Facilitating the Emergence of Intraverbal-Tacts in Autistic Children Via Joint Control

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FACILITATING THE EMERGENCE OF INTRAVERBAL-TACTS IN AUTISTIC CHILDREN VIA JOINT CONTROL

by

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A DISSERTATION

Presented to the Faculty of
The University of Nebraska Graduate College
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

Medical Sciences Interdepartmental Area
Graduate Program
(Applied Behavior Analysis)

Under the Supervision of Professor Nicole M. Rodriguez

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August, 2022

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FACILITATING THE EMERGENCE OF INTRAVERBAL-TACTS IN AUTISTIC CHILDREN VIA JOINT CONTROL

Michael A. Aragon, Ph.D.

University of Nebraska, 2022

Supervisor: Nicole M. Rodriguez, Ph.D.

Rodriguez et al. (2022) discovered that teaching four component skills was sufficient to facilitate the emergence of intraverbal-tacts across four applications with three participants. Our study evaluated an extension of this procedure aimed at facilitating intraverbal-tacts when a child learns the component skills but continues to fail to produce intraverbal-tacts. The extension consisted of procedures that attempted to enhance the divergent control exerted by the auditory stimulus (i.e., the question) and the discriminability of joint control. Intraverbal-tacts emerged for all three participants. These results are discussed in the context of Michael et al.’s (2011) conceptual analyses of intraverbal-tacts and the potential role of joint control.
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<th>Description</th>
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<tr>
<td>ASD</td>
<td>Autism Spectrum Disorder</td>
</tr>
<tr>
<td>DI</td>
<td>Divergent Intraverbal</td>
</tr>
<tr>
<td>DOR</td>
<td>Differential Observing Response</td>
</tr>
<tr>
<td>DSR⁺</td>
<td>Differential Reinforcement Condition</td>
</tr>
<tr>
<td>EVT-2</td>
<td>Expressive Vocabulary Test, Second Edition</td>
</tr>
<tr>
<td>IOA</td>
<td>Interobserver Agreement</td>
</tr>
<tr>
<td>IVT</td>
<td>Intraverbal-tact</td>
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<tr>
<td>PPVT-4</td>
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<td>SD</td>
<td>Discriminative Stimulus</td>
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<td>VB-MAPP</td>
<td>Verbal Behavior Milestones Assessment and Placement Program</td>
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</tbody>
</table>
**INTRODUCTION**

*Intraverbal-tacts*

Multiply controlled intraverbals are ubiquitous in our daily social interactions (Axe, 2008; Skinner, 1957; Stauch et al., 2017; Sundberg & Sundberg, 2011). In one type of multiply controlled intraverbal, the sources of control include both auditory and visual stimuli, as is the case when answering different questions about the same picture or object (e.g., saying “small” in response to a question about a shirt’s size or “black” in response to a question about its color). Researchers have referred to this type of response as an *intraverbal-tact* or *intraverbally controlled tact* (e.g., Bondy et al., 2004; Rodriguez et al., 2022). *Intraverbal* refers to the part of the response under the control of the auditory stimulus, and *tact* refers to the part under the control of the visual stimulus.

The importance of specifying the sources of control in the examples above becomes apparent when evaluating the types of errors that occur when responding is under just one source of antecedent control. For example, responding “black” when asked about the size of a shirt might suggest responding under control of just the color of the shirt and not also the content of the question. Although such errors of restricted stimulus control are common in typically developing children ages two and a half to three, responding under multiple control improves by ages three to five, seemingly without any direct or systematic instruction (Sundberg & Sundberg, 2011). By contrast, children diagnosed with autism spectrum disorder (ASD) often experience delays in such repertoires (Sundberg & Sundberg, 2011). This has led several researchers to evaluate procedures for teaching multiply controlled verbal behavior (e.g., Stauch et al., 2017) with an emphasis on identifying conditions that may lead to the emergence of multiply controlled intraverbals (degli Espinosa et al., 2020; degli Espinosa et al., 2021; Desouza et al., 2019; Meleshkevich et al., 2020; Rodriguez et al., 2022).

*Teaching Autistic Children Intraverbal-tacts*
Recently, Rodriguez et al. (2022) evaluated the effects of teaching a sequence of component skills on the emergence of intraverbal-tacts with three 3- to 6-year-old children diagnosed with ASD. The target stimuli varied across participants but generally included different questions about a visual compound stimulus consisting of two distinct elements. For example, answering questions about the color or state of different colored states presented on a computer screen (blue Vermont, red Vermont, red Kansas, yellow Utah, etc.). To evaluate their relevance, Rodriguez et al. probed and taught the following component skills: element tact, category tact, intraverbal categorization, and a multiply controlled selection response. During element-tact sessions, the experimenter presented each element as a simple stimulus (e.g., a black outline of the state of Vermont or a blue scribble) and asked, “What is it?” During category-tact sessions, participants were shown the same stimuli as in the element tact but filled in the statement “This is a type of…” with the category (e.g., “state” or “color”). During intraverbal categorization, the experimenter taught participants to list members of a category (e.g., “Red, yellow, blue” when asked “What are some colors?”). Finally, participants learned a multiply controlled selection response that paralleled the intraverbal-tact target such that participants had to respond to both a visual and auditory stimulus before responding but by selecting the target stimulus from an array rather than providing a vocal response. Like the intraverbal-tact, during selection response sessions, a compound stimulus was presented with a vocal instruction; however, instead of providing a vocal response, the participant selected the stimulus that corresponded to the instruction and compound stimulus from an array (e.g., selected the stimulus card with a blue scribble from an array of colors and states when presented with blue Vermont and instructed, “Show me color”). Intraverbal-tacts and any remaining unmastered component skills were probed before teaching and again after

---

1 Data were also gathered on participants’ ability to match all target compound and simple stimuli. The original purpose was to ensure participants were differentially responding to the visual compound stimuli’s elements. Although identical and non-identical matching were included as component skills, the authors concluded they might be better conceptualized as prerequisite skills because the participants would need to discriminate the elements of the pictures to be successful with any of the skills taught. All participants could accurately match the target compound and simple stimuli in Rodriguez et al. (2022).
learning a component skill to test for emergence. Unmastered component skills were taught one at a time until intraverbal-tacts emerged.

A Conceptual Analysis of the Emergence of Intraverbal-tacts

The component skills included in Rodriguez et al. (2022) were informed, in part, by Michael et al.’s (2011) conceptual analysis of multiple control. In their discussion of multiply controlled verbal behavior, Michael et al. described the potential role of divergent, convergent, and joint control. Using the example of answering a question about a visual stimulus (i.e., an intraverbal-tact), they suggested that the visual stimulus (e.g., a blue circle) evokes multiple responses (e.g., blue, circle, color, shape) if it exerts divergent control. Similarly, the auditory stimulus (e.g., the word “shape” in the question “What shape?”) evokes multiple responses (e.g., triangle, square, circle) if it exerts divergent control. Of the responses evoked by both sources of stimulus control (i.e., the visual and auditory stimulus), there is a single response with overlapping topography (in this case, “circle”). Emitting the response with overlapping topography is an example of convergent or joint control. Michael et al.’s conceptual analysis suggests the importance of (a) element tacts, without which the visual stimulus is unlikely to exert divergent control over relevant tacts, and (b) intraverbal categorization to ensure divergent control of the keyword (i.e., the category name) in the question over relevant intraverbal responses (e.g., increasing the probability of the responses “triangle, square, circle” when hearing the word “shape” or “red, yellow, blue” when hearing the word “color”).

