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The Establishment of Auditory-Visual Equivalence Classes with a Go/No-Go Successive Matching-to-Sample Procedure

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Abstract

The current study evaluated the effectiveness of a go/no-go successive matching-to-sample (S-MTS) to establish auditory-visual equivalence classes with college students. A sample and a comparison were presented, one at a time, in the same location. The auditory stimulus played for 3 s. A green box appeared in the center for participants to touch to produce the comparison. When the comparison was an auditory stimulus, a white box appeared. During training touching the visual comparison that was related to the auditory sample (e.g., A1B1) produced points, while touching or refraining from touching an unrelated comparison (e.g., A1B2) produced no consequences. Following training (AB/AC), participants were tested on untrained relations (i.e., BA/CA and BC/CB) as well as tacting and sorting. For BA/CA relations, a white box appeared for the selection response to the auditory comparison. For BC/CB relations, participants touched the visual comparison as the selection response. Across two experiments, all participants met emergence criterion for untrained relations and for sorting. Additionally, 14 out of 24 participants tacted all visual stimuli correctly. Results suggest the auditory-visual S-MTS procedure is an effective alternative to simultaneous MTS for establishing conditional relations and cross-modal equivalence classes.

Keywords: derived relations, equivalence, listener behavior, matching-to-sample, sorting

The Establishment of Auditory-Visual Equivalence Classes with a Go/No-Go Successive Matching-to-Sample Procedure

A common method for establishing auditory-visual conditional discriminations in both research and practice is through the matching-to-sample (MTS) procedure (Birch & Belmont, 1964). In a standard MTS training trial, the presentation of a sample stimulus (e.g., the dictated word “dog”) is followed by at least three comparisons (e.g., pictures of a cat, a dog, and a pig). Reinforcement occurs for selection of the correct comparison conditional on the sample and the array of comparisons (Green & Saunders, 1998). From these procedures, MTS can lead to the substitutability of stimuli. In other words, samples and all corresponding comparisons become equivalent.

Sidman and Tailby (1982) developed specific tests including reflexivity, symmetry, and transitivity, to verify the emergence of equivalence classes. For instance, after learning AB and BC relations, reflexivity measures whether the learner can select comparisons that are identical to the sample (e.g., select comparison A in the presence of sample A). Symmetry is demonstrated when the learner selects comparison A or B in the presence of sample B or C, respectively. Lastly, transitivity/combined equivalence relations are demonstrated when the learner selects comparisons A and C in the presence of samples C and A, respectfully. It is important to note that for equivalence classes to emerge, the conditional relations among stimuli are not taught directly. Rather, only some relations are taught (e.g., AB and BC) and as a result, new untaught relations emerge (BA, CB, AC, CA; Sidman, 2009).

Although simultaneous MTS is widely used when teaching auditory-visual conditional (i.e., listener behavior) relations to children with autism (Bao et al., 2017; Dixon et al., 2017; Kobari-Wright & Miguel, 2014; McLay et al, 2013; Vedora & Barry, 2016), several prerequisite skills may be at play (Green, 2001; Green & Saunders, 1998). For instance, the participant must differentially respond to a) comparisons that are discriminative (S^D) and non-discriminative (S-delta) for reinforcement within a trial (i.e., simple simultaneous discrimination) and, b) each sample across trials (i.e., simple successive discriminations). Children with developmental disabilities may lack these skills or have difficulty responding to these types of tasks, rendering the simultaneous MTS unsuccessful in establishing auditory-visual conditional discriminations (Da Hora et al., 2019). Although alternatives to simultaneous MTS have been proposed (e.g., Debert et al., 2007), a promising methodology involves the successive presentation of individual stimuli across trials (Frank & Wasserman, 2005), namely, successive matching-to-sample with go/no-go trial presentations (S-MTS).

In S-MTS, the sample stimulus is presented for a fixed amount of time before one comparison stimulus appears in its place. During training, reinforcement follows responses to correct sample-comparison relations (e.g., A1B1) and does not follow responses to incorrect sample-comparison relations (e.g., A1B2). During testing, no programmed consequences are in place for responding. Participants learn to touch the correct comparisons (e.g., if A1 then touch B1; go trials) and to refrain from touching the incorrect comparisons (e.g., if A1 then do not touch B2; no-go trials). The go/no-go S-MTS procedure has been successful in establishing conditional relations among visual stimuli in both pigeons (Frank & Wasserman, 2005; Urcuioli, 2008) and typically developing adults (Howland et al., 2020; Lantaya et al., 2018; Smeets et al., 2006).

Lantaya et al. (2018) exposed 32 college students to a visual-visual S-MTS training to produce two and three, 3-member equivalence classes across four experiments. The task began with a sample stimulus on a computer screen. Participants touched the sample, after which one comparison appeared in the same location at a 0-s delay. Participants either touched the comparison if it was related to the sample or waited until the comparison disappeared after 5 s if it was not related to the sample (i.e., did not touch the comparison). During training, experimenters prompted participants to touch related comparisons at 4 s if they did not do so independently. Touching related (e.g., A1B1) comparisons produced praise, whereas touching unrelated (e.g., A1B2) comparisons produced either an error correction (Experiment 1) or no programmed consequences (Experiments 2–4). Other variables, such as number of classes (Experiment 3) and omission of pretests (Experiment 4), were also evaluated. Across all experiments, 19 of 32 (59%) participants met emergence criterion on equivalence tests. Failures on equivalence relations may have been due to type and availability of instructions (Smeets et al., 2006), comparison duration (Debert et al., 2009), and mastery criterion during baseline training (Bortoloti et al., 2013; Fienup & Brodsky, 2017).

Howland et al. (2020) provided access to instructions by leaving them in front of participants throughout the experiment (Smeets et al., 2006). The authors also increased the duration of time that comparisons remained on the screen from 5 s to 8 s in all phases to give participants additional time to respond to novel relations (Debert et al., 2009). Lastly, the authors increased baseline training mastery criterion from one to two blocks at 100% correct responding. After these procedural modifications, 22 of 24 (92%) participants responded correctly during equivalence tests, suggesting that previous low yields were a function of specific procedural parameters, and that S-MTS may serve as an alternative to simultaneous MTS for the establishment of conditional relations among visual stimuli.

To the current authors' knowledge, S-MTS has never been evaluated for establishing auditory-visual conditional discrimination (although see Annett & Leslie, 1995 for olfactory-visual conditional discrimination and Woods et al., 2004 for visual-visual identity matching). Given the importance of auditory-visual discriminations in applied practice (Groskreutz et al., 2010; Keintz et al., 2011), assessing an alternative to MTS seems warranted. Thus, the purpose of Experiment 1 was to utilize an auditory-visual S-MTS procedure to establish two, 3-member equivalence classes, while the purpose of Experiment 2 was to generalize the equivalence-based S-MTS procedure to three, 3-member classes and a sorting task with typical adults. One advantage of establishing conditional relations comprised of auditory and visual stimuli in a S-MTS format is the possibility of using auditory stimuli as comparisons during symmetry tests. In addition, considering the importance of auditory-visual conditional discriminations in the establishment of listener behavior with individuals with developmental disabilities (e.g., Grow & LeBlanc, 2013; Maljaars et al., 2012), an initial evaluation of the auditory-visual S-MTS procedure with typically developing adults seems necessary.

Experiment 1

Method

Participants

Eight typically developing adults averaging 23 years old (range, 20-28), recruited from undergraduate psychology courses at a large public university participated. They had no previous exposure to stimulus equivalence content in their coursework and had not participated in any stimulus control research. Participants could end the experiment at any time and they received course credit regardless of their performance. The university's Institutional Review Board (IRB) approved all procedures described below.

Setting and Materials

Research sessions took place in a 3 x 5 m room on campus equipped with one large table, six chairs, and two computer stations. The computer presented all experimental tasks via software developed using Microsoft Visual Basic® (Lantaya et al., 2018). An experimenter and a second observer sat beside and behind the participants, respectively. Materials for the experimental condition included four pictures of shapes measuring 3.8 x 3.8 cm (i.e., B1, C1, B2, and C2) and two spoken one-syllable arbitrary words (i.e., A1 and A2) (see Figure 1). Materials for pretraining included a picture and a cartoon image of a horse and a mouse measuring 3.8 x 3.8 cm and the spoken words “horse” and “mouse,” presented within the computer software. Participants received laminated instruction cards measuring 7.5 x 12.5 cm with a Times New Roman 11-point font. A white outline of a rectangle measuring 10 x 15 cm for holding instruction cards was out of peripheral view of participants, located to the left and 0.3 m away of the participant. After participants read the instructions out loud, they placed the instruction card in the white box.

Procedure

All participants were exposed to the following sequence of conditions: pretraining, tact, BA/CA, and BC/CB pretests, baseline relations (AB/AC) training and testing, and finally, symmetry (BA/CA), equivalence (BC/CB), and tact posttests.

