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Training Intraverbal Naming to Establish Matching-to-Sample Performances

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Abstract The current study evaluated whether training *intraverbal naming* would be sufficient to establish visual-visual matching-to-sample (MTS) performances in college students. In the first experiment, we used a multiple-probe design across stimulus sets to assess whether six participants could match arbitrary visual stimuli (AB) after learning to tact their two experimentally defined classes (A' and B') and then intraverbally relate their names (i.e., "A' goes with B'"). All participants matched the stimuli accurately after training, as well as emitted the trained intraverbals. In the second experiment, we used a multiple baseline design across four participants to assess whether the same training would produce bi-directional intraverbals in the form of "B' goes with A'," and MTS performance consistent with symmetry (BA). All participants responded accurately during matching and intraverbal tests. Across both experiments, participants stated the trained intraverbals while performing the matching task. Results showed that MTS performance can be established solely by verbal behavior training.

Keywords Conditional discrimination · Intraverbal · Matching-to-sample · Naming · Symmetry

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Conditional discrimination occurs when behavior comes under the operant control of one stimulus in the presence of, or conditional upon, another stimulus (Catania 2007). Typically, conditional discrimination is investigated using a matching-to-sample (MTS) procedure (Cumming and Berryman 1965). In such a procedure, an individual is presented with a sample and comparison stimuli from which the correct selection produces a reinforcer. For instance, when presented with the sample A1, selecting B1 instead of B2 or B3 would be considered correct, while in the presence of A2 selecting B2 instead of B1 or B3, would be considered correct.

One of the outcomes of conditional discrimination training is the substitutability of sample and comparison stimuli (Sidman 1971). In other words, after training the conditional relations AB and BC, samples and comparisons may enter and subsequently become members of the same equivalence class (Sidman 2000). This form of substitutability is assessed by a series of MTS tasks, namely, reflexivity (AA; BB; CC), symmetry (BA; CB), transitivity (AC), and equivalence (CA; Sidman and Tailby 1982). The construct of stimulus equivalence has been used as the behavioral model for the study of meaning and symbolic behavior for several years (Sidman 1994) as it explains how certain stimuli (e.g., the printed word "dog") may stand for their "referents" (e.g., an actual dog).

Some researchers have suggested that humans often engage in verbal behavior to solve MTS tasks consistent with symmetry, transitivity, and equivalence (e.g., Eikeseth and Smith 1992; Horne and Lowe 1996; Horne et al. 2004; Lowenkron 1998; Randell and Remington 1999). Although others have pointed out that verbal behavior may not be necessary (e.g., Schusterman and Kastak 1993; Sidman 1992, 2000), it seems sufficient to produce performance consistent with equivalence (e.g., Miguel and Kobari-Wright 2013).

One of the main accounts used to investigate how verbal behavior may produce and mediate performance on MTS is *naming* (Horne and Lowe 1996). Naming has been defined as a higher order class of behavior that involves a bi-directional relation between "a class of objects and events, and the speaker-listener behavior they occasion" (Horne and Lowe 1996; p. 200). We refer to a *generalized naming repertoire* when an individual can respond both as a speaker (i.e., tact the stimulus) and a listener (i.e., select the stimulus when labeled) when only one component is directly trained (Miguel and Petursdottir 2009). For instance, an individual who is taught to say "giraffe" in the presence of the animal (i.e., tact training) can point or orient to the animal (i.e., giraffe) upon hearing its dictated name in the absence of direct training (i.e., listener training). Conversely, when taught to select a picture of a monkey when given its dictated name (i.e., listener training), an individual with an established naming repertoire can then tact the picture (i.e., say "monkey" in its presence) without additional training (for an extensive explanation on how naming is established, see Horne and Lowe 1996).

The role of naming (i.e., speaker and listener behavior) in the establishment of arbitrary stimulus classes has been demonstrated in several studies with both typically developing and developmentally disabled children (Horne et al. 2004, 2006, 2007; Kobari-Wright and Miguel 2014; Lee et al. 2015; Lowe et al. 2002; Mahoney et al. 2011; Miguel et al. 2008, 2015; Miguel and Kobari-Wright 2013; Ribeiro et al. 2015;

Sprinkle and Miguel 2012). Across all of these studies, only the participants who responded both as speakers and listeners towards the stimuli accurately sorted them into classes. Kobari-Wright and Miguel (2014), for example, taught four preschool children with autism to select pictures of hound, work, or toy dogs in the presence of their dictated names in an auditory-visual MTS task. Three of the four participants correctly categorized the pictures (i.e., visual-visual MTS). The remaining participant who failed to categorize, also failed to tact the stimuli. After tact training, this participant passed categorization tests. These results replicate previous findings that show that the bi-directional relation between speaker and listener behavior co-occurs with stimulus class formation. The authors suggested that participants were tacting the sample (e.g., say "toy dog" in the presence of a picture of a Chihuahua), whose response product served as a discriminative stimulus to evoke the selection of the correct comparison (e.g., the picture of the poodle) from the array. This is because the picture of the poodle already occasioned listener behavior. This interpretation is also corroborated by improvements in categorization performance when participants were required to tact the samples (e.g., Lee et al. 2015; Lowe et al. 2002; Miguel et al. 2008; Miguel and Kobari-Wright 2013).

Another type of naming that may generate and mediate performance in MTS tasks is *intraverbal naming* (Horne and Lowe 1996). Intraverbal naming involves the establishment of intraverbal relations between specific names of stimuli acquired incidentally during visual-visual conditional discrimination training (Horne & Lowe). Once these intraverbals are established, they may serve to mediate subsequent performance. For example, when a learner is taught to select a picture of a triangle in the presence of a star, he or she may intraverbally relate the stimuli by saying, "star goes with triangle." In subsequent trials, the participant's responses on MTS tests may be verbally mediated when he or she (1) tacts the sample and says, "star," (2) whose response product/star/ would evoke the previously learned relation, "star goes with triangle," and (3) whose product (i.e., triangle) occasions the behavior of selecting the correct comparison (i.e., picture of a triangle).

In the first study addressing intraverbal naming, Lowe and Beasty (1987) presented a visual-visual MTS task to 29 typically developing children (ages 2–5 years). The experimenter taught participants to match a vertical line sample to a green card comparison (A1B1 relation), and a horizontal line sample to a red card comparison (A2B2). In the second phase, the experimenter taught the children to match a vertical line sample to a triangle (A1C1) and a horizontal line sample to a cross (A2C2). The experimenter then assessed whether participants could match B to C, C to B (transitivity and equivalence, respectively), and B to A and C to A (symmetry) in a series of MTS tasks. Results indicated that 17 out of the 29 subjects passed these tests, and that participants who passed the tests had intraverbally named the correct sample-comparison pairs. Recordings of participants' vocal responses showed that participants labeled individual stimuli (e.g., "up" for the vertical line, "down" for the horizontal line, etc.), even though they received no instruction to do so. Furthermore, some participants responded with, "up green" when presented with the vertical line stimulus, in which the correct comparison was the color green. Similarly, when presented with the horizontal stimulus, they said, "down red." The 12 participants who failed the tests were subsequently taught to verbally relate the sample-comparison pairs. For instance, on A1B1 trials, they were taught to say, "up green." After this training, all but one participant passed the tests. The participant who failed the test also failed to state the intraverbal correctly, suggesting that intraverbal naming may have mediated test performance.