One of Rodriguez et al.’s (2022) goals was to maximize the probability of emergence of intraverbal-tacts as well as some component skills. Thus, Rodriguez et al. looked toward research on the emergence of related skills to identify additional component skills to evaluate. For example, based on research showing that intraverbal categorization sometimes emerges following multiple tact training (Miguel et al., 2005), which generally involves teaching participants to tact the element (e.g., blue) and the category to which it belongs (e.g., color), Rodriguez et al. also included the category tact. Doing so may facilitate the emergence of intraverbal categorization and, in turn,
divergent control by the auditory stimulus. Finally, Rodriguez et al. included a selection response that paralleled the intraverbal-tact based on the results of DeSouza et al. (2019), which showed the emergence of a different type of multiply controlled intraverbal—convergent intraverbals—following mastery of the listener conditional discrimination (i.e., the selection response that paralleled the convergent intraverbal). Thus, although Michael et al.’s conceptual analysis suggested that the element tact and intraverbal categorization would be sufficient for the emergence of intraverbal-tacts, given the paucity of empirical studies to guide the selection of component skills for intraverbal-tacts specifically, the experimenters included the category tact and multiply controlled selection response to increase the probability of emergence.

The role of Joint Control

In Rodriguez et al. (2022), intraverbal-tacts emerged only after mastery of all component skills across all four applications, suggesting that mastery of element tacts, category tacts, intraverbal categorization, and the multiply controlled selection response is sufficient, at least under some conditions, for the emergence of intraverbal-tacts. However, the emission of an intraverbal-tact when presented with different questions about the same object or picture is not solely dependent on mastering a set of component skills. Returning to the example from Michael et al.’s (2011) conceptual analysis above, it is not enough for the keyword in the question and the visual stimulus to exert divergent control over responses with overlapping topographies (e.g., “triangle, square, circle” evoked by “What shape?” and “blue circle” evoked by the visual stimulus). The participant must respond to the divergent-control responses as verbal stimuli (i.e., serving as a listener to their own vocal-verbal stimuli) and in particular those verbal stimuli that evoke the same response (i.e., circle) in order for the onset of joint control to take place (Michael et al., 2011). Thus, the presence of relevant component skills (e.g., element tact, intraverbal categorization) only allows these other variables to exert their effects; they do not guarantee that joint control will occur.

Purpose of the Current Study
Autistic children with developing verbal repertoires may need to learn how to leverage joint control in the context of intraverbal-tacts. If intraverbal errors persist (e.g., responding “blue” when shown a blue circle and asked, “What shape?”) despite mastering the element tact, category tact, intraverbal categorization, and multiply controlled selection response, additional strategies may be needed. Specifically, the persistence of intraverbal errors may suggest inadequate control by the keyword in the question or a lack of joint control. Studies that have sought to increase the discriminability of joint control have used strategies such as prompting echoic self-rehearsals of spoken instructions (e.g., Hozella et al., 2021; Vosters & Luczynski, 2020; see Ampuero & Miklos, 2019 for a review). With respect to intraverbal-tacts, teaching children to repeat the keyword and then engage in the corresponding intraverbal categorization (e.g., “shape: triangle, square, circle”; hereafter referred to as a divergent intraverbal response) prior to responding to the question (e.g., “What shape?”) may ensure that the keyword in the question exerts divergent control over relevant responses and increase the probability of joint control if the auditory stimulus (question) and visual stimulus are exerting divergent control close in time to each other. If intraverbal-tacts still do not emerge, teaching the child to rehearse the divergent intraverbal (“shape: triangle, square, circle, triangle, square, circle, triangle, square, circle”) prior to responding to the question may further increase the probability that the child responds to intraverbal responses as verbal stimuli and does so proximally while responding to the visual stimulus, thereby increasing the probability of joint control. Although other studies have suggested similar conceptualizations of the function of repeating the critical term in a question with the answer insofar as its role in enhancing intraverbal control (e.g., “color red”; degli Espinosa et al., 2020, 2021, degli Espinosa, 2022), to date no study has isolated the effects of a divergent intraverbal response or separated these effects from, for example, the effects of ensuring attending to the keyword in the question.

In the current study, we sought to replicate Rodriguez et al. (2022). When the component skills were insufficient to facilitate the emergence of intraverbal-tacts, we evaluated the effects of
two variations of a procedure aimed at enhancing both the divergent control exerted by the auditory stimulus and the discriminability of joint control.

CHAPTER 1: METHOD

Participants, Settings, and Materials

Three boys (Sam, Gabe, & Ivan) aged 3 to 7 years old, diagnosed with autism spectrum disorder and receiving early intervention services at a university-based clinic, participated. The participants’ primary language was English. Gabe spoke in complete sentences, and Sam and Ivan spoke using two- to three-word phrases. Participants’ scores on the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg, 2008) were at or above Level 2 on the echoic, tact, matching, intraverbal, and listener responding sections (developmental age equivalent of 18–30 months). Based on a record review of their early intervention programming and informal interviews with their early intervention team, none of the participants had previously demonstrated differential responding to a visual stimulus based on the content of a question. For example, a child may respond “ball” when shown a blue ball and asked, “What is it?” However, the child would also say, “ball” when asked, “What color?” Participants’ demographics and assessment scores on the Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4; Dunn & Dunn, 2007) and the Expressive Vocabulary Test, Second Edition (EVT-2; Williams, 2007) are displayed in Table 1.

The experimenter conducted all probes and teaching sessions in the cubicle where the participant's typical early intervention appointments took place. Cubicles contained (a) a child-sized table, (b) two chairs, (c) a laptop computer used to display the sample stimulus, (d) 8.5-by-11-in. (21.6-by-27.9 cm) laminated sheets with images used as either comparison stimuli or picture prompts, (e) edibles and leisure items used as reinforcers, and (f) a pen and paper for data collection. The experimenter displayed stimuli in the same manner as Rodriguez et al. (2022). Specifically, during intraverbal-tact probes, element tact, category tact, selection response probes, and teaching sessions, the experimenter presented sample stimuli (15.2-by-15.2-cm images) on a laptop screen.
using Microsoft® PowerPoint®. For the picture prompt (intraverbal categorization teaching only), the experimenter presented three 7.6-cm-by-7.6-cm images horizontally across a landscaped 8.5-by-11-in. (21.6-by-27.9 cm) laminated sheet. During selection response teaching, the comparison stimuli included six 7.6-by-7.6-cm images displayed horizontally across two landscaped 8.5-by 11-in. (21.6-by-27.9 cm) laminated sheets (three images on each sheet) and placed equidistant on the table in front of the child. For intraverbal-tact probes, visual compound stimuli consisted of combinations of colors and shapes, namely, combinations of red, yellow, and blue, and triangle, square, and circle. There were nine compound stimuli (yellow triangle, yellow square, yellow circle, blue triangle, red triangle, etc.). Table 2 displays the visual stimuli used throughout the evaluation.
<table>
<thead>
<tr>
<th>Participant’s Demographics</th>
<th>Insurance</th>
<th>VB-MAPP Level</th>
<th>PPVT-4&lt;sup&gt;a&lt;/sup&gt;</th>
<th>EVT-2&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sam (Black, male, 7 years old, ASD)</td>
<td>Tricare</td>
<td>2</td>
<td>2</td>
<td>39</td>
</tr>
<tr>
<td>Gabe (White, male, 3 years old, ASD)</td>
<td>Medicaid</td>
<td>2</td>
<td>2</td>
<td>89</td>
</tr>
<tr>
<td>Ivan (White, male, 5 years old, ASD)</td>
<td>Private</td>
<td>2</td>
<td>2</td>
<td>51</td>
</tr>
</tbody>
</table>

