

Effects of Procedural Variations in the Training of Negative Relations for the Emergence of Equivalence Relations

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Abstract This study aimed to determine whether the exclusive positive conditional relations established by the matching-to-sample (MTS) procedure are sufficient for equivalence class formation, or whether the negative conditional relations established with stimuli of alternative classes are necessary for it. In Experiment 1, two 3-choice MTS procedures were compared regarding equivalence class formation. The standard MTS procedure, where negative relations among stimuli of alternative classes are trained, was compared to an altered MTS procedure, where negative relations with stimuli that were not positive to any sample were trained. In Experiment 2, the positive and negative control patterns established by the standard and altered MTS procedures were assessed. Experiment 3 compared 2 further variations: (a) training only 1 negative relation with stimuli of alternative classes in each training trial type (semi-standard MTS procedure) or (b) varying the negative stimuli that did not belong to any class (varied-altered MTS procedure). The overall results indicate that for participants demonstrating high positive conditional baseline relations and high negative relations to stimuli from alternative classes, the probability of equivalence class formation was high, but when participants showed only high positive conditional baseline relations, the

probability of equivalence class formation was very low. All main theories of equivalence class formation have difficulty accounting for these results, and an account based on a learning history of classifying behavior is offered.

Keywords Conditional discrimination · Humans · Matching-to-sample · Stimulus control · Stimulus equivalence

Stimulus equivalence has become an important research paradigm for the behavioral analytic study of different aspects of complex human behavior, such as the symbolic character of language (e.g., Barnes-Holmes et al., 2005; Hayes & Hayes, 1989, 1992; Sidman, 1994; Sidman & Tailby, 1982), grammar (Lazar, 1977; Lazar & Kotlarchyk, 1986; Wulfert & Hayes, 1988), instruction and rule following (Hayes, Thompson, & Hayes, 1989), categorization (Fields, Reeve, Adams, & Verhave, 1991; Galizio, Stewart, & Pilgrim, 2001, 2004), and analogical reasoning (Barnes, Hegarty, & Smeets, 1997; Ruiz & Luciano, 2015; Stewart, Barnes-Holmes, Roche, & Smeets, 2002).

Equivalence relations are said to occur when a set of arbitrary conditional discriminations is trained and, as a consequence, a new set of untrained conditional relations emerges—specifically, reflexivity, symmetry, and transitivity relations (Sidman & Tailby, 1982). When this happens it can be stated that stimulus classes have been formed between stimuli that were positively related during training. Most stimulus equivalence studies have been carried out using the arbitrary matching-to-sample (MTS) procedure for training and/or testing the conditional relations involved. On a typical MTS trial, the selection of a comparison stimulus is reinforced in the presence of a specific sample stimulus, whereas the selection of alternative comparison stimuli is punished or extinguished in the presence of the same sample. The conditional positive

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relation that develops between the sample and the comparison stimulus choice reinforced in its presence is called a sample-S+ relation, or “select relation.” The conditional negative relations that develop between the sample and nonreinforced comparison selections is called a sample-S– relation, or “reject relation,” emphasizing that in the presence of the specific sample stimulus the subject has the tendency of select a different stimulus instead of this comparison (Berryman, Cumming, Cohen, & Johnson, 1965; Carrigan & Sidman, 1992; Carter & Werner, 1978; Cumming, & Berryman, 1961; Dixon & Dixon, 1978; Johnson & Sidman, 1993; McIlvane et al., 1987; Sidman, 1987; Stromer & Osborne, 1982).

A typical, and to some extent critical, characteristic of the standard MTS procedure is that negative relations in each trial involve comparison stimuli that are also in positive relations with other samples on other trials. For example, in a three-choice MTS training trial A1-B1/B2, B3 (where A1-B1 is the sample-S+) B2 and B3 are negative, but B2 will be positive in trials where the sample is A2, and B3 will be positive for those where the sample is A3. To illustrate, the positive and negative relations involved in training a three-choice, sample-as-node (one-to-many) MTS procedure are shown in the upper section of Table 1. As can be seen, in a standard three-choice MTS procedure, the number of trained negative relations is twice the number of trained positive relations.