In an attempt to directly manipulate intraverbal naming to produce matching performances, Petursdottir et al. (2015) evaluated whether AB and BA (symmetry) conditional discriminations would emerge after A'B' intraverbal training. In other words, experimenters trained participants to tact arbitrary pictures with individual names (e.g., "Psi" and "Kibi") and to relate these names in intraverbal frames (e.g., "Psi goes with Kibi"). The authors tested for the hypothesis that symmetry matching was dependent upon the emission of B'A' "symmetrical" intraverbals. Ten children (3.5–5.5 years old) were exposed to tact training, then A'B' intraverbal training, and subsequently tested on AB and BA emergent relations, as well as the B'A' symmetrical intraverbal. Four of the five participants who passed the matching-to-sample (MTS) tests (out of 10) did so without emitting the symmetrical intraverbal, challenging the naming hypothesis. Of note, baseline tact and intraverbal relations were slowly acquired, which would suggest that participants may have not had a sufficiently sophisticated verbal repertoire to derive bi-directional (i.e., symmetrical) intraverbals—a skill shown to be brought about after a history of multiple-exemplar training (Pérez-González et al. 2007). Thus, it is possible that the participants in Pettursdottir et al. were not representative of those who would solve categorization tasks via intraverbal naming.

Despite the limited literature on intraverbal naming, many of the studies in stimulus equivalence feature verbally sophisticated adults as participants who could be simply learning and solving MTS tasks by tacting and intraverbally relating experimental stimuli, even though this is rarely reported or discussed (e.g., Arntzen et al. 2014, 2015). Thus, the study of naming may serve to clarify how and if verbal behavior plays a critical role in the formation of stimulus classes by adults.

Therefore, the purpose this study was to extend the findings of Petursdottir et al. (2015) by assessing whether teaching college students to tact and intraverbally relate pictures would be sufficient to produce positive performances on visual-visual MTS (AB and BA) tasks. We also assessed whether participants' accurate verbal performance on intraverbal tests co-occurred with positive MTS performance. Additionally, we asked participants to describe any strategies that they might have been using while solving the tasks.

Experiment 1

Method

Participants and Setting Participants were six undergraduate psychology students (four females and two males, ages 20–32) recruited from a large public university. Students received course credits contingent upon completing the study. The criterion for participating included not speaking the Tagalog language (used in the experiment), as well as not having participated in any other stimulus control study. Sessions for participants 1 through 5 (P1-P5) were conducted at the Verbal Behavior Laboratory on campus, which measured 7 m by 3 m and contained four tables, nine chairs, three cabinets, and three computer stations. The participant and the experimenter sat side-by-side at a table, with a computer screen in front of them, while a research assistant sat behind them for data collection. Sessions for P6 were conducted at another data collection room on campus, which measured 1.5 m by 1.2 m and contained two tables, two chairs, and one desktop computer. Each participant completed between one and three sessions, with no more than 3 days between sessions, and no session lasting more than 2 h.

Materials The stimuli consisted of three sets of arbitrary pictures (see Fig. 1), with each set containing six pictures coded A1, A2, A3, B1, B2, and B3, for the experimenter's use only. For training purposes, the letters A and B were used to distinguish between the two groups of stimuli within a set. Each picture was 5.6 cm by 6.9 cm in size.

For all conditions, except intraverbal training, stimuli were presented using Microsoft PowerPoint on a desktop computer with a 43.38 cm display. Stimuli were presented against a white background, with trial slides separated by blank slides. The experimenter controlled the presentation of the stimuli, and participants made a selection by touching one of the pictures with their index finger. Each stimulus was given an

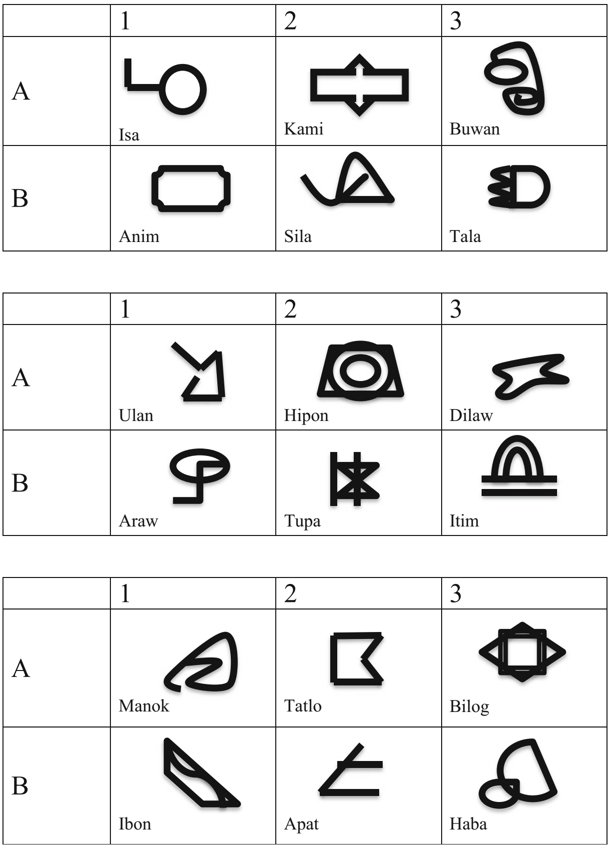


Fig. 1 Arbitrary stimuli for set 1 (*top*), set 2 (*middle*), and set 3 (*bottom*)

individual Tagalog name consisting of two phonemes. These names were selected because they could be easily pronounced, and the words did not sound like any word spoken in English (see Fig. 1).

Dependent Measures and Experimental Design The main dependent measure was the percentage of correct selections during MTS pretests and posttests. In the presence of sample A1, the correct response was selecting B1, in the presence of A2 selecting B2, and in the presence of A3 selecting B3. Additional dependent measures included the percentage of accurate tacts, defined as saying the name of the stimulus in Tagalog when presented with a visual sample on the computer screen (e.g., saying "Isa" when presented with A1). Another dependent measure was the percentage of correct selections when given the dictated name. For instance, when presented with the auditory stimulus (e.g., "Anim"), a correct response was selecting the corresponding visual stimulus (e.g., A2) from a three-stimulus array. Another dependent measure was the percentage of correct intraverbal responses, which consisted of emitting the related name when presented with a fill-in-the-blank statement. Table 1 lists the intraverbal statements trained using "goes with." For example, when the experimenter said, "Isa (A1) goes with …" the vocal response "Anim (B1)" was considered correct. The experimenters also assessed the number of trials to reach mastery criterion, and the percentage and accuracy of vocalizations emitted during MTS posttests (e.g., tacting stimuli and/or relating the stimuli intraverbally with or without experimentally defined names).