S-MTS Presentation. The experiment utilized a one-to-many (OTM) training structure (e.g., Arntzen, 2012) so that during training the sample stimulus was always auditory. This structure has been shown to be effective in producing equivalence classes using simultaneous MTS in both typically developing adults (e.g., Albright et al., 2015) and children with developmental delays (e.g., Arntzen, Halstadtro et al., 2010). During testing, the sample stimulus was visual, and the comparison was either auditory (symmetry) or visual (equivalence).

Depending on the condition, either an auditory sample was played three times (repeated presentations for auditory stimuli; Green, 2001) or a visual sample was presented in the center of the screen. If the sample was auditory, a green box appeared at a 0-s delay in the center of the screen after the auditory sample finished playing for participants to touch to produce the comparison. If the sample was visual, participants touched the sample to produce the comparison. All comparisons were presented at a 0-s delay. If the comparison was visual, participants touched or refrained from touching the comparison depending on the relation. If the comparison was auditory, a white box appeared at a 0-s delay in the center of the screen after the auditory comparison finished playing for participants to touch or refrain from touching depending on the relation. Participants had 8 s to respond to the comparison before the next trial started (Debert et al., 2009). Trials were separated by a 2-s intertrial interval (ITI) across all experimental tasks. The computer randomly interspersed correct (i.e., go) and incorrect (i.e., no-go) sample and comparison combinations within a 16-trial block in which each related and non-related relation appeared twice.

Each new experimental condition (pretest, baseline training, baseline test, symmetry, equivalence) began with participants reading the instructions aloud on a laminated card (see Table 1). Once participants read the card, they placed it in its designated location to the left and out of peripheral vision of the participants. Participants could re-read the instruction cards at any point during the experiment by removing the card from its location, but they had to place it back before returning to the experimental program. This provided a discrete and observable measure of re-reading the instructions.

Pretraining. The purpose of this phase was to teach participants to use the computer program. Trials appeared in the same S-MTS format as described above but with words and pictures familiar to the participants. In addition, the experimenters provided the same instruction as in the experimental condition, except for minor changes related to the nature of the stimuli (see Table 1). The auditory stimuli consisted of the spoken words' "horse" and "mouse" and the visual stimuli were pictures and cartoon drawings of those animals (see Figure 3). Instructions, prompts, and order of training and testing conditions for pretraining were the same as in the experimental conditions with arbitrary stimuli. Participants needed to respond correctly on at least four trials of pretraining baseline relations (e.g., /horse/ to picture and /horse/ to drawing of the horse), symmetry test (e.g., picture of a horse to /horse/ and drawing of horse to /horse/), and equivalence test (e.g., picture to drawing of a horse and drawing to picture of a horse) before progressing to experimental conditions. All participants responded correctly within the first four trials of each phase.

Pretests. Participants completed tact, BA/CA, and BC/CB pretests to ensure they did not already respond to those relations prior to training. Continuation criterion for BA/CA and BC/CB pretests was set at or below 69% (11 out of 16) for correct go and no-go responding for either one or two 16-trial blocks (Howland et al., 2020; Lantaya, 2018). Criterion was set at 69% because participants could score 50% by either touching all comparisons or refraining from touching all comparisons. Experiments did not expect participants to respond with correct tacts during any pretest trials as tacts were arbitrarily assigned and should not have been familiar to participants (e.g., "vek," "zog").

AB/AC Baseline Training. This condition served to teach participants to touch related comparisons (i.e., A1B1, A1C1, A2B2, A2C2) and to refrain from touching unrelated comparisons (i.e., A1B2, A1C2, A2B1, A2C1; see Table 2). Only two classes were taught to ensure blocks had an equal number of go and no-go trials. During training, all samples consisted of auditory stimuli and all comparisons were visual stimuli in the form of shapes. At the start of each trial, an auditory stimulus (one-syllable word) played three times from the computer and then a green box appeared on the center of the screen. Participants had to touch the green box to produce the comparison stimulus. Once they touched the green box, a single visual comparison (B or C) appeared in its place at a 0-s delay. On “go” trials, the experimenter vocally prompted participants to touch the comparison by saying, “Touch,” at a 4-s delay if they did not do so independently. Experimenters did not provide prompts during no-go trials. Prompting procedures ensured that participants contacted reinforcement for touching correct comparisons they would otherwise not touch. When participants touched the related comparison (e.g., A1B1; regardless of whether it was prompted or independent), a sound was played and accumulated points appeared at the top of the screen at a 0-s delay; there were no programmed consequences for touching or for refraining from touching unrelated comparisons (Debert et al., 2007). The comparison stayed on the screen for a total of 8 s before the next set of sample and comparisons appeared. Comparisons appeared for a fixed time to prevent participants from touching stimuli to remove them from the screen, as well as to ensure that training and testing conditions were similar. Mastery criterion for training was 100% (16 out of 16) for correct go and no-go responding for two consecutive 16-trial blocks.

AB/AC Baseline Test. During this condition, participants read new instructions (see Table 1), no programmed consequences (i.e., no sounds or points) followed correct or incorrect responses, and no prompts were provided. All other components were identical to AB/AC baseline training. The purpose of this phase was to ensure participants could respond to baseline relations in the absence of reinforcement and prompts, and to prepare them to continue responding on emergent relations’ tests (symmetry and equivalence). Baseline testing criterion was 100% (16 out of 16) for correct go and no-go responding for one, 16-trial block. Participants returned to AB/BC baseline training if they scored below 100%; however, remediation was not necessary as all participants met training criterion (see Results).

BA/CA Symmetry Test. A trial began with the presentation of a visual sample (e.g., B1) in the center of the screen. Participants touched the image, after which (0-s delay) an auditory comparison (e.g., A1) played three times. An image of a white box outlined in black appeared immediately after the auditory stimulus stopped playing. The white box served to direct participants where to touch during related trials. Emergence criterion was 94% (15 out of 16) for correct go and no-go responding for two consecutive 16-trial blocks. If participants failed to meet the emergence criterion, testing continued until the participant demonstrated stable incorrect performance for at least three blocks of identical scores or three blocks with decreasing scores. If there was an increasing trend, testing continued until participants met emergence criterion or performance became stable for three blocks. All combinations of BA and CA relations were tested within the same block, no prompts were provided, and no programmed consequences followed correct or incorrect responses. Regardless of how participants responded on symmetry tests, they moved on to the BC/CB equivalence test.

BC/CB Equivalence Test. For this condition, participants completed a combined test of BC and CB relations. A trial began with the presentation of a visual sample (e.g., B1). Participants touched the sample and a visual comparison (e.g., C1) appeared in the same location at a 0-s delay. Testing procedures were the same as in the BA/CA symmetry test described above. Equivalence emergence criterion was set at 94% (15 out of 16) for correct go and no-go responding for two consecutive 16-trial blocks. Testing continued if there was an increasing trend. Criterion for termination of the BC/CB equivalence testing was the same as for the BA/CA symmetry test. If participants met termination criterion, they returned to baseline training and testing conditions for remediation before equivalence tests were presented for the second time. However, remediation was not necessary as all participants met criterion (see Results).

Tact Test. The final experimental condition served to evaluate the effects of listener training on emerging speaker behavior in the form of tacts. Tact tests consisted of the presentation of a single image on the screen while the experimenter asked the participant either, "What is it?" or "What is it called?" to prevent strict control by the instruction. The test consisted of one, 8-trial block, in which each image appeared twice.

Dependent Variables

The main dependent variable for S-MTS training and testing was the percentage of correct go and no-go responses. A correct response was defined as independently (without prompting) touching the correct comparison (i.e., go) and refraining from touching the incorrect comparison (i.e., no-go). In addition, the experimenter collected data on the percentage of correct vocal tacts, number of trials to meet training and testing criteria, the number of times participants re-read instructions, and reaction time on go-trials. The computer program recorded reaction time from the presentation of a comparison and the selection response during both training and testing conditions.

Experimental Design

The study employed a two-tier non-concurrent multiple-baseline across participants design (Watson & Workman, 1981) to demonstrate the effects of auditory-visual S-MTS training on the emergence of equivalence classes and emergent tacts. The first tier of participants completed one BA/CA and BC/CB pretest block and the second tier of participants completed two BA/CA and BC/CB pretest blocks. This design served to demonstrate that the establishment of conditional relations was not a result of repeated exposure to experimental stimuli or any other variable, but rather a product of the experimental contingencies. The second participant in the tier only received two pretest blocks to limit exposure to derived relations, as equivalence performance may be negatively affected by multiple pretests (Lantaya et al., 2018).