Table 1. Participant’s Gender, Ages, Diagnosis, and Assessment Scores. ASD = Autism spectrum disorder; PPVT-4 = Peabody Picture Vocabulary Test – Fourth edition; EVT-2 = Expressive Vocabulary Test – Second edition.<sup>a</sup> Mean score for standard score is 100 with a standard deviation of 15.
Table 2. Visual Stimuli Used in This Study. The simple stimuli served as comparison stimuli for non-identical matching and selection responses and sample stimuli for the element tact and category tact. The compound stimuli served as comparison stimuli for identical matching and sample stimuli for intraverbal-tact probes, identical matching, non-identical matching, and LCD.
Preassessments

The experimenter also evaluated whether participants could differentially respond toward the components of the target compound and simple stimuli to rule out indiscriminability as a barrier to learning the component skills. Identical and non-identical matching tasks were conducted as the evaluations. In either task, participants were presented with a sample compound stimulus. During identical matching, participants chose the matching compound stimulus from an array of three compound stimuli sharing one element (e.g., three of the same shape in different colors or three different shapes in the same color). During non-identical matching, participants chose the matching simple stimulus from an array of three stimuli (e.g., three colors or three shapes). Each combination of sample and comparison stimuli was shown once per probe for a total of 18 trials per session. All participants could match target compound and simple stimuli with 100% accuracy.

Experimental Design

A concurrent multiple baseline design across participants was used to evaluate the effects of teaching the component skills and the divergent intraverbal or divergent intraverbal with rehearsal (hereafter referred to as rehearsal) on the emergence of intraverbal-tacts. We probed and taught (as necessary) the following component skills evaluated in Rodriguez et al. (2022): element tact, category tact, intraverbal categorization, and selection response. Like Rodriguez et al., baseline probes for each component skill occurred before teaching any component skill. Following mastery of a component skill, the experimenter probed for the emergence of subsequent component skills and the intraverbal-tact. Only one or two intraverbal-tact probes were conducted following mastery of a component skill to minimize testing as a threat to internal validity (Gast et al., 2014). In other words, changes in correct responding may occur with repeated testing simply due to the contingencies in place during testing; for example, responding may decrease when correct responding is not differentially reinforced or increase as a function of trial-and-error learning when correct responding is differentially reinforced. In either case, limiting the number of intraverbal-
tact probes would minimize these potential threats to internal validity while allowing for tests of emergent responding as we expected the effects of our procedures on emergence to be relatively immediate.

Each evaluation concluded with an assessment of correct intraverbal-tacts in the absence of a differential observing response (DOR) prompt.

**Response Measurement and Interobserver Agreement**

Response measures were identical to Rodriguez et al. (2022). The primary dependent variable was the percentage of correct intraverbal-tacts. A correct intraverbal-tact was scored when the participant’s vocal response corresponded with the visual compound stimulus and the question (e.g., “red” when presented with a red triangle and "What color?"). Any response that did not correspond to the compound stimulus and question was scored as incorrect. The research team defined the emergence of intraverbal-tacts as a relatively abrupt shift in the level of correct responding to at or above 89% correct. Data collectors also took data on error types; of primary interest were intraverbal errors, which were scored when a response corresponded to the visual compound stimulus but not the question (e.g., responding "red" when presented with a red triangle and "What shape?"). We also took data on two-component tact errors, which were scored when a participant’s response included both elements of the visual compound stimulus (e.g., responding “red triangle” when presented with a red triangle regardless of the question).

Concerning component skills probes and teaching, data were collected on correct independent and prompted responses (see Table 3 for examples of correct responses). A correct element tact was scored if the participant tacted the visual stimulus (e.g., “red”). A correct category tact was scored if the participant tacted the category to which the visual stimulus belonged (e.g., "color" in response to "This is a type of…" in the presence of a red scribble). If the child responded with the element tact (e.g., saying “red” instead of “color” when asked, “This is a type of …”), the experimenter restarted the trial and replaced “this” with the element (e.g., “Red is a type of …”; Loughrey et al., 2014). A correct response was scored if the participant responded with the category
after the experimenter adjusted the discriminative stimulus. Correct intraverbal categorization was scored if the participant listed the three target exemplars (e.g., "red, yellow, blue" in response to "What are some colors?"). Correct selection response was scored if the participant pointed to, touched, or handed the corresponding comparison stimulus to the experimenter (e.g., pointed to the red scribble when presented with a red triangle and asked, "Show me color."). A trial was scored as incorrect if the child emitted any response other than those previously described or failed to respond within 10 s. The emergence of a component skill was either defined as any target response not previously emitted during probes (for intraverbal categorization only) or correct responding at or above 89% (all other component skills) before direct teaching.