During MTS and listener trials, the first response of touching the screen with the index finger was scored as either correct or incorrect. During tact and intraverbal trials, the first vocalization was recorded. All sessions were videotaped and later coded by a second observer for interobserver agreement (IOA) and treatment integrity (TI) purposes.

We used a concurrent multiple-probe design across three sets of stimuli (Horner and Baer 1978) to determine the effects of intraverbal training on MTS performance and to evaluate the degree to which exposure to the training conditions affected responses on subsequent sets. In the first session during which set 1 stimuli were trained and tested, participants were also presented with MTS pretest probes for sets 2 and 3. These probe blocks were interspersed between the training conditions of the target set (e.g., presented between tact training and listener testing). After completing set 1, set 2 was trained in the next session, and probe blocks for set 3 were continually presented. P1 and P2 were exposed to four probe blocks for set 2, and eight probe blocks for set 3. The remaining four participants (i.e., P4-P6) were exposed to two probe blocks for set 2, and four for set 3.

Table 1 Intraverbal relations trained vocally across sets

	Set 1	Set 2	Set 3
A1-B1	"Isa goes with Anim"	"Ulan goes with Araw"	"Manok goes with Ibon"
A2-B2	"Kami goes with Sila"	"Hipon goes with Tupa"	"Tatlo goes with Apat"
A3-B3	"Buwan goes with Tala"	"Dilaw goes with Itim"	"Bilog goes with Haba"

Interobserver Agreement and Treatment Integrity A second observer independently recorded data from videotaped sessions for at least 33 % of all sessions per participant. For each trial, an agreement was scored if both the experimenter and the second observer scored the trial as correct, incorrect, or prompted. Point-by-point agreement was calculated by dividing the number of agreements by the sum of agreements and disagreements and then multiplied by 100. Mean IOA was as following: 98 % (range, 94–100 %) for P1, 98 % (range, 94–100 %) for P2, 99 % (range, 94–100 %) for P3, 98 % (range, 94–100 %) for P4, 99 % (range, 94–100 %) for P5, and 98 % (range, 94–100 %) for P6.

The second observer assessed treatment integrity (TI) for at least 33 % of all sessions per participant. Data were taken on whether a trial was correctly or incorrectly implemented. Correct implementation consisted of presenting the correct auditory samples during the tact and intraverbal phase, as well as providing the appropriate consequence (e.g., praise for correct responses and error correction for incorrect responses). An incorrect implementation was scored if any of the trial components were not executed correctly. TI was calculated by dividing the number of correctly implemented trials by the total number of trials conducted by the experimenter. Mean TI was as follows: 96 % (range, 94 to 100 %) for P1, 98 % (range, 94 to 100 %) for P2, 98 % (range, 94 to 100 %) for P3, 95 % (range, 89 to 100 %) for P4, 99 % (range, 94 to 100 %) for P5, and 99 % (range, 94 to 100 %) for P6.

Experimental Conditions We exposed participants to the conditions as summarized in Table 2. Pretraining consisted of 9-trial blocks, while all other conditions were presented on 18-trial blocks. Passing criterion refers to testing, while mastery criterion refers to training (see below).

MTS Pretraining with Familiar Pictures During this condition, the experimenter gave participants instructions similar to the ones given during the MTS test described below. MTS pretraining was conducted using six nonarbitrary stimuli (i.e., three pairs) to familiarize participants with the experimental procedures. Pictures of two animals, two vehicles, and two food items were presented. Stimuli were counterbalanced so that each correct comparison stimulus appeared three times, once on the left, once on the middle, and once on the right on the screen. The correct response was touching the

Table 2 Order of experimental phases

Phase	Passing criterion	Mastery criterion
1. Pretraining	1 block at 89 %	–
2. Pretest	1 block at 56 %	–
3. Tact training	–	2 blocks at 94 %
4. Listener test	2 blocks at 94 %	–
5. Intraverbal training	–	2 blocks at 94 %
6. Review	–	3 blocks at 94 %
7. Posttest	2 blocks at 78 %	–
8. Vocal posttest	–	–

comparison related to the sample based on a shared common name (e.g., vehicle). The criterion to proceed to the pretest condition was a score of 89 % (eight out of nine trials) in one nine-trial block. Responses produced no consequences.

MTS Pretest and Posttest At the beginning of this phase, the experimenter read the following script to the participant:

> "An image will appear on the screen. I want you to touch the image with your index finger, and when you do, three more images will appear. Touch the picture that best goes with the first image. You have 5 s to respond. I will count your first response as your answer. I won't give you feedback on your response. Can you repeat these instructions?"

A trial began when a sample stimulus appeared at the center of the screen. After participants touched the picture as an observing response, three more pictures appeared on the screen, positioned horizontally below the sample. When participants touched one of the comparison stimuli, a blank slide was shown and the next trial started. If they did not respond within 5 s, the experimenter provided the instruction, "please make a selection." A correct response was scored when, in the presence of a sample (e.g., A1), participants selected the related comparison (e.g., B1). An incorrect response was scored when an unrelated comparison was selected (e.g., B2 or B3), or if participants did not respond for another 5 s. Each sample was presented six times in a randomized order within each 18-trial block. After training, all participants were exposed to a minimum of two posttest blocks. We took additional data on participants' tacts of the sample, and intraverbal vocalizations. Passing criterion consisted of a minimum of 78 % (14 out of 18 trials) accuracy for two consecutive blocks.

Tact Training At the beginning of this phase, the experimenter read the following script:

> "When a picture appears, touch the picture with your finger, I will say the name, and I want you to repeat it. I will help you this time, but for the next block I will give you the chance to respond independently. You have 5 s to respond before I help you. If you answer incorrectly, I will correct it. Can you repeat these instructions?"

A trial began when a sample stimulus appeared on the screen. Only one picture positioned in the center was shown at a time. Participants touched the picture with their index finger as an observing response. For the first 18-trial block, the experimenter provided an immediate vocal prompt. For subsequent blocks, she used a constant 5 s prompt delay. Praise was delivered for prompted responses during the first block (e.g., "nice job"), while feedback followed prompted responses during subsequent blocks (e.g., "yes" or "uh-huh"). Incorrect responses were followed by an error correction that consisted of the experimenter saying "No," stating the correct response, and re-presenting the trial. All six stimuli were presented in a predetermined order using an 18-trial block, and each picture appeared three times within a block. The mastery criterion was a minimum of 94 % (i.e., 17 out of 18 trials) accuracy for two consecutive blocks.

Listener Test At the beginning of this phase, the experimenter read the following script:

> "Three pictures will appear on the screen, and I will say a name. Touch the picture that goes with the name I just said. You have 5 s to respond, and I will count your first selection as your answer. I won't give you any feedback if you answered correctly or not. Can you repeat these instructions?"

The experimenter waited for the participant to look at the screen as an observing response, then the comparison stimuli positioned horizontally on the screen and the auditory stimulus (e.g., "Anim") were presented simultaneously. The experimenter told the participants to "make a selection" when they did not respond within 5 s. The correct response was pointing to the picture that corresponded to the dictated word, while an incorrect response was pointing to a different picture, or not responding for 5 s. No feedback was provided. All six stimuli were presented three times each in a predetermined order in an 18-trial block. The passing criterion was a minimum of 94 % (i.e., 17 out of 18 trials) accuracy for two consecutive blocks.