Interobserver Agreement and Treatment Integrity

Although the computer software automatically recorded selection responses, reaction times, and presented all stimuli, an independent observer was necessary to track whether responses during baseline training were independent or prompted by the experimenter, to record vocal responses during tact tests, and in the event of a software malfunction. An independent observer collected data on correct and incorrect responses for 100% of sessions across all experimental conditions. Interobserver agreement (IOA) was calculated by dividing the number of agreements by the sum of agreements and disagreements, then multiplying by 100 (Kazdin, 2011). IOA averaged 98.6% (range, 96.1%-100%). Treatment integrity (TI) data were collected for 100% of sessions across all experimental conditions on the experimenter's delivery of prompts at a 4-s delay on go trials and non-delivery on no-go and all testing trials. TI was calculated by dividing the number of trials accurately implemented by the total number of trials per block, multiplied by 100. TI averaged 99.6% (range, 99%-100%).

Results

Figure 2 depicts the percentage of correct independent go and no-go responses for participants 1 through 8 across all experimental conditions. Participants never responded correctly when asked "What is it called/What is it?" in the presence of B1, C1, B2 and C2 during the tact pretest. Four participants (P4, P5, P6, and P7) scored 50% on all presentations of BA/CA and BC/CB pretests by not touching any of the relations. P1, P2, P3, and P8 responded between 19% and 63% correctly during BA/CA and BC/CB pretests.

During AB/AC baseline training, participants required between 64–128 trials to reach baseline mastery criterion (i.e., baseline training and testing blocks). All participants responded without errors during the baseline relations test, suggesting that the absence of reinforcement did not disrupt or weaken baseline performance. In addition, all eight participants met symmetry and equivalence emergence criteria in two blocks, rendering remediation unnecessary. Two participants (P4 and P7) re-read the instructions only during BA/CA and/or BC/CB pretests, two participants (P5 and P8) re-read during baseline training, P8 also re-read the instructions during the equivalence test, and P2 re-read during pre- and posttests only (noted with an asterisk in Figure 2). Re-reading varied across experimental conditions and did not seem to affect performance.

Responses on post-tact tests varied unsystematically across participants and type of instruction. Following training and testing, P1, P3, P4, P6, and P8 tacted the individual images as “vek” and “zog” 100% correctly. P2, P5, and P7 tacted the images the same way as they had during the pre-test (e.g., B1 as “right angle,” B2 as a “plus sign,” C1 as a “dash”).

Reaction time data, measured from the presentation of a comparison stimulus to the correct selection response on go trials, were collected via the computer software for all participants during posttests. Mean reaction times across participants during the first block of baseline, symmetry, and equivalence posttests were 1.109 s (range, 0.686-2.184), 0.919 s (range, 0.421-4.368), and 1.213 s (range, 0.577-4.056), respectively. All participants selected the go comparison in under 5 s across all conditions.

Discussion

The purpose of Experiment 1 was to assess whether the S-MTS procedure could establish auditory-visual conditional relations and cross-modal equivalence classes. S-MTS was successful in establishing conditional relations between auditory and visual stimuli and therefore, could be an alternative to simultaneous MTS. The S-MTS procedure does not require learners to scan an array of comparisons and respond to simultaneous simple discriminations of comparisons (Green, 2001).

Moreover, the S-MTS was successful in establishing two, 3-member equivalence classes as all participants met the symmetry and equivalence emergence criterion with no need for remediation. The suggestion by Debert et al. (2009) to increase comparison duration during novel testing conditions did not seem to play a role in equivalence responding as participants touched correct comparisons under 5 s across all conditions (range, 0.421–4.368 s), replicating results from Howland et al. (2020). Re-reading instructions during training and testing conditions did not seem to improve performance. However, typically developing adult participants already enter the experiment with specific histories in which instructions may exert strong control over behavior (Rosenfarb et al., 1992), and this may influence how they respond on equivalence-based tasks (Sidman, 2000). Therefore, it is important to continue to evaluate the role of instructions when participants are typical adults (e.g., Rosales-Ruiz et al., 2000).

Although results from Experiment 1 have shown that S-MTS produces auditory-visual conditional relations and equivalence classes, some limitations are worth noting. Since the current study only used two classes to equate the number of go and no-go trials, participants needed to respond correctly to only one relation and reject the other to respond at criterion levels in equivalence tests. For example, participants may only need to respond to B1 and C1 as related, and reject B1 and C2, so B2 and C2 would become part of another class by exclusion (Johnson

& Sidman, 1983; McIlvane & Stoddard, 1981). Some participants' (i.e., P2, P3, and P7) anecdotal statements suggested that their responding may have been under reject control. For example, P3 stated that every time C2 would appear, she would expect B2, and if it was not either, she would select B1 and C1 by default. Several authors (Green, 2001; Grow & LeBlanc, 2013; Sidman, 2009) have stressed the importance of teaching three classes to establish appropriate stimulus control.

In addition to the limitation discussed above, an evaluation of more complex behaviors associated with equivalence would have provided further support for the utility of auditory-visual S-MTS. Previous research evaluated the generality of equivalence-based MTS to sorting tasks and found high correspondence between performance on MTS and sorting (Arntzen et al., 2015; Fields et al., 2012, 2014; Lian & Arntzen, 2013). Performance on sorting tests could inform if conditional discriminations established via a S-MTS training would produce the same type of derived performance as when simultaneous MTS procedures are implemented. Thus, the purpose of Experiment 2 was to address the aforementioned limitations by evaluating the effects of S-MTS on the establishment of three, 3-member equivalence classes and assessing generalization of S-MTS to a sorting task. Eight participants were exposed to symmetry trials, equivalence trials, and the sorting task prior to baseline training, while another eight participants were exposed to the sorting task only. Given that previous research suggested sorting may serve as an additional measure of stimulus substitutability (e.g., Fields et al., 2014), we eliminated other tests for half of participants as a way to limit their exposure to experimental stimuli prior to training (Lantaya et al., 2018).

Experiment 2

Method

Participants

Sixteen typically developing adults averaging 22 years old (range, 19–31), recruited from undergraduate psychology courses at a large public university, participated. Inclusion criteria were the same as in Experiment 1. At the completion of the study, participants received course credit regardless of their performance. The university's IRB approved all procedures described below.

Setting and Materials

The setting and materials were the same as in Experiment 1 with the addition of a third stimulus class (i.e., A3, B3, and C3; see Figure 1). Materials for the sorting task included six, cards measuring 3 x 5 in. with one visual stimulus (i.e., B-C) per card.

Procedure

Pretraining, experimental conditions, sequence, and instructions were the same as in Experiment 1, except for the addition of a sorting pre-and posttest.

S-MTS Presentation. Training structure and the format of S-MTS presentation was the same as in Experiment 1. Each block had sample and comparison combinations randomly interspersed and depending on the phase, trials per block were either 24 (i.e., baseline and symmetry) or 36 (i.e., equivalence; see Table 3). Unlike Experiment 1, three classes of stimuli produced an unequal number of related and nonrelated trials. For symmetry and equivalence tests, there were six related and 12 and 24 unrelated trials, respectively. Due to unbalanced trial types and the need to randomize how many related trials followed unrelated trials in equivalence tests, each related trial type appeared twice and each unrelated trial type appeared once per block across all conditions (e.g., Debert et al., 2007).

Pretraining. Pretraining was the same as in Experiment 1. All participants responded correctly within the first four trials of each phase.

Pretests. Instructions and presentation format for tact, BA/CA, and BC/CB pretests were the same as in Experiment 1. The continuation criteria were 4 of 6 correct (67%) or below for sorting pretests (see below for details on the sorting test), 6 of 12 correct (50%) or below for tact pretests, 16 of 24 correct (67%) or below for BA/CA pretests, and 24 of 36 correct (67%) or below for BC/CB pretests. The experimenter stated a clarifying instruction (e.g., "Put the cards that go together") only during the sorting pretest if participants arranged the cards in a row instead of grouping them. Participants 9–16 completed sorting, tact, BA/CA, and BC/CB as pretests and participants 17–24 completed only sorting and tact as pretests.

AB/AC Baseline Training. This condition was the same as in Experiment 1. Training blocks consisted of six related (go) trials presented twice and 12 unrelated (no-go) trials presented once per block for a 24-trial block (see Table 3). Participants needed to score 24 of 24 (100%) for two blocks to move on to the baseline test.

AB/AC Baseline Test. This condition was the same as in Experiment 1. Participants needed to score 24 of 24 (100%) for one block of the AB/AC baseline test to move on to symmetry and equivalence tests.

BA/CA Symmetry Tests. This condition and the instructions were the same as in Experiment 1. Participants first completed the symmetry test, which consisted of six related (go) trials presented twice and 12 unrelated (no-go) trials presented once per block for a 24-trial block in the absence of feedback (see Table 3). Regardless of performance, participants continued to equivalence tests. Experimenters considered symmetry relations to be intact if participants scored 22 of 24 (92%) correct or higher for two 24-trial blocks.