Finally, the research team scored data on correct prompted and independent divergent intraverbals and rehearsals for the first presentation of the question per trial. Data on prompted responding were only collected during phases that included a DOR prompt (e.g., “Say, [Category].”), and data on independent divergent intraverbals and rehearsals were only collected during phases in which the DOR prompt was removed. A correct divergent intraverbal was scored when the child (a) repeated the keyword in the question and then (b) independently listed the three target exemplars corresponding to that category (e.g., “Color: red, yellow, blue” when asked, “What color? Say, ‘Color’” or “What color?” for phases not including a DOR prompt) before emitting an intraverbal-tact. The divergent intraverbal was scored incorrect if the list was correct but the participant did not repeat the correct keyword. A correct rehearsal was scored when the child repeated the keyword in the question followed by three independent repetitions of the three target exemplars corresponding to that category (e.g., “Color: red, yellow, blue, red, yellow, blue, red, yellow, blue” when asked, “What color? Say, ‘Color’” or “What color?” for phases not including a DOR prompt). Note that for both divergent intraverbals and rehearsals, the DOR prompt only included an echoic prompt for the keyword in the question and not the intraverbal, such that the intraverbal portion of the response was independent for both prompted and independent divergent intraverbals and rehearsals.
<table>
<thead>
<tr>
<th>Component Skill</th>
<th>Vocal SD/ Visual Sample Stimulus</th>
<th>Target Response &amp; Stimulus Arrangement</th>
<th># of Trials</th>
<th>Teaching Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element Tact</td>
<td>&quot;What is it?&quot;/ Simple stimulus</td>
<td>Label element (e.g., red or triangle)</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Category Tact</td>
<td>&quot;This is a type of …&quot;/ Simple stimulus</td>
<td>Label category (e.g., color)</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Intraverbal Categorization</td>
<td>&quot;What are some [color/shape]?&quot;/ No Visual stimulus</td>
<td>List target elements of the category (e.g., red, yellow, blue)</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Selection Response</td>
<td>&quot;Show me [color/shape].&quot;/ Compound stimulus</td>
<td>Touch picture of corresponding simple stimulus from an array of all 6 simple stimuli</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 3. Vocal discriminative stimulus, target response, stimulus arrangement, number of trials, and type of prompt, for each component skill. SD refers to discriminative stimulus. See Table 2 for a visual representation of the simple and compound stimuli used in this study.
Interobserver agreement (IOA) was assessed across intraverbal-tact probes, component skills probes, and component skills teaching sessions. An agreement was scored if both observers recorded the same response for a given trial (e.g., correct vs. incorrect for intraverbal-tacts; intraverbal error). IOA was calculated by dividing the number of trials with agreements by the total number of trials in a probe or session and multiplying by 100. IOA data were collected for 39%, 48%, and 72% intraverbal-tact probes for Sam, Gabe, and Ivan; IOA was 100% for Sam and Gabe and 99% for Ivan. IOA on error types was 100% for Sam and Gabe and 99% for Ivan. IOA data were collected for 35% of all component skills probes and teaching sessions across participants and was 98% (range 89-100%).

**Procedures**

All procedures were identical to Rodriguez et al. (2022) except for the divergent intraverbal and rehearsal training and probes, which was unique to this study. Figure 1 depicts the order in which skills were probed and taught. The experimenter started each probe or teaching session by having the participant choose an item or edible from an array of at least five items. Items included in the array were based on reports of items that the participant commonly requested during their typical early intervention appointments. The selected item, hereafter referred to as the reinforcer, was delivered according to the contingencies outlined below throughout the following probe or session and was replaced as the reinforcer only if the child requested a different item. A reinforcement interval ended after 30 s elapsed for toys and leisure activities and at least 2 s without chewing for edibles.
Figure 1. Flowchart of Intraverbal-Tact and Component skills Probe and Teaching Procedures
IVT = intraverbal-tact. DSR+ = differential reinforcement condition. DI = divergent intraverbal.
**Intraverbal-Tact Probes**

Each of nine compound stimuli (e.g., red triangle, red square) was presented twice, once with each question (e.g., "What color? vs. "What shape?") for a total of 18 intraverbal-tact trials per probe. At the start of each trial, the experimenter secured attending to the compound stimulus (e.g., pointed to or tapped the computer screen). Once the child oriented toward the stimulus, the experimenter issued the question or instruction.

Probes initially occurred in the absence of reinforcement. The experimenter acknowledged the participant’s response by saying, “Okay,” regardless of performance (Miguel & Kobari-Wright, 2013). During this initial, no differential reinforcement phase, mastered tasks consisting of common tacts were interspersed approximately every three trials for a total of six tasks per probe. A putative reinforcer was delivered contingent on correct responding to maintain overall responding.

The experimenter introduced an echoic DOR prompt before teaching any component skills to ensure errors were not the result of a lack of attending to the relevant antecedents (Kisamore et al., 2016). After asking the question, the experimenter immediately prompted the participant to repeat the keyword in the question (e.g., “What color? Say, ‘Color’”). If the participant said anything other than the category, the experimenter restated the category alone (e.g., “color”) while pointing at the experimenter’s lips, which, based on participants’ extra-experimental learning history, indicated an echoic response requirement. Brief praise (e.g., “good”) was contingent on an echoic DOR.

For Sam and Gabe, the experimenter introduced differential reinforcement following mastery of all component skills to evaluate whether the lack of emergence was due to the absence of contacting direct reinforcement for correct intraverbal-tacts. For Ivan, differential reinforcement was introduced before teaching any component skill to avoid the potential for false-negative outcomes due to the absence of reinforcement for correct responses. Trials with differential reinforcement were identical to trials with no differential reinforcement except that mastered tasks were no longer interspersed throughout sessions, and correct intraverbal-tacts produced the
reinforcer and brief general praise (e.g., “Nice job!”). Following incorrect responses, the experimenter moved on to the subsequent trial.

The DOR prompt remained in place throughout the teaching of component skills and during the divergent intraverbal and rehearsal phases (described in more detail below). Following the emergence of the intraverbal-tact, the experimenter probed intraverbal-tacts under differential reinforcement alone to evaluate whether correct intraverbal-tacts would maintain in the absence of a DOR prompt.

**Component Skills Probes**

Component skills probes were identical to Rodriguez et al. (2022). The experimenter probed the component skills in the following order: element tact, category tact, intraverbal categorization, and selection response. All component skills were probed prior to any teaching. Upon mastery of a component skill and before probing for the emergence of intraverbal-tacts, the experimenter probed for the emergence of any remaining untaught component skills. For any component skill probe for which there was less than 100% correct responding (or less than three elements listed for intraverbal categorization), the experimenter conducted an additional probe as a repeated measure.

Table 3 denotes the following for each component skill probe: (a) question, or instruction, (b) type of visual sample stimulus presented (if applicable), (c) target response, (d) stimulus arrangement, and (e) the number of trials for each component skill. The experimenter ensured that each simple stimulus (element tact and category tact), instruction (intraverbal categorization), or combination of compound stimuli and instructions (selection response) were presented once per probe in a random order, resulting in six trials for element and category tact probes, two trials for intraverbal categorization, and 18 trials for the selection response.

Across all component skill probes, the experimenter delivered brief general praise and a reinforcer contingent on a correct response and moved on to the next trial contingent on an incorrect or no response within 10 s, with two exceptions. For intraverbal categorization, the experimenter
delivered brief verbal praise following each correct element the participant listed and asked, “any more?” if they paused for more than 10 s. The experimenter repeated this procedure until the participant stopped responding for 10 s, repeated the same element a second time, or erred (i.e., listed an element from another category). At the end of a trial, the participant received praise and a reinforcer as long as they listed at least one correct element and no incorrect elements. For category tacts, the experimenter modified the fill-in statement when participants responded with an element tact. Instead of saying, “This is a type of…” the experimenter replaced the word “this” with the element (e.g., “Red is a type of…” if the element the participant is responding toward is a red scribble). We refer the reader to Rodriguez et al. (2022) for a more detailed description of how each component skill was probed.