Intraverbal Training At the beginning of this phase, the experimenter read the following script:

> "For this block, I want you to repeat the statement that I will say. Then, I will only say the first part of the statement, and I want you to finish it. Later on, I will only say the first part of the statement, and I want you to finish it as best as you can. You have 5 s to respond before I help you. If you respond incorrectly, I will correct it. Can you repeat these instructions?"

The participant was taught to relate the names from group A with names from group B using the statement "[A'] goes with [B']" (see Table 1). Each intraverbal relation was presented six times in a predetermined order. The first block consisted of (a) the experimenter emitting the intraverbal statement, (b) the participant repeating the statement heard, (c) the experimenter stating a fill-in-the-blank statement, and (d) the participant finishing the fill-in-the blank statement by saying the corresponding name.

During the first block, the experimenter emitted the intraverbal statement (e.g., "Isa goes with Anim") and asked participants to repeat the statement. Correct repetitions were followed by praise. During the second block, the experimenter presented a fill-in-the-blank statement (e.g., "Isa goes with ___"), and the participant was required to emit the corresponding intraverbal (e.g., "Anim"). As the experimenter stated the fill-in-the blank, she gave an expectant look and made a hand gesture (i.e., raised eyebrow and one hand reaching toward the participant with the palm facing up) to prompt participants to finish the statement. In subsequent blocks, only the fill-in-the blank was presented, and the participants were given 5 s to respond. A correct response consisted of saying the correct name, and was followed by praise. An incorrect response consisted of saying the wrong name and was followed by an error correction. The error correction procedure consisted of (a) the experimenter saying the intraverbal statement (e.g., "Tatlo goes with Apat"), (b) the participant repeating the statement, and (c) the trial being re-presented. The mastery criterion consisted of a minimum of 94 % (17 out of 18 trials) accuracy for two consecutive blocks.

Review The purpose of this phase was to ensure that participants maintained accurate tact, listener, and intraverbal responses before being exposed to the MTS posttest. The experimenter presented one 18-trial block per condition, and the order in which the conditions were presented was counterbalanced across participant. Participants 1 and 2 were exposed to listener, intraverbal, and tact; participants 3 and 4 were exposed to blocks of tact, listener, and intraverbal; and participants 5 and 6 to listener, tact, and intraverbal. The sequence of block presentations was never tact, intraverbal, and listener to avoid incidentally training the sequence required for intraverbal naming. Praise was faded within each block. For instance, if the first block presented was for listener behavior, responses to the first nine trials of the 18-trial block were followed by praise, while the last nine trials were not. Thinning the schedule ensured that failure to perform accurately during posttests was not due to lack of consequences. The criterion to move to the next testing block was a score of 94 % (17 out of 18 trials); scoring below resulted in exposure to another block in the same condition.

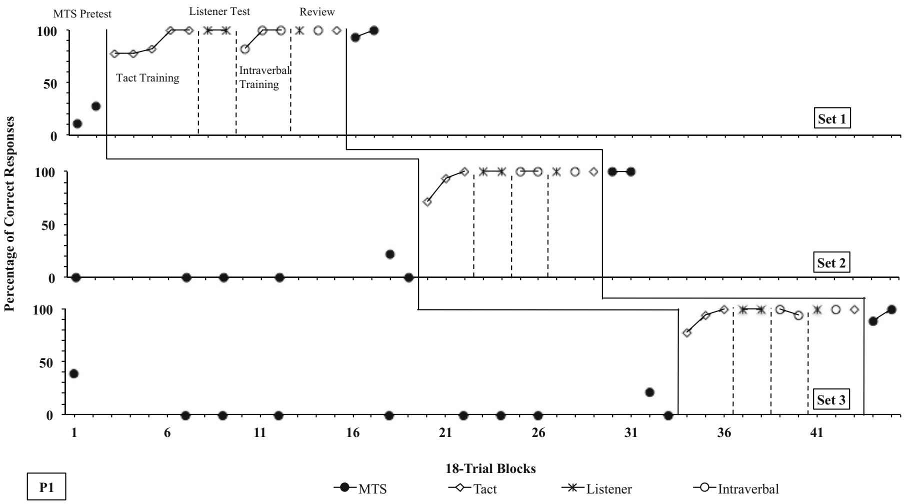
Vocal Posttest An additional MTS posttest block was conducted to assess participants' vocalizations. At the beginning of this phase, the experimenter stated the instruction, "I want you to vocalize the strategy that you are using to select the pictures." The vocal posttest was not conducted with P1 due to a procedural error.

Results

All six participants scored 100 % during pretraining with familiar pictures suggesting that subsequent errors made during the MTS tests were not due to unfamiliarity with the task. Additionally, none of them matched the pictures accurately during pretests (see Figs. 2, 3, and 4).

Figure 2 depicts data on percentage of correct matches (closed squares), tacts (open diamonds), listener responses (asterisk), and intraverbal responses (open circle) for P1 and P2 across sets of stimuli. The first block (i.e., training block with immediate prompt delay) for each of the training phases (i.e., tact and intraverbal training) was not included in any of the graphs. After tact training (54–90 trials across sets), P1 passed the listener test with 100 % accuracy, mastered intraverbal training (36–54 trials across sets) and scored 100 % during the review phase for all the conditions (i.e., tact, listener, and intraverbal), across all sets. P1 passed the MTS posttest with 100 % (M=97 % for set 1, M=100 % for set 2, and M=94.5 % for set 3) accuracy but did not emit any unsolicited vocalizations. However, at the end of the experiment, P1 said, "…I remembered the verbal exercise and said it in my head."

After tact training (108–162 trials across sets), P2 passed the listener test (M=94 %), mastered intraverbal training (54–126 trials across sets), and maintained accurate responding during the review phase. After scoring 83 % on the tact review in set 1, we conducted an additional tact review block (100 %). P2 passed the posttests (M=94.5 % for set 1, M=100 % for set 2, and M=100 % for set 3). During the vocal posttest, P2 vocalized the correct sample-comparison relation (e.g., "Isa goes with Anim"; grey bars) and correctly matched the pictures during all trials.