BC/CB Equivalence Tests. This condition and instructions were the same as in Experiment 1. The equivalence test consisted of six related (go) trials presented two times per block and 24 unrelated (no-go) trials presented one time per block for a 36-trial block without feedback (see Table 3). Equivalence emergence criterion was 34 of 36 correct (94%) for two 36-trial blocks.

Sorting Test. Participants received six cards and read the following instructions: “Please sort the cards.” A correct response was scored if cards from the same class were placed together. For example, if B1 and C1 were put together, and B2, B3, C2, and C3 were put together, then the score was two out of six correct (33%). The emergence criterion for the sorting test was six of six correct (100%); however, participants moved on to the tact test regardless of their performance on the sorting test.

Tact Test. A tact test for all visual stimuli (i.e., B1, C1, B2, C2, B3, and C3) followed the sorting test and was presented in the same format as in Experiment 1. The tact test consisted of one, 12-trial block in which each visual stimulus appeared on the computer screen two times.

Dependent Variables

The dependent variables were the same as in Experiment 1 with the addition of the percentage of correct number of cards sorted into experimentally defined classes. A correct sort consisted of grouping all stimuli in a class together (e.g., B1 and C1, C2 and B2). Any other configuration was considered incorrect (e.g., B1 only, B1 and B2).

Experimental Design

The design was the same as in Experiment 1. Participants 9–16 received tact, BA/CA, BC/CB, and sorting pretests and participants 17–24 received only tact and sorting pretests. Sorting has been previously proposed as an alternative measure to symmetry and equivalence tests to assess equivalence class formation (Arntzen et al., 2015; Fields et al., 2014). Thus, during pretests, sorting was utilized to demonstrate that repeated exposure to experimental stimuli was not sufficient to establish conditional relations.

Interobserver Agreement and Treatment Integrity

A second observer collected IOA and TI for 100% of sessions across all experimental conditions and was calculated the same way as in Experiment 1. IOA scores averaged 99.1% (range, 94.7%–100%) and TI scores averaged 99.8% (range, 97.2%–100%).

Results

Figures 3 and 4 depict the percentage of correct responses for participants 9–16 and 17–24, respectively, across all experimental conditions. Participants responded at 0% during sorting and tact pretests and at or below 63% on BA/CA and BC/CB pretests (P9–P16). Participants required between 96–336 trials to reach baseline mastery criterion (i.e., baseline training and testing blocks). Fourteen out of 16 participants responded without errors during the baseline relations test. P16 and P22 required additional baseline training blocks before performance reached 100% on the baseline test. All 16 participants met symmetry and equivalence emergence criterion within two blocks. In addition, there were no differences in baseline trials to criterion or passing derived tests between participants that received sorting, BA/CA, and BC/CB pretests and those that only received sorting as pretests. Five participants (P9, P10, P13, P23, and P24) did not re-read instructions at any point during the experiment. The rest of the participants varied unsystematically at what phase of the experiment they re-read the instructions. Re-reading did not seem to affect performance, as participants who did and those who did not re-read instructions during baseline completed training in a similar number of trials to criterion (e.g., P13 and P15; see Figure 3) and passed derived tests.

Following testing of symmetry and equivalence, 8 out of 16 participants (P9, P10, P11, P18, P20, P22, P23, and P24) tacted the individual images as “vek,” “zog,” and “pif” at 100% accuracy, and P12, P13, P16, and P17 tacted all the images using familiar names (e.g., B3 as “oval”; diamonds in graphs). Anecdotally, three participants stated that they did not tact the images as “vek,” “zog,” and “pif,” because these images already had conventional names (e.g., C1 as “rectangle”). P14, P15, and P19 scored 67-75% because they tacted zog as “h,” pif as “sig,” and vek as “zak,” respectively. In addition, 15 out of 16 participants sorted the stimuli in experimenter-defined classes. P19 sorted the stimuli into the same grouping that she did in the pretest.

The mean reaction times during the first block of baseline, symmetry, and equivalence posttests were 1.078 s (range, 0.483-2.871), 0.826 s (range, 0.358-2.933), and 1.200 s (range, 0.655-7.098), respectively. For one of the trials, P15 selected a correct comparison at 7.098 s, while responding at or below 4 s in all other trials.

Discussion

One purpose of Experiment 2 was to assess whether the results of Experiment 1 could be extended to three, 3-member equivalence classes. S-MTS produced three, 3-member equivalence classes as all participants met emergence criteria. Only two participants (P16 and P22) required additional training blocks before meeting criterion on the baseline test.

Moreover, the addition of a third class in Experiment 2 ruled out the possibility that correct responses on equivalence tests in Experiment 1 were due to chance or learning by exclusion (McIlvane & Stoddard, 1981). Participants could not pass equivalence by only correctly grouping two stimuli based on physical similarities because there were four additional stimuli. Furthermore, the addition of the third class and unbalanced trial types did not hinder correct responding on equivalence tests or produce bias towards unrelated trials, replicating results from Lantaya et al. (2018; Experiment 3). In addition, similarly to Experiment 1, the reaction time data remained under 5 s across all conditions and participants. Even though previous research (Debert et al., 2009) has suggested that comparisons should remain on the screen for 8 s to give participants enough time to respond, this did not seem necessary given the current procedural parameters.

The secondary purpose of Experiment 2 was to evaluate if conditional discrimination training via S-MTS could produce stimulus substitutability as assessed via a sorting task. Sorting has been suggested as one way to provide additional validation of class-consistent responding (Dymond & Rehfeldt, 2001). Previous research utilizing MTS to establish conditional discriminations demonstrated that equivalence responding was consistent across simultaneous MTS and sorting presentations (e.g., Arntzen et al., 2014; 2017). All participants of the present experiment met the equivalence emergence criterion assessed via S-MTS (P9-P24) and 15 out of 16 sorted visual stimuli in experimenter-defined classes.

General Discussion

The go/no-go auditory-visual S-MTS established auditory-visual conditional relations (i.e., listener behavior) and demonstrated the emergence of equivalence classes for all 24 participants with either two (Experiment 1) or three, 3-member classes (Experiment 2). The addition of a third class did not seem to have made the task any more difficult or bias responding. Baseline trials to criterion (i.e., training and testing trials) were higher in Experiment 2 (M = 182, SD = 64) than in Experiment 1 (M = 86; SD = 24). The differences in trials to criterion can be attributed to the addition of a third class in Experiment 2, which resulted in a higher number of trials per block (24 trials compared to 16 trials in Experiment 1). All participants passed equivalence tests, replicating the most recent findings obtained with visual-visual S-MTS (Howland et al., 2020). In addition, as discussed above, increasing the comparison duration to 8 s may not have been necessary as all participants responded within 5 s of the related comparison presentations. Previous research requiring longer comparison durations have utilized a go/no-go arrangement with compound, rather than single stimulus presentations (Debert et al., 2009).

The S-MTS format with go/no-go produced the same outcomes on sorting tests as the simultaneous MTS format, and may therefore be a viable alternative for establishing auditory-visual conditional relations and auditory-visual equivalence classes. In addition, there were no differences in subsequent responding between participants that were only exposed to sorting pretests and those that were exposed to symmetry, equivalence, and sorting pretests. With exception of one participant (P19), there was correspondence between performance on SMTS and sorting posttests. Even though sorting does assess all properties of an equivalence class (i.e., reflexivity, symmetry, and transitivity), it may serve to test for stimulus substitutability (Arntzen et al., 2015; Dymond & Rehfeldt, 2001; Fields et al., 2014). The use of sorting as a pretest may be advantageous as it limits the exposure to conditional stimulus relations pretests which could have detrimental effects on equivalence yields (e.g., Lantaya et al., 2018).

A possible advantage of S-MTS is that it may allow for the assessment of emergent auditory-auditory conditional relations without procedural modifications. Dube et al. (1993) attempted to establish an all-auditory equivalence class with a two-comparison array. Once the sample was paired with each comparison location (left and right) successively, participants touched the comparison location that went with the sample. Even though this procedure was successful in demonstrating equivalence class formation for two of seven participants, the location of each comparison may have likely become part of the class. There have been a few studies attempting to remediate poor listener repertoires in children with developmental disabilities by establishing auditory-auditory conditional discriminations via simultaneous MTS (e.g., Choi et al., 2015; Speckman-Collins et al., 2007). Thus, the S-MTS may serve as an alternative for establishing these types of auditory-auditory discriminations, and for developing equivalence classes comprised solely of auditory stimuli.