**Component Skills Teaching**

A component skill was taught if a child scored less than 100% correct when probed. Component skills teaching sessions were identical to component skills probes (e.g., instructions, sample stimuli) except for the number of trials per session and the use of prompts (See Table 3) as well as other remedial teaching strategies (described below). Each teaching phase began with a differential reinforcement baseline. Following two baseline sessions below mastery with stable responding or a decreasing trend, the experimenter introduced a 0-s prompt delay. Following two consecutive sessions with 100% correct prompted responses, the experimenter introduced a 2-s prompt delay. Both correct independent, and prompted responses resulted in praise and a reinforcer. Contingent on errors, the experimenter represented the instruction together with the prompt and provided praise and a reinforcer for correct prompted responses. Incorrect prompted responses never occurred during either 0-s or 2-s prompt delay phases.

The experimenter added remedial teaching strategies for the category tact (Sam and Ivan only), intraverbal categorization (all participants), and the selection response (all participants). Differential reinforcement for independent responding (Karsten & Carr, 2009) and further increasing the prompt delay were included as remedial strategies for each component skill.
Additional remedial teaching strategies used to teach intraverbal categorization included remedial trials (DeSouza et al., 2019), prompting the child to repeat the variable term from the instruction (i.e., a DOR; Kisamore et al., 2016), and a token exchange system with response cost for incorrect responding (similar to Keeney et al., 2000). For the selection response, we evaluated the effects of an echoic DOR and a problem-solving strategy involving a differential response toward the category before selecting the visual match from that category. The mastery criterion was set at two consecutive sessions with 100% correct independent responses.

**Divergent Intraverbal**

**Divergent Intraverbal Training.** Before introducing the divergent intraverbal response requirement within the context of intraverbal-tact probes, the experimenter taught the participant to emit the divergent intraverbal contingent on the DOR prompt (i.e., “say [category]”). No visual stimuli were present during training sessions. Specifically, the experimenter issued the question followed by the DOR prompt (e.g., “What color? Say, ‘Color’”). Immediately after the participant emitted the echoic DOR (e.g., “color”), the experimenter provided a vocal model of the corresponding list of target elements (i.e., intraverbal categorization; e.g., “red, yellow, blue”). Contingent on the participant repeating the list within 10 s of the vocal model, the experimenter delivered praise and a reinforcer. Contingent on any other vocal response or no response, the experimenter restarted the trial and re-presented the vocal model. A session consisted of 12 total trials, six for each question (i.e., “What color?” and “What shape?”) presented in a semi-random order. Following two consecutive sessions with 100% correct prompted divergent intraversals, the experimenter introduced a 2-s delay to the vocal model. The mastery criterion was two consecutive sessions with 100% correct divergent intraversals contingent on the DOR prompt alone.

**Divergent Intraverbal Probes.** Following mastery of the divergent intraverbal within the separate training sessions, the experimenter delivered the DOR prompt in the context of intraverbal-tact probes. Specifically, the experimenter presented the visual compound stimulus and
said, “What [category]? Say, ‘[Category]’” (e.g., “What color? Say, ‘Color’”). Contingent on a correct divergent intraverbal (e.g., “Color: red, yellow, blue”), the experimenter delivered brief praise (e.g., “good”), then repeated the question and allowed up to 10 s for a response. If the participant did not respond or said anything other than the correct divergent intraverbal (e.g., stated elements that belonged to a different category or repeated only the category), the experimenter vocally modeled the correct divergent intraverbal and represented the trial. The experimenter represented the trial until the participant emitted a correct divergent intraverbal or until five representations. Contingencies for correct and incorrect intraverbal-tacts were identical to intraverbal-tact probes with differential reinforcement. Each of nine compound stimuli was presented twice, once with each question (e.g., "What color? vs. "What shape?") for a total of 18 intraverbal-tact trials per probe. Data on training the divergent intraverbal are depicted in Figure 2.
Figure 2. Divergent Intraverbal Training. PD = prompt delay; DSR\(^+\) = differential reinforcement; DSR\(^+\) Independent = differential reinforcement for independent responses. Prompt delays were selected for each participant according to the last duration that resulted in mastering component skills.
Transfer of Stimulus Control Training (Gabe only). Gabe’s data suggested that correct intraverbal-tacts depended on the DOR prompt. Correspondingly, Gabe did not emit the divergent intraverbal if the experimenter did not deliver the DOR prompt (i.e., “Say, [Category]”), further suggesting prompt dependence. Thus, during separate training sessions conducted in the absence of the visual compound stimuli, we used a constant prompt delay procedure to transfer stimulus control from the DOR prompt to the question. Specifically, the experimenter delivered a question followed by an immediate vocal model of the divergent intraverbal (e.g., “What color? Say, Color: red, yellow, blue”). Contingent on a correct prompted divergent intraverbal, the experimenter delivered praise and a reinforcer. Following two consecutive sessions with 100% correct prompted responses, the experimenter introduced a 2-s prompt delay. Both correct independent, and prompted responses resulted in praise and a reinforcer. Contingent on any other vocal response or no response, the experimenter re-presented the question followed by an immediate vocal model of the divergent intraverbal and provided praise and a reinforcer for correct prompted responses. Incorrect prompted responses never occurred during either 0-s or 2-s prompt delay phases. A session consisted of 12 total trials, six for each question (i.e., “What color?” and “What shape?”) presented in a semi-random order. The experimenter returned to divergent intraverbal probes after two consecutive sessions with 100% correct independent responses.

Rehearsal (Sam and Ivan only)

Rehearsal Training. Sam and Ivan’s performance on intraverbal-tact probes with the divergent intraverbal response requirement remained the same as in baseline. The research team hypothesized that this lack of an effect of the divergent intraverbal was due, at least in part, to the absence of joint control. Anecdotally, unlike Gabe, Sam and Ivan appeared to orient to the visual stimulus only after emitting the divergent intraverbal. The probability of convergence of the two sources of control (intraverbal and tact) may have been low. To increase the likelihood of joint control, the experimenter taught Sam and Ivan to rehearse the divergent intraverbal. In other words,
once introduced into the intraverbal-tact probes, this response requirement may increase the probability of the auditory and visual stimulus exerting divergent control concurrently, thereby increasing the discriminability of the onset of joint control.