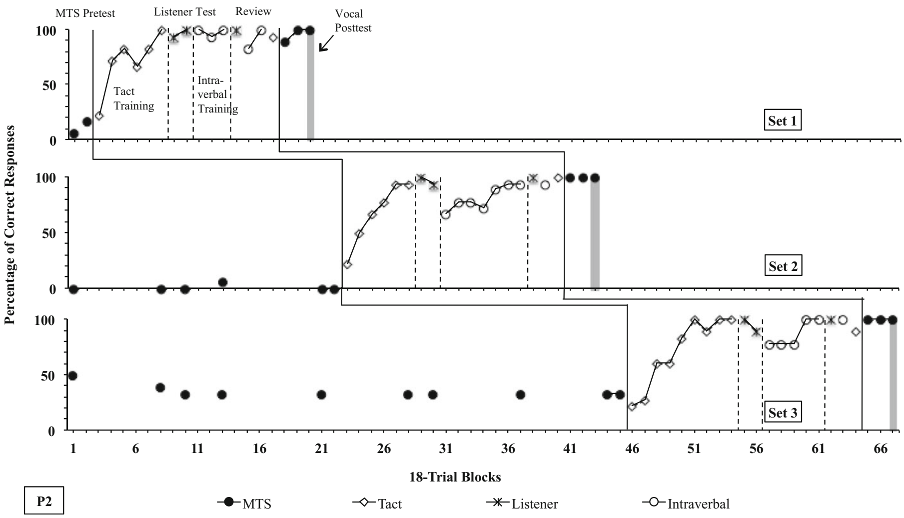


Fig. 2 Percentage of correct responses for P1 (*upper panel*) and P2 (*lower panel*) during training and testing probes across sets

Figure 3 depicts data on the percentage of correct matches, tacts, listener responses, and intraverbal responses for P3 and P4 across sets of stimuli. After tact training (72–126 trials across sets), P3 scored 100 % in the listener test for all three sets, mastered intraverbals (36–72 trials across sets) and passed the review phase for all conditions across all sets. During posttests, she accurately matched arbitrary pictures during all trials across sets (M=100 % across all sets). While she did not emit any unsolicited vocalizations, she vocalized the correct sample-comparison relation (e.g., “Ulan goes with Araw”) during the vocal posttest, while accurately matching the pictures.

Following tact training (72–108 trials across sets), P4 passed the listener test with 100 % accuracy, mastered intraverbals (54–72 trials across sets), and scored 94–100 %

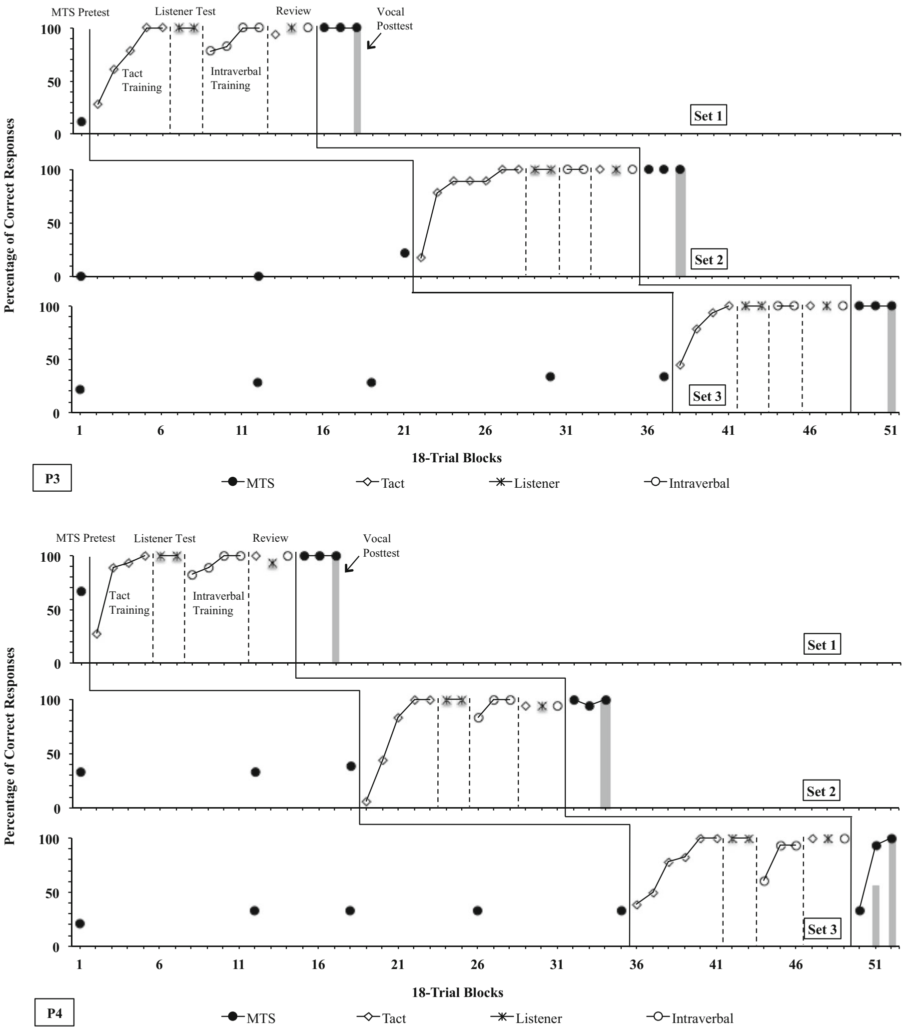


Fig. 3 Percentage of correct responses for P3 (*upper panel*) and P4 (*lower panel*) during training and testing probes across sets

during the review phase for all conditions. P4 passed the first two sets (*M*=100 % for set 1, and *M*=97 % for set 2). However, she failed the first posttest block for set 3, with a score of 33 %. Anecdotally, P4 reported, "I'm doing what I originally matched, which I know is wrong. I wasn't doing this on the other pictures. I know I should match them based on what you told me." P4 was observed to be moving her mouth as if she was talking softly while she matched the pictures on the first two posttest blocks. When presented with a second posttest block, her score drastically increased to 94 %. Interestingly, during the second posttest block, P4 vocalized the correct sample-comparison intraverbals in 56 % of trials (i.e., 10 out of 18 trials). During the vocal posttest, P4 vocalized the correct sample-comparison relation during all trials and matched at 100 % accuracy for all three sets.

Figure 4 depicts data on percentage of correct matches, tacts, listener responses, and intraverbal responses for P5 and P6 across three sets of stimuli. After tact training (72–108 trials across sets), P5 passed the listener (range 94–100 % accuracy) test, mastered intraverbals (36–72 trials across sets), and scored at 94–100 % accuracy during the review phase for all the conditions (i.e., tact, listener, and intraverbal). P5 matched the pictures accurately during posttests across sets (M=100 % for set 1, M=100 % for set 2, and M=100 % for set 3), while engaging in unsolicited vocalizations. He emitted accurate sample-comparison intraverbals during 37 and 33 % of trials for the first and second posttest blocks, respectively. P5 emitted the correct intraverbal vocalizations during all trials for set 2 and during 44 % of trials for the first posttest block of set 3. During vocal posttests, P5 emitted correct sample-comparison intraverbals, except on