Previous studies on simultaneous MTS with typically developing children comparing auditory-visual and visual-visual MTS reported improved performances on equivalence and sorting tests following auditory-visual rather than visual-visual matching (Smeets & Barnes-Holmes, 2005; Plaza & Cortez, 2017). For example, Smeets and Barnes-Holmes (2005) found that only two out of eight participants passed equivalence tests following visual-visual simultaneous MTS. Of the eight participants that underwent visual-visual discrimination, seven passed equivalence tests once they were taught auditory-visual conditional discriminations. In contrast, seven out of eight other participants passed equivalence tests when the first exposure to MTS was auditory-visual. Furthermore, all eight participants passed the sorting task when auditory-visual MTS was presented and only one out of eight passed when exposed to visual-visual MTS. The current study, the first employing S-MTS to establish auditory-visual conditional relations, produced more consistent yields in equivalence tests than previous studies which trained visual classes only (Howland et al., 2020; Lantaya et al., 2018). Thus, it may be important to further evaluate the role of stimulus modality on equivalence class formation in the go/no-go S-MTS format.

A possible limitation of the study is that by asking participants to tact stimuli during pretests, their vocal-verbal responses may have come under control of specific physical features of the stimuli, and for some participants, these tacts remained unchanged throughout the experiment. Anecdotally, P2 stated, “I thought to label as zog and vek, but I know them [shapes] as other names” and P5 said, “It’s too weird to call them that” when asked why they did not label the visual stimuli as “vek” or “zog.” All participants who failed tact tests, responded similarly during both tact pre and posttests.

Another possible limitation is that the effects of written instructions on equivalence responding were unclear. Only four participants in the present study (i.e., P8 in Experiment 1 during symmetry; P14, P17, and P20 in Experiment 2 during equivalence) re-read instructions during derived tests. There were no differences on equivalence performances between those participants who re-read and those who did not, as all participants, across both experiments, passed equivalence tests. Re-reading instructions could have influenced responding during baseline training (e.g., P5, P8, P12, P15, P16); however, there were no differences in trials to criterion across participants within and between Experiments 1 and 2. Since we did not directly assess the effects of instructions on equivalence yields, conclusions regarding the role of instructions cannot be made. However, previous research has suggested that when employing typically developing adults as participants, the availability (Smeets et al., 2006) and content of instructions may enhance equivalence yields (Pilgrim et al., 2000; Saunders et al., 1993). Future studies should systematically manipulate the availability and content of instructions during S-MTS procedures.

In summary, as conducted, the auditory-visual S-MTS procedure may be effective in establishing listener behavior and auditory-visual equivalence classes. The ability to easily incorporate auditory stimuli as comparisons makes S-MTS also ideal for establishing auditory-only classes. Additionally, to evaluate whether S-MTS can be utilized in an applied setting some modifications may be necessary, such as incorporating prompting procedures to prevent participants from touching incorrect comparisons (Silva & Debert, 2017) and teaching an alternative response to no-go comparisons (Tovar & Chavez, 2012). Future research should evaluate the possible applied uses of this procedure, as well as compare its efficiency and effectiveness with the simultaneous MTS.

References

Adams, B. J., Fields, L., & Verhave, T. (1993). Effects of test order on intersubject variability during equivalence class formation. *The Psychological Record*, *43*(1), 133-152.

Albright, L., Reeve, K. F., Reeve, S. A., Kisamore, A. N. (2015). Teaching statistical variability with equivalence-based instruction. *Journal of Applied Behavior Analysis*, *48*(4), 883-894. https://doi.org/10.1002/jaba.249

Annett, J. M., & Leslie, J. C. (1995). Stimulus equivalence classes involving olfactory stimuli. *The Psychological Record*, *45*(3), 439-450. https://doi.org/10.1007/BF03395153

Arntzen, E. (2004). Probability of equivalence formation: Familiar stimuli and training sequence. *The Psychological Record*, *54*(2), 275-291. https://doi.org/10.1007/BF03395474

Arntzen, E. (2012). Training and testing parameters in formation of stimulus equivalence: Methodological issues. *European Journal of Behavior Analysis*, *13*(1), 123-135. https://doi.org/10.1080/15021149.2012.11434412

Arntzen, E., Granmo, S., & Fields, L. (2017). The relations between sorting tests and matching-to-sample tests in the formation of equivalence classes. *The Psychological Record*, *67*(1), 81-96. https://doi.org/10.1007/s40732-016-0209-9

Arntzen, E., Grondahl, T., & Eilifsen, C. (2010). The effects of different training structures in the establishment of conditional discriminations and subsequent performance on tests for stimulus equivalence. *The Psychological Record*, *60*(3), 437-462. https://doi.org/10.1007/BF03395720

Arntzen, E., Halstadtro, L., Bjerke, E., & Halstadtro, M. (2010). Training and testing music skills in a boy with autism using a matching-to-sample format. *Behavioral Interventions*, *25*(2), 129-143. https://doi.org/10.1002/bin.301

Arntzen, E. & Lian, T. (2010). Trained and derived relations with pictures versus abstract stimuli as nodes. *Psychological Record*, *60*(4), 659-677. https://doi.org/10.1007/BF03395738

Arntzen, E., Nartey, R. K., & Fields, L. (2014). Identity and delay functions of meaningful stimuli: Enhanced equivalence class formation. *The Psychological Record*, *64*(3), 349-360. https://doi.org/10.1007/s40732-014-0066-3

Arntzen, E., Norbom, A., & Fields, L. (2015). Sorting: An alternative measure of class formation? *The Psychological Record*, *65*(4), 615-625. https://doi.org/10.1007/s40732-015-0132-5

Bao, S., Sweatt, K.T., Lechago, S. A., & Antal, S. (2017). The effects of receptive and expressive instructional sequences on varied conditional discriminations. *Journal of Applied Behavior Analysis*, *50*(4), 775-788. https://doi.org/10.1002/jaba.404

Bentall, R. P., Jones, R. M., & Dickins, D. W. (1999). Errors and response latencies as a function of nodal distance in 5-member equivalence classes. *The Psychological Record*, *49*(1), 93-115. https://doi.org/10.1007/BF03395309

Birch, H. G., & Belmont, L. (1964). Auditory-visual integration in normal and retarded readers. *American Journal of Orthopsychiatry*, *34*(5), 852–861. https://doi.org/10.1111/j.1939-0025.1964.tb02240.x

Bortoloti, R., Rodrigues, N. M., Cortez, M. D., Pimentel, N., & de Rose, J. C. (2013). Overtraining increases the strength of equivalence relations. *Psychology and Neuroscience*, *6*(3), 357-364. https://doi.org/10.3922/j.psns.2013.3.13

Choi, J., Greer, R. D., & Keohane, D. (2015). The effects of an auditory matching-to-sample procedure on listener literacy and echoic responses. *Behavioral Development Bulletin*, *20*(2), 186-206. https://doi.org/10.1037/h0101313

Da Hora, C. L., Debert, P., LaFrance, D. L., & Miguel, C. F. (2019). Inadvertent establishment of location control in matching-to-sample tasks in individuals with autism. *Brazilian Journal of Behavior Analysis*, *14*(1), 15-23. https://doi.org/10.18542/rebac.v14i1.7155

Debert, P., Huziwara, E. M., Faggiani, R., de Mathis, M. E., & McIlvane, W. J. (2009). Emergent conditional relations in a go/no-go procedure: Figure-ground and stimulus-position compound relations. *Journal of the Experimental Analysis of Behavior*, *92*(2), 233-243. https://doi.org/10.1901/jeab.2009.92-233

Debert, P., Matos, M. A., & McIlvane, W. (2007). Conditional relations with compound abstract stimuli using a go/no-go procedure. *Journal of the Experimental Analysis of Behavior*, *87*(1), 89-96. https://doi.org/10.1901/jeab.2007.46-05

Dixon, M. R., Belisle, J., Stanley, C. R., Speelman, S. R., Rowsey, K. E., Kime, D., & Daar, J. H. (2017). Establishing derived categorical responding in children with disabilities using the PEAK-E curriculum. *Journal of Applied Behavior Analysis*, *50*(1), 134-145. https://doi.org/10.1002/jaba.355

Dube, W. V., Green, G., & Serna, R.W. (1993). Auditory successive conditional discrimination and auditory stimulus equivalence classes. *Journal of the Experimental Analysis of Behavior*, *59*(1), 103-114. https://doi.org/10.1901/jeab.1993.59-103

Dube, W. V., & McIlvane, W. J. (1996). Some implications of a stimulus control topography analysis for emergent behavior and stimulus classes. *Advances in Psychology*, 117, 197-218. https://doi.org/10.1016/S0166-4115(06)80110-X

Dymond, S., & Rehfeldt, R. A. (2001). Supplemental measures and derived stimulus relations. *Experimental Analysis of Human Behavior Bulletin*, *19*, 8-12. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.532.1081&rep=rep1&type=pdf

Fields, L., Arntzen, E., & Moksness, M. (2014). Stimulus sorting: A quick and sensitive index of equivalence class formation. *The Psychological Record*, *64*(3), 487-498. https://doi.org/10.1007/s40732-014-0034-y

Fields, L., Arntzen, E., Nartey, R. K., & Eilifsen, C. (2012). Effects of meaningful, a discriminative, and a meaningless stimulus on equivalence class formation. *Journal of the Experimental Analysis of Behavior*, *97*(2), 163-181. https://doi.org/10.1901/jeab.2012.97163

Fields, L., & Reeve, F. (1997). Equivalence class formation using stimulus-pairing and yes-no responding. *The Psychological Record*, *47*(4), 661-686. https://doi.org/10.1007/BF03395252

Fienup, D. M., & Brodsky, J. (2017). Effects of mastery criterion on the emergence of derived equivalence relations. *Journal of the Experimental Analysis of Behavior*, *50*(4), 842-848. https://doi.org/10.1002/jaba.416

Frank, A. J., & Wasserman, E. A. (2005). Associative symmetry in the pigeon after successive matching-to-sample training. *Journal of the Experimental Analysis of Behavior*, *84*(2), 147-165. https://doi.org/10.1901/jeab.2005.115-04

Green, G. (2001). Behavior analytic instruction for learners with autism: Advances in stimulus control technology. *Focus on Autism and Other Developmental Disabilities*, *16*(2), 72-85. https://doi.org/10.1177/108835760101600203

Green, G., & Saunders, R. R. (1998). Stimulus equivalence. In K. A. Lattal & M. Perone (Eds.), *Handbook of Research Methods in Human Operant Behavior* (pp. 229-262). Springer.

