission of an echoic (the first term of the matched autoclitic frame) that exerted additional intraverbal control over a class of variable responses, of which the specific member (the tact) was the sample at hand.

In other words, it is possible that responding as part of a frame may have raised the strength of the target dimension over that of the incompatible competing responses (i.e., identity over feature) due to the established history of these terms occurring together and in the presence of the corresponding verbal antecedent. Thus, the final response could be said to have been emitted under the multiple control of the verbal antecedent, the echoic, the intraverbal relation between the frame elements and the nonverbal stimulus. The multicomponent intervention established a history of responding under those convergent conditions, reflected in both children's generalized performance beyond the stimuli that had been taught and by their use of the frame extending to novel stimuli (*Baseline 2* and *Probe* conditions). Provided the verbal antecedents were the same, both children were able to respond to any novel nonverbal stimulus presented and used the relevant frame.

Because a multicomponent procedure with the same sequence of interconnected steps was implemented, however, it is not possible precisely to isolate the separate contributions of the different intervention phases. It is not possible to determine, for example, whether *Echoic* teaching (Step 1) was necessary, or whether it might have been just as effective to begin with *Autoclitic tacting* (Step 2), or whether both elements could be dispensed with, in favor of commencing intervention from the *Discrimination* step (Step 3). This is a limitation that could be addressed in future research by conducting a component analysis.

Because accurate responding was differentially reinforced and emitted in a conditional discrimination preparation during the *Discrimination* phase (Step 3), it is possible that responding with the relevant matched frame, rather than serving an additive convergent control function, might more simply be viewed as an additional conditional stimulus that altered the discriminative value of the relevant part of the compound stimulus (Eikeseth & Smith, 2013). Thus, although the multicomponent intervention was effective in remediating errors, we cannot conclusively determine whether generalized responding subsequent to the intervention phase occurred as a result of the summation of control from different verbal sources (including an autoclitic frame function), or of having established conditional control of the verbal antecedent over the relevant discriminative nonverbal property through conditional discrimination training, irrespective of the frame. In the absence of a control condition in which teaching occurs without a frame,

the functional contribution of autoclitic frames to enhancing verbal stimulus control in the present study remains speculative. Future research comparing conventional conditional discrimination procedures (e.g., full prompting, fading, differential reinforcement, and blocked trials) in the absence and presence of autoclitic frames will further clarify the critical variables and lead to more efficient procedures.

A key issue in establishing verbal behavior in children with autism is that the language established should not only occur under the relevant sources of stimulus control, but that it should also sound "natural." In other words, the topography emitted should be the one conventionally employed by the verbal community, so that it can be maintained by unprogrammed contingencies once teaching has ceased. In the present procedure, for example, responding "Color green" to the question "What color?" although functional, does not resemble the vocal topography that would typically be produced in response to these questions. We would exercise caution in recommending specific procedures to extinguish spontaneous frame use, however, because of its potential effect in facilitating multiply-controlled tacting in children with significant language impairment. Given the negative and pervasive impact that question-discrimination deficits play in language comprehension and production skills, sacrificing form for the benefit of function in this case seems a reasonable compromise, especially if it is only temporary. In our continued work with the children in the research reported here, as well as tens of other children in our clinical practice with similar procedures, the use of the less conventional frames fades out completely over time, but the use of more conventional ones (i.e., "It's a") does not, as would be expected from the differential reinforcement contingencies in the verbal environments at large.

An important question for future research is the extent to which, having learned to respond to the questions "What color?" and "What number?" children would show accurate discriminations if the more common extended version "What color is it?" or "What number is it?" was presented. Future systematic replications could address stimulus generalization with regard to the color and number questions by assessing performance to the extended question after intervention. Future research could also explore whether the effectiveness of these procedures extends to other stimulus classes. For example, Brocchin (2014) successfully taught the frames "S/he is [verb]*ing*" (e.g., "She is swimming") vs "It's [person's name]" to evoke generalized discrimination between the verbal stimuli "What is s/he doing?" vs "Who is it?" on pictures of familiar people carrying out actions. Research of this kind would provide additional information regarding the generality of the procedures and the analysis.

Given the potential facilitating effect of teaching children to tact using autoclitic frames in establishing multiply-controlled tacting, one question that might be raised is whether children should be taught to respond using autoclitic frames at the same time they are taught simple tacts of items and colors (e.g., teaching children to say "Color X" when first teaching tacting the names of colors). We would not recommend this practice, but would suggest that prior to attempting to establish question discrimination with autoclitic frames, an extensive element tact repertoire be present. We would also be cautious in recommending the autoclitic frame procedure be used to establish multiply controlled tacting with all children. Some children may acquire the ability to respond differentially to verbal antecedents during early tact teaching, without the necessity of additional procedures, or may learn it through more traditional conditional discrimination procedures.

In sum, this is the first published study to explore the issue of multiply-controlled tacting in children with ASD. As such, further research is needed not only on the present frame procedure, but on exploring the range of conditions under which this procedure may be more or less efficient than others for individual children. Regardless of which procedures are employed, greater attention should be paid to the teaching of multiply-controlled tacting as a formal objective in language intervention and how to sequence this skill in language programs. Incorporating multiply-controlled verbal behavior in language curricula may help move applied efforts beyond teaching specific responses under restricted stimulus control, toward establishing generalized (higher-order) response classes. This has important theoretical implications as well, as it confronts directly the problem of language generativity – the ability to respond to novel stimuli – commonly regarded as a limitation of a Skinnerian (1957) approach to language.

Note

1. With Richard, we did not conduct object versus color probes between the last baseline session and Session 21 because he was receiving ABA intervention throughout the study during which he was asked to tact various items. The parents did not wish to interrupt this skill, which would have otherwise been necessary, but agreed to cease asking Richard the "What color?" questions until he had reached *Baseline 2* for number versus color.

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No potential conflict of interest was reported by the authors.

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Compliance with Ethical Standards

This study has been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. This manuscript is not under review, nor has it been published, elsewhere. All children's parents provided written informed consent for participation in the study.

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