Like divergent intraverbal training, separate sessions were conducted to teach participants to emit the rehearsal contingent on the experimenter presenting the DOR prompt. Training occurred across three phases (described below). Examples of teaching trials are presented in Table 4. Data on training the rehearsal are depicted in Figure 3.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Question</th>
<th>DOR Prompt</th>
<th>Sample Visual Stimuli and Distractors</th>
<th>Correct Response</th>
<th># of Teaching Trials</th>
<th>Teaching Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>“What color?”</td>
<td>Yes</td>
<td>None</td>
<td>Saying, ”Red, yellow, blue” three times</td>
<td>12</td>
<td>Point at Participant + Vocal Model</td>
</tr>
<tr>
<td>2</td>
<td>“What color?”</td>
<td>Yes</td>
<td>![Shoe Image]</td>
<td>Rehearsal + “Red”</td>
<td>12</td>
<td>Point, Vocal Model</td>
</tr>
<tr>
<td>3</td>
<td>“What color?”</td>
<td>Yes</td>
<td>![Triangle Image]</td>
<td>Rehearsal + “Red”</td>
<td>18</td>
<td>Point, Vocal Model</td>
</tr>
</tbody>
</table>

Table 4. Divergent Intraverbal Rehearsal Teaching Phase Examples.
Figure 3. Rehearsal Training. Pt = point; VM = vocal model. Each trial started with a question (“What shape?” or “What color?”) and a differential observing response prompt (e.g., “Say, ‘Shape’” or “Say, ‘Color,’” respectively). In Phase 1, the target independent response was the rehearsal (open circles), and data depicted by the open triangle and open square represent prompted rehearsals following the experimenter pointing to the participant or following the experimenter providing a vocal model (if the point prompt was not effective). During phases two and three, the target independent response was the intraverbal-tact (closed circles), and data depicted by the open triangle and open square represent prompted intraverbal-tacts following the experimenter pointing to the target element on the screen or following the experimenter providing a vocal model (if the point prompt was not effective). Thus, the response depicted by the open triangles and squares varies across Phase 1 and Phases 2 and 3.
**Phase 1 (no visual stimuli).** The purpose of the first phase was to teach participants to emit the rehearsal contingent on the DOR prompt. No visual stimuli were presented during this phase. At the start of each trial, the experimenter delivered the question followed by the DOR prompt (e.g., “What color? Say, ‘Color.’”). Contingent on the participant repeating the keyword in the question (e.g., “color”), the experimenter immediately vocally modeled three repetitions of the three target exemplars corresponding to that category while pointing at the participant at the start of each repetition (e.g., “[point] red, yellow, blue, [point] red, yellow, blue [point] red, yellow, blue”). Contingent on a correct rehearsal, the experimenter delivered praise and a reinforcer. If the participant emitted any other vocal or no response, the experimenter represented the trial until the participant emitted a correct rehearsal or until five representations elapsed.

Following two sessions with 100% correct prompted rehearsals, the experimenter transferred control from the vocal model to the point prompt by introducing a 0-s prompt delay to pointing at the participant and a 2-s prompt delay to the vocal model if the participant did not rehearse following the point. This prompting hierarchy occurred for each of the three repetitions within each trial. In other words, each trial consisted of three point prompts and up to three vocal models. If a participant did not require vocal models to respond correctly across all trials within their first session, during subsequent sessions, the experimenter pointed only once to initiate the rehearsal (e.g., [point] “red, yellow, blue, red, yellow, blue, red, yellow, blue”). Otherwise, this change was instituted after two sessions with 100% correct responding without a vocal model. The experimenter delivered praise and a reinforcer contingent on correct rehearsals following the one point prompt. After two sessions with 100% correct prompted rehearsals, the experimenter introduced a 2-s delay to the point prompt. Sessions were 12 trials with each of the two categories (color and shape) presented in a semi-random order. Following two consecutive sessions with 100% correct independent rehearsals, the experimenter began Phase 2.
**Phase 2 (distractor stimulus).** The purpose of this phase was to provide participants with a history of reinforcement for correct intraverbal-tacts (a) following the rehearsal (b) using a visual simple discrimination preparation to increase the probability of correct responding. Specifically, the visual array included two stimuli: one of the three elements corresponding to the question presented as a simple stimulus (e.g., a red scribble given the question “What color?”) and a distractor that did not share any of the elements of the compound stimulus (e.g., a black and white shoe). Participants were only shown simple stimuli rather than the target compound stimuli to prevent directly teaching the target intraverbal-tact.

At the start of each trial, the experimenter delivered the question followed by the DOR prompt (e.g., “What color? Say, ‘color’”). The experimenter delivered the point prompt if the participant did not emit the rehearsal within 2 s of the DOR prompt. Contingent on any vocal response other than the correct rehearsal or no response, the experimenter vocally modeled the correct rehearsal. Following a correct prompted rehearsal, the experimenter restarted the trial until the participant emitted the correct rehearsal for up to five representations. If the participant independently and correctly emitted the first two repetitions of the rehearsal, the experimenter presented the visual array on a computer screen as the participant completed the third repetition. If, within 2 s following the rehearsal, the participant emitted the correct intraverbal-tact (e.g., “red”), the experimenter delivered verbal praise and a reinforcer. If the participant emitted any other response or no response, the experimenter prompted the correct response by pointing at the visual stimulus of the target element. If the child erred within 2 s of the point, the experimenter vocally modeled the correct response.

Each of the six target elements was presented twice for a total of 12 trials per session. The position of the target stimulus relative to the distracter was counterbalanced across presentations. After two consecutive sessions with 100% correct intraverbal-tacts, the experimenter began Phase 3.
**Phase 3 (simple stimuli).** The purpose of this phase was to provide participants with a history of reinforcement for correct intraverbal-tacts following the rehearsal using a visual conditional discrimination preparation but with simple stimuli. This preparation served as a closer approximation to the target preparation in which both elements were presented within a compound stimulus. Procedures for Phase 3 were identical to Phase 2 except one element from each category, instead of distracters, was presented as simple stimuli on the screen (e.g., a picture of a red scribble next to a picture of a black outlined triangle). Each combination of colors, shapes, and questions was presented once in a random order for 18 trials per session. Mastery criterion included two consecutive sessions with 100% correct intraverbal-tacts.

**Rehearsal Probes.** Following mastery of phase 3 of rehearsal training, the experimenter delivered the DOR prompt in the context of the intraverbal-tact probes. Procedures were identical to divergent intraverbal probes except for the change in response requirement following the DOR prompt and the timing of the presentation of the visual stimulus. Specifically, while the laptop screen was black, the experimenter delivered the question followed by the DOR prompt (e.g., “What color? Say, ‘Color’”). If the participant did not emit the correct rehearsal within 2 s, the experimenter vocally modeled the correct rehearsal and re-presented the trial until the participant emitted the correct rehearsal for up to five representations. Contingent on a correct rehearsal, the experimenter presented the visual compound stimulus (e.g., a red triangle) on the computer screen as the participant rehearsed a third time. The participant then had up to 10 s to emit the intraverbal-tact. Correct intraverbal-tacts following the rehearsal resulted in the reinforcer and brief general praise (e.g., “Nice job!”). Incorrect intraverbal-tacts resulted in the experimenter moving on to the next trial. Each of nine compound stimuli was presented twice, once with each question (e.g., “What color?” vs. “What shape?”) for a total of 18 intraverbal-tact trials per probe.

**CHAPTER 2: RESULTS**
The percentages of correct independent intraverbal-tacts are depicted in the first, third, and fifth panels of Figure 4. Initial baseline performance on intraverbal-tacts was around 50% correct for Sam and Ivan and 0% for Gabe. The introduction of an echoic DOR prompt during baseline did not improve accuracy for any participants. The percentage of correct intraverbal-tacts remained stable across participants following mastery of each component skill with one exception: Gabe’s responding during intraverbal-tact probes increased from 0% to 50% following mastery of the selection response. Throughout the initial baseline as well as phases immediately following the teaching of component skills, Sam and Ivan’s errors primarily consisted of intraverbal errors, and Gabe’s errors primarily consisted of two-component tact errors (data available upon request; e.g., saying, “Red triangle” when presented with a red triangle and asked, “What color?”) when there was 0% correct intraverbal-tacts and intraverbal errors when there was 50% correct intraverbal-tacts. Differential reinforcement for correct responding during intraverbal-tact probes was introduced after there was no change in correct intraverbal-tacts despite mastery of all component skills for Sam and Gabe but prior to teaching any component skill for Ivan, and had no effect on correct responding.