Groskreutz, N. C., Karsina, A., Miguel, C. F., & Groskreutz, M. P. (2010). Using complex auditory-visual samples to produce emergent relations in children with autism. *Journal of Applied Behavior Analysis*, *43*(1), 131-136. https://doi.org/10.1901/jaba.2010.43-131

Grow, L., & LeBlanc, L. (2013). Teaching receptive language skills: Recommendations for instructors. *Behavior Analysis in Practice*, *6*(1), 56-75. https://doi.org/10.1007/BF03391791

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior*, *65*(1), 185-241. https://doi.org/10.1901/jeab.19-96.65-185

Howland, T. G., Zhelezoglo, K., Hanson, R. J., Miguel, C. F., & Lantaya, C. A. (2020). Evaluating procedural parameters of successive matching-to-sample for the establishment of equivalence classes. *The Psychological Record*.

Jennings, A. M., & Miguel, C. F. (2017). Training intraverbal bidirectional naming to establish generalized equivalence class performances. *Journal of the Experimental Analysis of Behavior*, *108*(2), 269-289. https://doi.org/10.1002/jeab.277

Johnson, C., & Sidman, M. (1993). Condition discrimination and equivalence relations: Control by negative stimuli. *Journal of the Experimental Analysis of Behavior*, *59*(2), 333-347. https://doi.org/10.1901%2Fjeab.1993.59-333

Kazdin, A.E. (2011). *Single-case research designs: Methods for clinical and applied Settings* (2nd ed.). Oxford University Press.

Keintz, K. S., Miguel, C. F., Kao, B., & Finn, H. E. (2011). Using conditional discrimination training to produce emergent relations between coins and their values in children with autism. *Journal of Applied Behavior Analysis*, *44*(4), 909-913. https://doi.org/10.1901/jaba.2011.44-909

Kobari-Wright, V., & Miguel, C. F. (2014). The effects of listener training on the emergence of categorization and speaker behavior in children with autism. *Journal of Applied Behavior Analysis*, *47*(2), 431-436. https://doi.org/10.1002/jaba.115

Lantaya, C. A., Miguel, C. F., Howland, T. G., LaFrance, D. L., & Page, S. P. (2018). An Evaluation of a visual-visual successive matching-to-sample procedure to establish equivalence classes in adults. *Journal of the Experimental Analysis of Behavior*, *109*(3), 533-550. https://doi.org/10.1002/jeab.326

Lian, T., & Arntzen, E. (2013). Delayed matching-to-sample and linear series training structures. *The Psychological Record*, *63*(3), 545-562. https://doi.org/10.11133/j.tpr.2013.63.3.010fo

Lowe, C. F., Horne, P. J., Harris, F. D. A., & Randle, V. R. L. (2002). Naming and categorization in young children: Vocal tact training. *Journal of the Experimental Analysis of Behavior*, *78*(3), 527-549. https://doi.org/10.1901/jeab.2002.78-527

Ma, M. L., Miguel, C. F., & Jennings, A. M. (2016). Training intraverbal naming to establish equivalence class performances. *Journal of Experimental Analysis of Behavior*, *105*(3), 409-426. https://doi.org/10.1002/jeab.203

Maljaars, J., Noens, I., Scholte, E., & van Berckelaer-Onnes, I. (2012). Language in low-functioning children with autistic disorder: Differences between receptive and expressive skills and concurrent predictors of language. *Journal of Autism and Developmental Disorders*, *42*(10), 2181-2191. https://doi.org/10.1007/s10803-012-1476-1

McIlvane, W. J, & Stoddard, T. (1981). Acquisition of matching-to-sample performances in severe retardation: Learning by exclusion. *Journal of Intellectual Disability Research*, *25*(1), 33-48. https://doi.org/10.1111/j.1365-2788.1981.tb00091.x

McLay, L. K., Sutherland, D., Church, J., & Tyler-Merrick, G. (2013). The formation of equivalence classes in individuals with autism spectrum disorder: A review of the literature. *Research in Autism Spectrum Disorders*, *7*(2), 418-431. https://doi.org/10.1016/j.rasd.2012.11.002

Miguel, C. F. (2018). Problem-solving, bidirectional naming, and the development of verbal repertoires. *Behavior Analysis Research and Practice*, *18*(4), 340-353. https://doi.org/10.1037/bar0000110

Nartey, R., Arntzen, E., & Fields, L. (2014). Two discriminative functions of meaningful stimuli that enhance equivalence class formation. *The Psychological Record*, *64*(4), 777-789. https://doi.org/10.1007/s40732-014-0072-5

Pilgrim, C., Jackson, J., & Galizio, M. (2000). Acquisition of arbitrary conditional discrimination by young normally developing children. *Journal of the Experimental Analysis of Behavior*, *73*(2), 177-193. https://doi.org/10.1901/jeab.2000.73-177

Plaza, E. A., & Cortes, D. (2017). Relation between exclusion and stimulus equivalence class formation in auditory-visual and visual-visual matching in preschoolers. *International Journal of Comparative Psychology*, *30*, 2-20. https://escholarship.org/uc/item/48c2f95q

Rosales-Ruiz, J., Eikeseth, S., Duarte, A., & Baer, D. M. (2000). Verbs and verb phrases as instructional stimuli in the control of stimulus-equivalence effects. *The Psychological Record*, *50*(1), 173-187. https://doi.org/10.1007/BF03395349

Rosenfarb, I. S., Newland, M. C., Brannon, S. E., Howey, D. (1992). Effects of self-generated rules on the development of schedule-controlled behavior. *Journal of the Experimental Analysis of Behavior*, *58*(1), 107-121. https://doi.org/10.1901/jeab.1992.58-107

Saunders, K. J., Saunders, R. R., Williams, D. C., & Spradlin, J. E. (1993). An interaction of instructions and training design on stimulus class formation: Extending the analysis of equivalence. *The Psychological Record*, *43*, 725-744. https://doi.org/10.1007/BF03395909

Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research*, *14*(1), 5-13. https://doi.org/10.1044/jshr.1401.05

Sidman, M. (1994). Commentary: The verbalization of contingencies. *Equivalence Relations and Behavior: A Research Story* (pp. 509-530). Authors Cooperative, Inc.

Sidman, M. (2000). Equivalence relations and the reinforcement contingency. *Journal of the Experimental Analysis of Behavior*, *74*(1), 127-146. https://doi.org/10.1901/jeab.2000.74127

Sidman, M. (2009). Equivalence relations and behavior: An introductory tutorial. *The Analysis of Verbal Behavior*, *25*(1), 5-17. https://doi.org/10.1007/bf03393066

Sidman, M. & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of Experimental Analysis of Behavior*, *37*(1), 5-22. http://doi.org/10.1901/jeab.1982.37-5

Silva, R., & Debert, P. (2017). Go/no-go procedure with compound stimuli with children with autism. *Journal of Applied Behavior Analysis*, *50*(4), 750–755. https://doi.org/10.1002/jaba.421

Smeets, P. M. & Barnes-Holmes, D. (2005). Auditory-visual and visual-visual equivalence relations in children. *The Psychological Record*, *55*(3), 483-503. https://doi.org/10.1007/BF03395522

Smeets, P. M., Barnes-Holmes, D., & Striefel, S. (2006). Establishing and reversing equivalence relations with a precursor to the relational evaluation procedure. *The Psychological Record*, *56*(2), 267-286. https://doi.org/10.1007/BF03395550