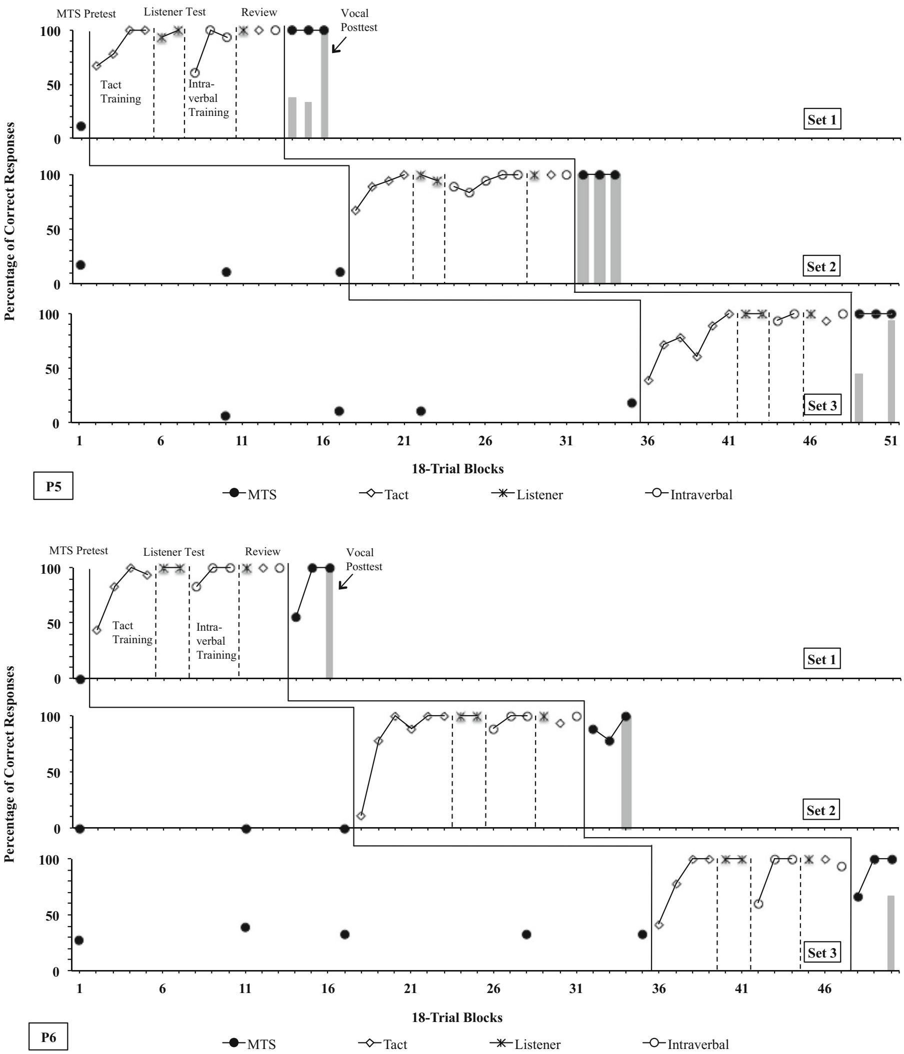


Fig. 4 Percentage of correct responses for P5 (*upper panel*) and P6 (*lower panel*) during training and testing probes across sets

one trial in set 3 wherein he mispronounced a name. His matching performances during the vocal posttests were 100 % accurate.

Following tact training (72–108 trials across sets), P6 passed the listener test with 94–100 % accuracy. After intraverbal training (54 trials in each set), he scored 94–100 % during the review phase for all conditions. P6's performance during posttests was lower than other participants (M=78 % for set 1, M=83.5 for set 2, and M=83.5 for set 3), and he did not vocalize while performing the MTS tasks. During the vocal posttest, he engaged in intraverbal vocalizations during 100 % of trials for sets 1 and 2. In set 3, however, he emitted only the sample-comparison intraverbals during 67 % of trials, despite matching the pictures with 100 % accuracy.

Discussion

All six participants in Experiment 1 performed accurately on MTS tasks after tact and intraverbal training. Of the six participants, two (P4 and P5) vocalized the trained intraverbal statements during posttests without any prompts. The remaining participants emitted vocalizations when required to do so during the vocal posttest. Of the five participants who completed the vocal posttest (P1 was not exposed to this condition), four vocalized during all trials. P6 vocalized during 12 out of 18 trials (i.e., 67 %), but matched the pictures at 100 % accuracy. All five participants vocalized the sample-comparison intraverbal statements taught during training (i.e., [A'] goes with [B']).

P4 did not vocalize without instructions in sets 1 and 2, but did so in set 3. This participant failed the first MTS posttest block (i.e., 33 %) for set 3 and did not engage in any vocalizations. However, on the second posttest block, she vocalized during 56 % of trials, and her matching performance increased to 94 %. The fact that she vocalized in only 56 % of trials, and yet responded at a high accuracy in MTS suggests that either she did not use the verbal strategy in some trials, or did so covertly. P4's performance supports previous studies (e.g., Kobari-Wright and Miguel 2014; Miguel et al. 2008; Lee et al. 2015; Miguel and Kobari-Wright 2013) that found that when participants are required to tact the sample, their visual-visual MTS performance improves as tacting stimuli may serve to generate the discriminative stimulus necessary to evoke the selection response.

Results from Experiment 1 showed that participants responded accurately to visual-visual matching tasks after learning to tact and intraverbally relate visual stimuli. Even if verbal mediation was not required for participants to respond during MTS tasks (more below), this study shows that conditional relations between A and B stimuli can be established solely by intraverbal naming.

Perhaps one of the most prominent limitations of Experiment 1 is that it assessed only baseline (AB) conditional relations. Horne and Lowe (1996) suggested that intraverbal naming may serve as a potential underlying mechanism for the emergence of novel stimulus relations. More specifically, the self-echoic repetition (Skinner 1957) of intraverbal chains may facilitate the formation of equivalence classes. For example, in repeating, "Isa goes with Anim, Isa goes with Anim, Isa goes with Anim," (A1'B1') the frequency of "Anim" preceding "Isa" may be sufficient to establish the intraverbal (e.g., "Anim goes with Isa" [B1'A1']) which would serve to mediate the corresponding matching performance (Wollen and Gallup 1968). Hence, the purpose of Experiment 2 was to evaluate the role of intraverbal naming on the emergence of symmetry relations by assessing whether the procedures used in Experiment 1 could facilitate the emergence of bi-directional relations (Pérez-González et al. 2008). That is, after being taught AB relations using intraverbal naming, we assessed whether participants could relate BA relations in both MTS and vocal posttests.

Experiment 2

Method

Participants, Setting, and Materials Participants included one male (P6) who served as a participant in Experiment 1 and three females (P7, P8, and P9) undergraduate students from the same university, ages 23 to 28, recruited based on the same criteria as specified in Experiment 1. Settings and materials were identical to those described in Experiment 1.

Dependent Measures and Experimental Design We used a two-tier nonconcurrent multiple-baseline design across participants (Watson and Workman 1981) to assess the effects of training on subsequent matching and intraverbal performance. Mastery, passing, and emergence criteria for each condition were the same as Experiment 1 (see Table 2).

Interobserver agreement (IOA) and treatment integrity (TI) data were also collected as described in Experiment 1. IOA and TI across conditions for P6 were reported in Experiment 1. IOA averaged 99.1 % (range 96 to 100 %) for P7, 99 % (range 97 to 100 %) for P8, and 98 % (range 93 to 100 %) for P9. TI across conditions averaged 93.7 % (range 87 to 100 %) for P7, 97 % (range 89 to100%) for P8, and 98 % (range 93 to 100 %) for P9.