Next, we taught participants to emit the divergent intraverbal (e.g., “Color: red, yellow, blue”) following the DOR prompt (e.g., “Say, ‘Color’”). For Sam and Ivan, correct intraverbal-tacts did not increase following the introduction of the divergent intraverbal response requirement despite consistently high levels of correct prompted divergent intraverbals. Thus, we taught them to emit the rehearsal response (e.g., “Color: red, yellow, blue, red, yellow, blue, red, yellow, blue”) following the DOR prompt. Intraverbal-tacts immediately emerged upon introducing the rehearsal response requirement for Sam and Ivan, and correct intraverbal-tacts maintained after the DOR prompt was removed.

For Gabe, intraverbal-tacts emerged shortly after introducing the divergent intraverbal response requirement; thus, Gabe was not taught the rehearsal response. However, unlike Sam and Ivan, correct intraverbal-tacts did not maintain when the DOR prompt was removed. We
implemented a brief reversal to the DOR prompt during which intraverbal-tacts returned to 100% correct, suggesting that correct intraverbal-tacts depended on the DOR prompt. Thus, we taught Gabe to emit the divergent intraverbal contingent on the question. Upon returning to intraverbal-tacts probes without the DOR prompt, intraverbal-tacts increased but not to desirable levels. Levels of correct intraverbal-tacts generally correlated with the percentage of correct independent divergent intraverbals, which were inconsistent. Thus, we conducted a second set of separate training sessions in hopes of further increasing the probability that Gabe would emit the divergent intraverbal contingent on the question alone. Upon returning to intraverbal-tact probes without the DOR prompt, independent divergent intraverbals and intraverbal-tacts increased to above 89%.

Although intraverbal-tacts were the primary dependent variable of interest, we also collected data on performance on component skill probes to assess the emergence of latter component skills following mastery of skills taught earlier in the sequence. Performance on component skills probes is depicted as black or white squares in the second, fourth, and sixth panels of Figure 4. The absence of a square indicates it was not probed because it had either just been taught or previously mastered. During the initial component skills probes, Sam demonstrated mastery of the element tacts, consistently responded with the correct category tact for colors only, provided one correct element for each category during intraverbal categorization, and consistently selected the color that corresponded to the visual sample stimulus regardless of the instruction. During the initial component skills probes for Gabe, Gabe emitted 100% correct element tacts, no correct responses for category tacts and intraverbal categorization, and 50% correct for the selection response (selecting the color on each trial regardless of the question). Ivan emitted 83% correct element tacts, no correct responses for category tacts and intraverbal categorization, and 39% correct for the selection response. Performance on component skills probes remained relatively stable following mastery of each component skill except for the increase to listing two colors and three shapes during intraverbal categorization probes following mastery of the category tact for Sam (demonstrating the emergence of intraverbal categorization) and a decrease from 50% to 0%
during selection response probes following mastery of intraverbal categorization for Gabe (instead of a selection response, Gabe tacted both components of the sample stimulus on each trial; e.g., “red triangle”).
Figure 4. Intraverbal-Tact Probes and Component Skill Probes for Sam, Gabe, and Ivan. DSR+ = differential reinforcement; DOR Prompt = differential observing response prompt introduced for the remaining probes until a phase label indicates otherwise; TOSC = transfer of stimulus control. Probes with a DOR prompt that occurred following divergent intraverbal training and rehearsal training included a divergent intraverbal rehearsal response requirement (i.e., divergent intraverbal probes and rehearsal probes), respectively. Squares depict which component skills were probed. The numbers next to the squares indicate the percentage correct on the component skill probe for anything less than 100%; for intraverbal categorization, a pair of numbers indicate the number of correct colors (left) and shapes (right) listed. The absence of a box for any given skill indicates it was not probed. The dashed horizontal line indicates the mastery criterion.
CHAPTER 3: DISCUSSION

We sought to replicate Rodriguez et al. (2022), but teaching the component skills was insufficient for intraverbal-tacts to emerge for all participants. Rodriguez et al. showed the following component skills might be sufficient to facilitate the emergence of intraverbal-tacts: element tact, category tact, intraverbal categorization, and a multiply controlled selection response. However, mastery of these skills does not guarantee that the keyword (i.e., the variable term) in the question will exert divergent control or that the onset of joint control will be discriminable when presented with different questions about a picture or object, particularly for autistic children with developing verbal repertoires. Mastery of the aforementioned component skills was insufficient for the emergence of intraverbal-tacts for all three participants. Further, neither prompting participants to repeat the keyword in the question (DOR prompt) nor providing differential reinforcement for correct intraverbal-tacts had any differential effects on correct intraverbal-tacts.

An analysis of errors revealed that when the percentage of correct intraverbal-tacts was around 50%, the majority of errors consisted of intraverbal errors (i.e., a vocal response that corresponded to one of the elements in the visual compound stimulus but did not correspond to the question; 91%, 95%, and 66% for Sam, Gabe, and Ivan, respectively). Persistent intraverbal errors despite mastery of component skills may suggest insufficient divergent control by the auditory stimulus (in this case, the keyword in the question), the absence of joint control, or both. Thus, we evaluated the effects of two variations of a differential response requirement to address divergent intraverbals and rehearsal. During divergent intraverbal training, participants were taught to repeat the keyword (category) and then independently emit the corresponding list of target elements contingent on the question and DOR prompt. In this way, we aimed to enhance the divergent control exerted by the question. Although participants could list the elements belonging to a category when asked “What are some [category]?” (i.e., had mastered intraverbal categorization), thereby demonstrating divergent control under some conditions, this did not guarantee that the keyword would similarly exert divergent control when presented in a question. This appeared pertinent even
for participants who demonstrated some emergence of intraverbal categorization following mastery of the category tact. Gabe’s data showed an additional example of restricted stimulus control. Divergent stimulus control (i.e., the overt listing of the elements belonging to the category) needed to be transferred from the DOR prompt to the question itself to achieve consistently high levels of divergent intraverbals and intraverbal-tacts when the experimenter no longer prompted the DOR. Rather than teach participants to engage in a divergent intraverbal (or rehearsal) following a DOR prompt, future research might consider teaching participants to emit the response following the question alone to avoid prompt dependency. Future research might also evaluate ways to increase the probability that the divergent control taught during intraverbal categorization will generalize to intraverbal-tact probes by, for example, teaching participants to repeat the category name before listing elements belonging to that category during intraverbal categorization teaching (similar to degli Espinosa et al., 2020, 2021).