Speckman-Collins, J., Park, H. L. & Greer, R. D. (2007). Generalized selection-based auditory matching and the emergence of the listener component of naming. *Journal of Early and Intensive Behavior Intervention*, *4*(2), 412-429. https://doi.org/10.1037/h0100382

Tovar, A. E., & Chavez, A. T. (2012). A connectionist model of stimulus class formation with a yes/no procedure and compound stimuli. *The Psychological Record*, *62*(4), 747-762. https://doi.org/10.1007/BF03395833

Urcuioli, P. J. (2008). Associative symmetry, antisymmetry, and a theory of pigeon's equivalence-class formation. *Journal of the Experimental Analysis of Behavior*, *90*(3), 257-282. https://doi.org/10.1901/jeab.2008.90-257

Vedora, J., & Barry, T. (2016). The use of picture prompts and prompt delay to teach receptive labeling. *Journal of Applied Behavior Analysis*, *49*(4), 960-964. https://doi.org/10.1002/jaba.336

Watson, P.J. & Workman, E.A. (1981). The non-concurrent multiple baseline across-individuals design: an extension of the traditional multiple baseline design. *Journal of Behavior Therapy and Experimental Psychiatry*, *12*(3), 257-259. https://doi.org/10.1016/0005-7916(81)90055-0

Woods, A. T., O'Modhrain, S., & Newell, F. N. (2004). The effect of temporal delay and spatial differences on cross-modal object recognition. *Cognitive, Affective, & Behavioral Neuroscience*, *4*(2), 260-269. https://doi.org/10.3758/CABN.4.2.260

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Table 1

Experiment 1 Instructions for Pretraining and Experimental Conditions

Pretraining	Experimental Conditions
Pretest	
	Once the task begins, an image will appear on the screen. After you touch that image, another image or a sound will appear. Touch the second image or sound if you think it goes with the first one. During this phase, you get no points or sounds as feedback. Remember, you can read these instructions at any time. They will be placed here.
Baseline Training	
During this phase you *will group* sounds and images together. Once the task begins, an audio will play. Then a green box will appear. You will touch the green box and an image will appear in the same location. If the image goes with the audio, touch the image. If the image does not go with the audio, then do not touch it and wait for the image to disappear. As you go through, you will get points when sounds and images go together, and you will not get points when they don't. Remember, you can read these instructions at any time. They will be placed here.	During this phase you *are going to learn how to* group sounds and images together. Once the task begins, an audio will play. Then a green box will appear. You will touch the green box and an image will appear in the same location. If the image goes with the audio, touch the image. If the image does not go with the audio, then do not touch it and wait for the image to disappear. As you go through, you will get points when sounds and images go together, and you will not get points when they don't. Remember, you can read these instructions at any time. They will be placed here.
Baseline Test	
	Continue touching the sounds and images that go together as before. During this time no points or sounds will be presented. Remember, you can read these instructions at any time.
Symmetry Test	
This is a new phase. An image will appear on the screen. After you touch that image, a sound will play. Touch the white box if the sound goes with the image. During this phase, you will get no points or sounds as feedback. Remember, you can read these instructions at any time. They will be placed here.	This is a new phase. *Use what you have learned so far to figure out which images and sounds go together.* An image will appear on the screen. After you touch that image, a sound will play. Touch the white box if the sound goes with the image. During this phase, you will get no points or sounds as feedback. Remember, you can read these instructions at any time. They will be placed here.

Equivalence Test	
This is a new phase. An image will appear on the screen. After you touch the image, another image will appear. Touch the second image if you think it goes with the first one. During this phase, you will get no points or sounds as feedback. Remember, you can read these instructions at any time. They will be placed here.	This is a new phase. *Use what you have learned so far to figure out which images go together*. An image will appear on the screen. After you touch the image, another image will appear. Touch the second image if you think it goes with the first one. During this phase, you will get no points or sounds as feedback. Remember, you can read these instructions at any time. They will be placed here.

Table 2

Experiment 1 Stimulus Relations and Target Responses

Relations	Related (Go)	Nonrelated (No-Go)
AB/AC relations	A1B1	A1B2
	A1C1	A1C2
	A2B2	A2B1
	A2C2	A2C1
BA/CA relations	B1A1	B2A1
	C1A1	C2A1
	B2A2	B1A2
	C2A2	C1A2
BC/CB relations	B1C1	B2C1
	B2C2	B1C2
	C1B1	C1B2
	C2B2	C2B1

Table 3

Experiment 2 Stimulus Relations and Target Responses

Relations	Related (Go)	Nonrelated (No-Go)	
AB/AC Baseline relations	A1B1	A1B2	A2B3
	A1C1	A1C2	A2C3
	A2B2	A1B3	A3B1
	A2C2	A1C3	A3C1
	A3B3	A2B1	A3B2
	A3C3	A2C1	A3C2
BA/CA Symmetry relations	B1A1	B2A1	B3A2
	C1A1	C2A1	C3A2
	B2A2	B3A1	B1A3
	C2A2	C3A1	C1A3
	B3A3	B1A2	B2A3
	C3B3	C1A2	C2A3
BC/CB Equivalence relations	B1C1	B1B2	B2B1
	C1B1	B1C2	C2B1
	B2C2	B1B3	B3B1
	C2B2	B1C3	C3B1
	B3C3	C1B2	B2C1
	C3B3	C1C2	C2C1
		C1B3	B3C1
		C1C3	C3C1
		B2B3	B3B2
		B2C3	C3B2
		B3C2	C2C3
		C2B3	C3C2

Figure 1

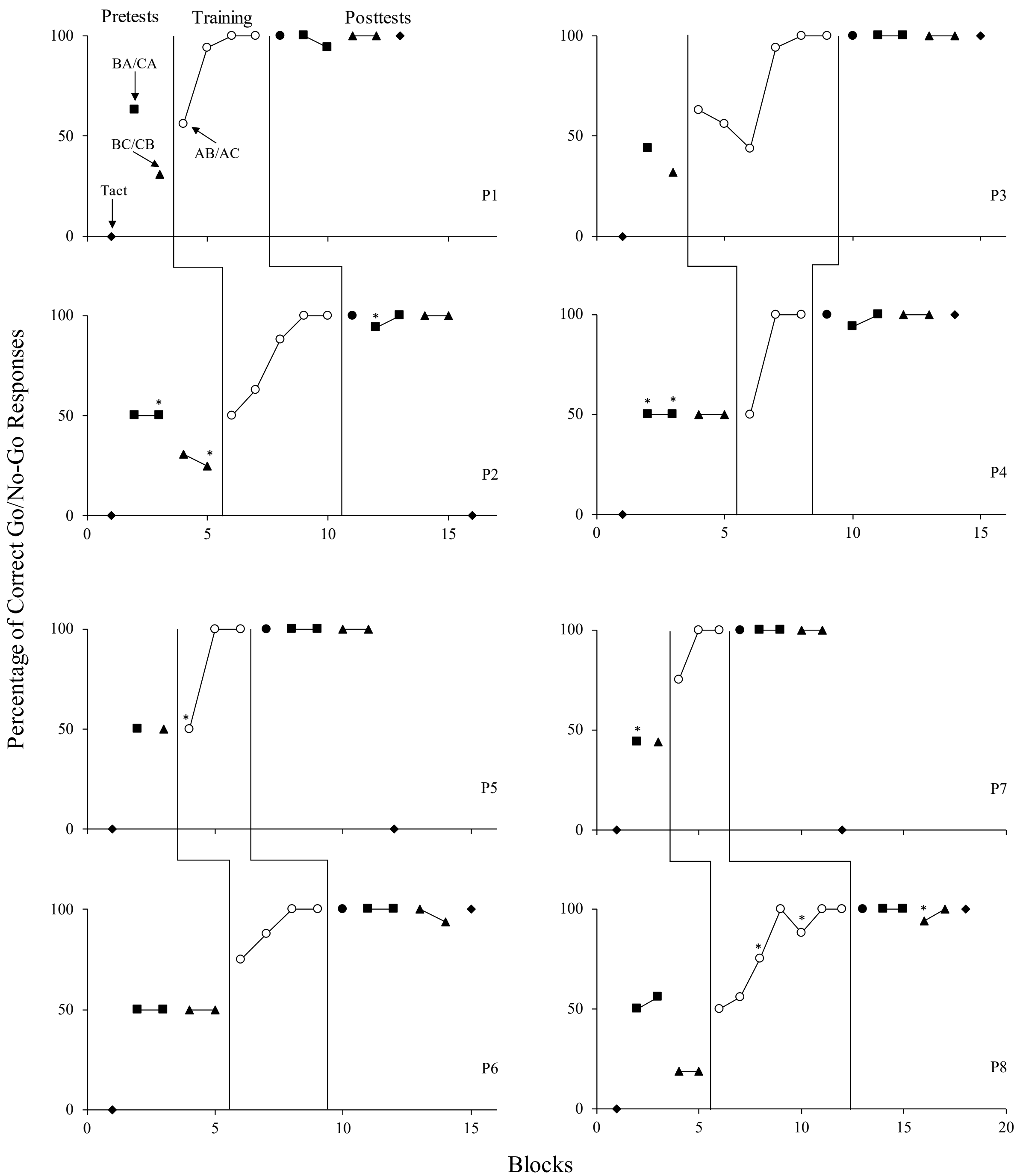
Experiment 1 and 2 Stimuli

	A	B	C
Class 1	"VEK"		
Class 2	"ZOG"		
Class 3	"PIF"		

Note. Classes 1 and 2 were used in Experiment 1. Classes 1-3 were used in Experiment 2.