Procedures Participants were exposed to only set 3 stimuli used in Experiment 1 (see Fig. 1). All training and testing conditions were identical to those described above with the addition of a BA MTS and B'A' Intraverbal posttest following the AB MTS posttest. The BA MTS posttest was identical to the AB MTS posttest with the exception that members of class B (e.g., B2) served as sample stimuli and members of class A (e.g., A1, A2, and A3) served as comparison stimuli. Similarly, the B'A' Intraverbal posttest was conducted in the same manner as the A'B' Intraverbal posttest, but with the B' stimulus presented first. For example, in the A'B' Intraverbal posttest, experimenters presented "Manok (A1') goes with…" with the correct response being "Tatlo" (B1') and in the B'A' Intraverbal posttest, experimenters presented "Tatlo (B1') goes with…" and the correct response was "Manok (A1')." The three symmetry relations tested were as follows: (1) B1'A1'—Ibon goes with Manok, (2) B2'A2'—Apat goes with Tatlo, and (3) B3'A1'—Haba goes with Bilog.For P6 and P7, the B'A' Intraverbal posttest was presented before the corresponding BA MTS posttest to control for a possible sequence effect. Conversely, P8 and P9 completed the B'A' Intraverbal posttest following the BA MTS posttest.

Results

All participants passed pretraining with familiar pictures. Figure 5 depicts the percentage of correct responses across MTS pretests and posttests, listener probes, and intraverbal tests for P6-P9 (training data are not included in this figure). All participants performed below criterion for AB MTS pretests. Mastery criterion for tact training was met after ten blocks (180 trials) for P7, four blocks (72 trials) for P6, five blocks (90 trials) for P8, and eight blocks (144 trials) for P9. Subsequently, they all passed the listener test (*M*= 100 %). Intraverbal training required two blocks (36 trials) for P7, three blocks (54 trials) for P6, and three blocks for P8 and P9. P7, P6, and P8 completed the review within one block for each condition, while P9 required two blocks of tact. P7, P6, and P9 passed all posttests. P8 scored 94 % on the first block (18 trials) and 67 % on the second block (18 trials) of the A'B' intraverbal posttest, failing to meet the emergence criterion. Errors were mainly due to mispronounced tacts (see below). However, P9 met the emergence criterion for the B'A' intraverbal posttest by scoring 94 % on two consecutive blocks (36 trials).

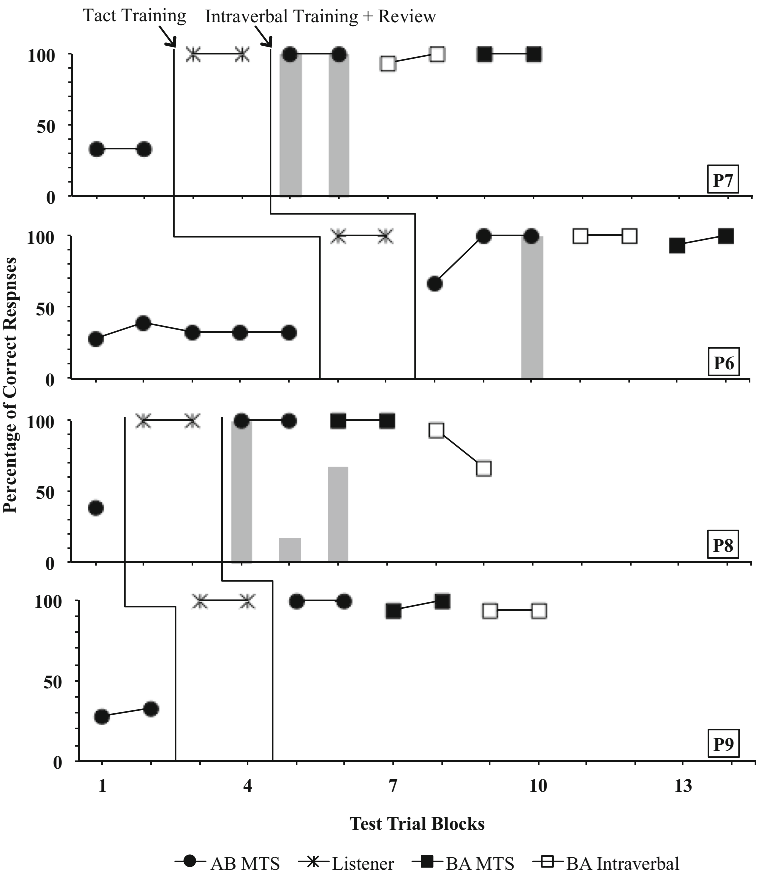


Fig. 5 Percentage of correct responses during training and testing probes across participants (Experiment 2)

As mentioned in Experiment 1, P6 vocalized in 67 % of the trials for the vocal AB MTS posttest and matched at 100 % accuracy. He did not vocalize during the BA MTS posttest but met criterion within two blocks (*M*= 97 %,). P7 passed the AB MTS posttest in two blocks (*M*= 100 %) and vocalized during all trials (100 %). She did not vocalize during the BA MTS posttest, yet passed it within two blocks (*M*= 100 %). P8 vocalized for 100 and 17 % of the AB MTS posttest blocks and performed with 100 % matching accuracy for both blocks. For the BA MTS posttest, she vocalized for 67 % of the first block and 0 % of the second block but maintained 100 % MTS accuracy for both blocks. Lastly, P9 did not vocalize for any of the MTS posttests despite instructions to do so during the vocal posttest, but passed the AB (*M*= 100 %) and BA (*M*= 94 %) MTS posttests within two blocks each.

Following the completion of posttests, three of the four participants independently described (i.e., no prompts were required) how they "solved" the MTS task. P7 and P9 reported initially using the taught intraverbal statements, but then not needing to reference them. P8 said she made abbreviations for each set of stimuli. For example, "M.E." represented the Manok-Ibon [A1'B1'] relation. An error analysis of her B'A' intraverbal posttest showed that she failed to meet emergence criterion for the second block because of mispronounced tacts (e.g., /mee-nook/ vs. /mah-nook/).

Discussion

The purpose of Experiment 2 was to evaluate whether tact and intraverbal training alone would facilitate symmetrical (i.e., bidirectional) intraverbals and MTS relations. All four participants performed accurately on AB and BA MTS posttests following tact and intraverbal training. Two of the four participants (P7 and P8) emitted experimentally defined tacts and/or intraverbals during posttests without any prompts. One participant (P6) did not overtly emit vocalizations until he was required to do so during the vocal posttest. P9 did not vocalize during the vocal posttest, despite instructions to do so. Additionally, three of the four participants (P6, P7, and P9) passed the B'A' intraverbal posttest, while one participant (P8) failed. These results extend previous research by showing that A'B' intraverbal training is sufficient to produce not only novel bi-directional intraverbals (B'A'), but also MTS performance consistent with symmetry (BA). Thus, stimuli that are intraverbally related may became substitutable for one another, such that seeing or hearing one member evokes selecting or naming the other.