Whereas the divergent intraverbal response requirement was sufficient to produce emergent intraverbal-tacts for Gabe, correct intraverbal-tacts remained around 50% for Sam and Ivan. However, the experimenter conducted only one probe for Ivan during divergent intraverbal probes. Thus, it is unclear whether the divergent intraverbal would have had a slightly delayed effect like Gabe. We did not obtain repeated measures of intraverbal-tact probes with the divergent intraverbal response requirement for Ivan based on the success of the rehearsal response requirement for Sam and anecdotal observations suggesting that Ivan, like Sam, appeared to orient to the visual stimulus only after emitting the divergent intraverbal rather than while looking at the visual stimulus. Rehearsal training entailed a series of phases to strengthen the divergent control exerted by the question and increase the discriminability of the onset of joint control. Vosters and Luczynski (2020) facilitated delayed completion of instructions via joint control by teaching an echoic or rehearsal of the instructions. For one of the participants, Bruce, successful rehearsal of the instruction occurred on every trial but he did not reliably complete the instructions. It is possible he was not responding to his rehearsal as a listener (i.e., responding to his own vocal behavior as
verbal stimuli). After several sessions during which he repeatedly contacted reinforcement for responding to his rehearsals as verbal stimuli, rehearsal of the instruction became predictive of him completing the instruction. Thus, to ensure participants in the current study responded to their divergent-intraverbal responses or their rehearsal as a listener, they underwent a series of instructional phases that created a history of reinforcement for discriminating joint control. During the first phase, participants learned to repeat the keyword in the question, followed by three repetitions of the three target exemplars corresponding to that category. The second and third phases were designed to provide participants with a history of reinforcement for correct intraverbal-tacts following the rehearsal using a relatively errorless approach in which the experimenter controlled the complexity and timing of the visual stimuli. Several procedural features may have increased the saliency of the onset of joint control. First, during both Phases 2 and 3, the target visual stimulus for each trial was presented as a simple stimulus (colored scribble or black outlined shape) rather than a compound stimulus (colored shape). As a result, it is possible that the saliency of the tact (e.g., “triangle”) that overlapped in topography with the intraverbal (e.g., “shape: triangle, square, circle, triangle, square, circle, triangle, square, circle”) was enhanced. Second, by presenting the visual stimuli as the participant emitted the third repetition within the rehearsal, we aimed to increase the probability that the divergent control exerted by the auditory stimulus would co-occur with the divergent control exerted by the visual stimuli, potentially increasing the discriminability of joint control. Third, the second (nontarget) visual stimulus in the array in Phase 2 did not contain any of the target elements from either category (e.g., a black and white drawing of a shoe), potentially reducing the probability of errors (see discussion below). Fourth, simple stimuli from the opposite category (Phase 3) were only introduced within the visual array after mastery during Phase 2, such that participants had a history of responding under joint control before Phase 3. Fifth, by using simple stimuli in Phases 2 and 3, the experimenter used a point prompt, evoking an overt tact of overlapping topography with the rehearsal. In other words, the prompting procedures promoted control by the relevant visual stimulus. Finally, the rehearsal training context
included prompts to engage in overt responses of the same form and function as those presumed to be involved in intraverbal-tacts, and reinforcement was provided for correct responding. Notably, throughout rehearsal training, prompting and reinforcement of intraverbal-tacts did not occur with target visual compound stimuli to not interfere with the ability to assess emergence.

Although it is difficult to tease apart which specific features of rehearsal training contributed to the emergence of intraverbal-tacts during rehearsal probes, the immediacy with which mastery criterion for intraverbal-tacts was met in Phases 2 and 3 of rehearsal training speaks toward the likely importance of each phase (see Supporting Information 3). For example, for Sam, the percentage of intraverbal-tacts was near 100% during the first session of Phases 2 and 3, potentially suggesting that the rehearsal could have been sufficient for the emergence of intraverbal-tacts during rehearsal probes (with compound visual stimuli). In other words, Phases 2 and 3 may have been unnecessary. By contrast, for Ivan, whereas 100% correct intraverbal-tacts were observed during the first session of Phase 2, the percentage of correct intraverbal-tacts dropped to 50% in Phase 3. Thus, it seems unlikely that the rehearsal alone (Phase 1) would have been sufficient for the emergence of intraverbal-tacts during rehearsal probes. Decrements in responding upon introducing visual stimuli from the opposite category may have been due to overshadowing. That is, the relative saliency of the color may have interfered with the stimulus control exerted by the shape (Olaff et al., 2022). Indeed, when responding was around 50% during intraverbal-tacts and selection response component skills probes, participants consistently responded toward the color. The ability to prompt an overt tact of the target element by pointing to the element that corresponded with the rehearsal when elements from both categories were presented as simple stimuli in Phase 3 may have helped by increasing the saliency of the shapes; this history may have similarly addressed potential issues with overshadowing when colors and shapes were presented as compound stimuli.

Although the relative importance of each of these procedural features is unknown, the effects of rehearsal training on the emergence of intraverbal-tacts during rehearsal probes were
replicated across Sam and Ivan. Given the topographical and conceptual similarities of the divergent intraverbal and rehearsal, it seems likely that rehearsal training would have also produced immediate effects on intraverbal-tacts for Gabe had rehearsal training been implemented instead of divergent intraverbal training (What Works Clearinghouse, 2020). Nevertheless, the fact that the procedure that ultimately resulted in the emergence of intraverbal-tacts with visual compound stimuli varied slightly across participants represents a limitation of the current study. Future research might seek to replicate the effects of rehearsal training across participants to evaluate its generality before conducting evaluations aimed at understanding the conditions under which various procedural manipulations are necessary.

The current study adds to our understanding of intraverbal-tacts and the literature demonstrating the practical implications of an analysis of joint control. Overall, Michael et al.’s (2011) conceptual analysis of multiply controlled verbal behavior informed our procedures. When the set of component skills from Rodriguez et al. (2022) was insufficient for the emergence of intraverbal-tacts, we evaluated procedures aimed at addressing potentially absent sources of stimulus control that were implicated by Michael et al.’s conceptual analysis, namely, divergent control and joint control. Although Rodriguez et al. (2022) provided preliminary data on the necessity of each of the component skills, it is possible that the category tact and multiply controlled selection response would not have been necessary if rehearsal training had been introduced following mastery of the element tact and intraverbal categorization. In other words, multiple approaches may result in the emergence of intraverbal-tacts. The success of various approaches may depend partly on participants’ history of responding under multiple antecedent control, or more specifically, joint control (Ampuero & Miklos, 2019). Future research might be directed at further exploring necessary and sufficient conditions for promoting the emergence of intraverbal-tacts as well as potential moderating variables (e.g., history of responding under joint control). Upon future replications, the flowchart in Figure 1 may serve as a curriculum guide for practitioners seeking to teach intraverbal-tacts. The external validity of our approach may also be
strengthened by including generalization tests where intraverbal-tacts are probed using compound stimuli consisting of familiar elements (e.g., colors and shapes a participant has previously learned outside of the study).
BIBLIOGRAPHY