Figure 2

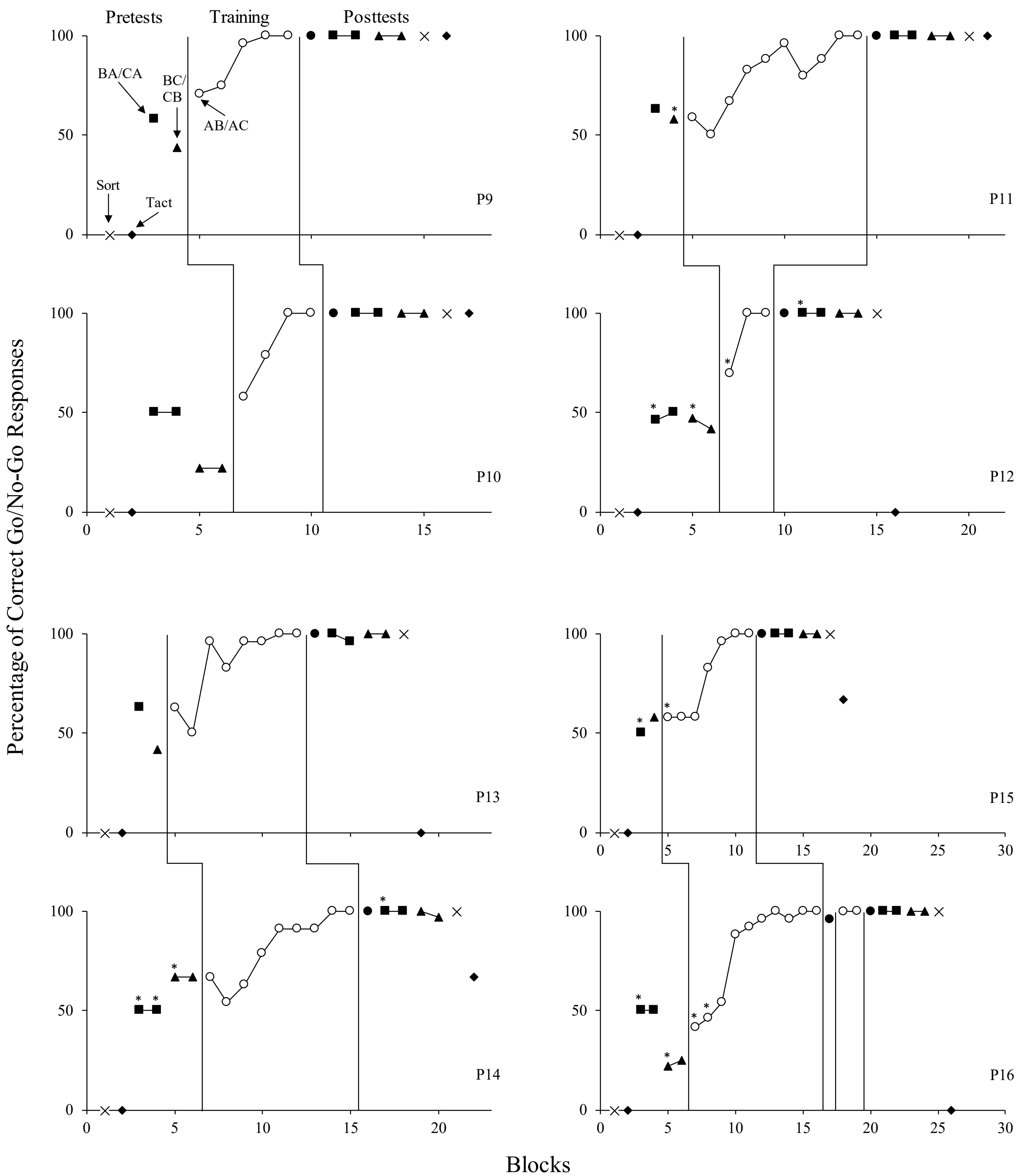
Experiment 1 Results for P1–P8



Note. Open shapes denote training and closed shapes denote testing. An asterisk above a shape indicates that participants re-read the instructions.

Figure 3

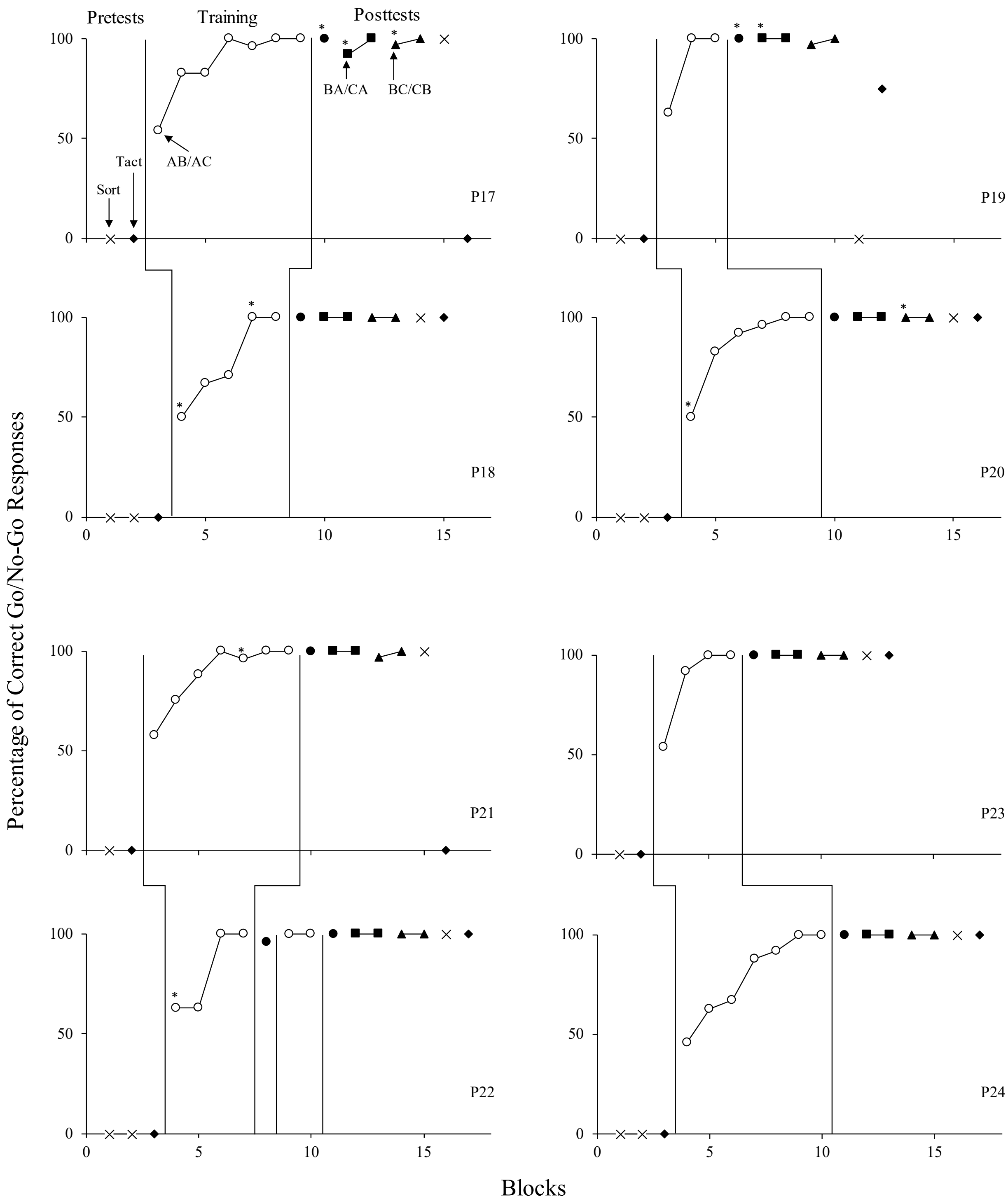
Experiment 2 Result for P9–P16



Note. Open shapes denote training and closed shapes denote testing. An asterisk above a shape indicates that participants re-read the instructions.

Figure 4

Experiment 2 Results for P17–P24



Note. Open shapes denote training and closed shapes denote testing. An asterisk above a shape indicates that participants reread the instructions.