General Discussion

Our findings indicate that verbal behavior training (tact and intraverbal) of baseline (A'B') relations was sufficient to establish conditional baseline (AB) and symmetrical (BA) relations, as well as novel bi-directional intraverbal (B'A') relations. The co-occurrence of correct intraverbals and matching performances during intraverbal and MTS tests, in addition to the emission of unprompted and prompted intraverbal vocalizations during MTS and vocal posttests, respectively, suggest that intraverbal naming mediated MTS performance.

All of our participants passed MTS tests consistent with baseline (AB) and symmetry (BA) relations after A'B' intraverbal training. Additionally, all participants emitted experimentally defined or self-generated tacts and intraverbals at some point during MTS tests. Thus, differently from Petursdottir et al. (2015), whose participants included children between 3.5 and 5.5 years old, our results show that at least under our experimental preparation, college students' responses during symmetry matching tasks seems dependent upon the emission of B'A' "symmetrical" intraverbals.

In the current study, four out of nine participants (P4, P5, P7, and P8) emitted unprompted vocalizations of samples and comparisons during MTS trials, while all who were exposed to the vocal posttest reported using some form of verbal strategy (i.e., intraverbal) during the MTS task. The fact that participants' vocalizations were similar both in the presence and absence of instructions to talk aloud suggests that their overt vocalizations likely corresponded to the covert ones (Hayes et al. 1998). Additionally, correct A'B' and B'A' intraverbal test performance correlated with AB and BA MTS test performance. In other words, A'B' intraverbal training led to the emission of A'B' and B'A' intraverbals which are assumed to be necessary to perform the AB and BA MTS tasks, since during these MTS trials, the only way participants could have matched stimuli is if they could both (1) tact and (2) relate them intraverbally given that they were never directly trained to match these pictures. Thus, our data suggest that during MTS trials, participants tacted the samples, whose product evoked the corresponding intraverbal, the product of which occasioned the listener behavior of selecting the corresponding stimulus (Horne and Lowe 1996).

Although the co-occurrence of vocalizations (during MTS, intraverbal, and vocal posttests) and correct selection responses suggests that intraverbal naming may have played a role in participants' matching performance, stronger support would have come from correlations between failures to emit intraverbals and failures to select correct comparisons. Previous naming research has shown that when participants fail to engage in speaker behavior, they also fail related MTS tests (e.g., Kobari-Wright and Miguel 2014). Moreover, when the speaker repertoire is improved through additional training, so is MTS performance (e.g., Lee et al. 2015). Thus, future studies should further evaluate this co-dependency between intraverbal naming and MTS performance.

It is quite possible that vocalizations during vocal posttests were under control of the researcher's instructions and did not reflect what participants were doing when these instructions were not provided. Participants could have initially matched the pictures based on learned intraverbal relations, but over time, physical features of the stimuli may have acquired control over their selection responses. For example, P4 stated that A2 and B2 from set 3 "both look like an open mouth." Both pictures did indeed contain an open triangle shape, which may be visualized as an open mouth. Likewise, P3 anecdotally reported that A1 and B1 from set 3 matched because "both have a curvy line."

Likely, accurate responding during initial MTS test trials during both AB and BA tests required that participants tact and intraverbally relate the stimuli, but over the course of testing, the contiguity between positive samples and comparisons may have been sufficient to establish conditional discriminative control. Even if this were the case, our data suggest that the training of intraverbal naming was sufficient to establish conditional stimulus relations consistent with baseline and symmetry. Future studies should control for the possibility that conditional relations could be established solely through contiguity among samples and comparisons.

An alternative interpretation involves another form of verbal mediation, namely, joint stimulus control (Lowenkron 1998). Mediation via joint control may have occurred if, in the presence of the sample (e.g., Sila), the participants tacted it, which evoked rehearsing "Sila" as a self-echoic. Since the name Anim is the next name in the intraverbal chain (e.g., "Amin-Sila-Amin-Sila…"), the participants may have begun to say, "Anim" as a new self-echoic. Concurrently, the comparisons were scanned and tacted individually until the one with the tact that matched the self-echoic was selected (i.e., "Sila"). Two indicators that would suggest that joint control was the mechanism mediating performance in the current study were the occurrence of self-echoic behaviors and tact responses to comparison stimuli. However, we did not observe participants engage in these behaviors, nor did we instruct them to do so. Nevertheless, future studies should attempt to observe and manipulate the specific behaviors that may be necessary for passing these MTS tests.

Yet, another possible interpretation of our results that would dispense with verbal mediation is that tacts of A and B stimuli consisted of the training of AC' and BD' relations, where C' and D' are participants' vocal responses. Based on this, the independent variable in the current study included the training of the intraverbal C'D', while the independent variables included the emergence of AB (baseline matching), BA (symmetrical matching), and D'C' (symmetrical/bi-directional intraverbal). Although plausible, this interpretation of the procedures may be limited by the fact that the trained and tested relations were not comparable (Hall and Chase 1991). The AB and BA relations consisted of a series of conditional discriminations in which a sample visual stimulus strengthened the evocative function of the correct comparison for a selection response. On the other hand, during tact (i.e., AC' and BD') as well as intraverbal tasks (i.e., C'D', D'C'), the relations consisted of a series of simple discrimination tasks in which a visual stimulus (the picture) or an auditory stimulus, respectively, evoked a specific response form. This interpretation would still suggest that the AC', C'D', and C'D' (verbal) relations were necessary for the emergence of AB and BA matching, supporting our conclusions that accurate MTS performance depended on accurate tacts and intraverbals.

Lastly, we used the term mediation in this paper to describe a sequence of behaviors (intraverbal naming) that may occur between the onset of the sample and the selection of the comparison. These behaviors seemed to have occurred either overtly or covertly, as observed during tests or reported by participants after the study. Although some of these behaviors may have not been directly observed, we are in no way appealing to events existing in a different dimension. We believe that "inferences about private events play an important role in behavior analysis, just as analogous inferences play a role in other sciences" (Palmer 2011 p.203).

The current study extended previous research by showing that by simply learning to tact visual stimuli and relate their names intraverbally, adult participants can pass MTS tasks consistent with baseline (AB) and symmetry (BA). This is an important finding as many stimulus control studies use verbally capable adults as participants who are likely tacting and intraverbally relating stimuli, even though this is seldom reported or discussed. Although the current study supports the idea that tact and unidirectional intraverbal training (A'B') is sufficient to establish conditional discriminations, it also shows that adult participants may not need to continuously engage in verbal behavior to maintain their matching performance. Future studies should investigate whether intraverbal naming is necessary or sufficient to establish and maintain responding during equivalence (symmetry and transitivity) tests. This information will not only serve to refine our experimental model of meaning and symbolic behavior (Sidman 1994) but also to generate verbal behavior technologies to teach equivalence-type responding to individuals with developmental disabilities (LaFrance and Miguel 2014; Miguel and Petursdottir 2009).

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