This procedural characteristic, namely that negative relations are being trained simultaneously to positive relations and in a larger number, might have implications that have not been fully investigated. For example, the arbitrary conditional discrimination procedure is considered, at least implicitly, to be a paradigm about how linguistic relations between names and its referents are learned (e.g., Horne & Lowe, 1996; Horne, Lowe, & Randle, 2004; McIlvane, Munson, & Stoddard, 1988; Savage-Rumbaugh, 1984; Schusterman & Krieger, 1984; Skinner, 1957; Sidman, 1992, 1994; Stemmer, 1996). It can be argued that when a child learns her first words in natural settings, the correct naming of an object does not

imply the simultaneous learning of the names of other surrounding objects. For example, a child learns to say “shoe” in the presence of different kinds of shoes, but this does not imply that the child learns to name the remaining objects that surround a specific shoe in the same period. A case can then be made to suggest that, in the learning of naming relations, conditional positive relations between a word and some objects are trained, but without the simultaneous training of other positive relations or any negative relation between them, although this is an empirical question that has yet to be answered.

This raises the issue of whether the emergence of equivalence relations is possible from the exclusive training of positive conditional relations. In their analysis of the positive and negative relations involved in the standard MTS procedure, Carrigan and Sidman (1992) suggested the possibility that stimulus equivalence could be formed by exclusively positive or negative control, possibly resulting in different response patterns on reflexivity and transitivity tests but not on symmetry tests. Johnson and Sidman (1993) confirmed these predictions by using a two-choice MTS procedure with a linear training structure, designed to generate exclusive negative control via trials in which the negative comparison for a sample stimulus was always the same, but the positive comparison changed from trial to trial. Carrigan and Sidman (1992) also suggested a procedure to yield exclusively positive control by introducing negative comparison stimuli that are not positive to any sample stimulus in the training trials, but this suggestion has yet to be empirically tested.

There is some evidence suggesting that the negative relations involved in the standard MTS procedure are not important for the emergence of equivalence relations. In the respondent-type training procedure, a pair of arbitrary stimuli is presented during each trial, and the participants are not required to perform any choice response. Then, the symmetry and equivalence relations between the stimuli presented in pairs are tested in an MTS format. This procedure has been demonstrated to be equally as effective as the standard MTS for establishing a class of equivalent stimuli (Barnes, Smeets, & Leader, 1996; Clayton & Hayes, 2004; Kinloch, Anderson, & Foster, 2013; Leader, Barnes, & Smeets, 1996; Leader & Barnes-Holmes, 2001a, 2001b; Leader, Barnes-Holmes, & Smeets 2000; Smeets, Barnes, & Roche 1997). Apparently, in this procedure no negative relations are trained, and only the positive relations seem to be sufficient for the emergence of equivalence relations.

Alternatively, other researchers suggest that negative relations might be important for the emergence of equivalence relations, especially with the MTS format. For example, Tomonaga (1993) showed that symmetry performances by chimpanzees were related to both “select” and “reject” relations. Similarly, Urcuioli (2008) has partially attributed the success of the go/no-go (successive) symbolic and identity

Table 1 Positive and Negative Relations Trained in Three-Choice, Sample-as-Node (One-to-Many) Matching-to-Sample

Standard MTS procedure								
	B1	B2	B3	C1	C2	C3		
A1	+	-	-	+	-	-		
A2	-	+	-	-	+	-		
A3	-	-	+	-	-	+		
Altered MTS procedure								
	B1	B2	B3	C1	C2	C3	X1	X2
A1	+			+			-	-
A2		+			+		-	-
A3			+			+	-	-

matching procedure in yielding symmetric relations in pigeons to the fact that this procedure emphasized the nonreinforced (negative) relations more than the MTS procedure.

Carr, Wilkinson, Blackman, and McIlvane (2000) evaluated sample-S+ (select) and sample-S– (reject) relations in conditional discrimination training in an equivalence study employing individuals with intellectual disabilities with very poor verbal repertoires. They found that the four individuals who performed well in equivalence tests also performed well in the sample-S+ and sample-S– test trials. The single individual who did not perform accurately in the equivalence tests showed low results in the sample-S– (reject) control test. These authors concluded that both positive and negative control are important conditions for establishing equivalence relations.

An experiment by Harrison and Green (1990) used multiple S– comparisons for each sample during conditional discrimination training without differential reinforcement, so that the negative comparisons for each trial did not appear as positive comparisons on trials with other samples. Most participants performed poorly in a subsequent transitivity test, showing that the training of positive conditional relations was not sufficient for the emergence of equivalence relations. This suggests that the training of negative relations in the standard MTS format could be relevant for the emergence of equivalence relations, an idea that is apparently in conflict with Carrigan and Sidman's (1992) hypothesis, and with the results of the respondent-type procedure showing that positive conditional control is sufficient for the emergence of equivalence relations.

We conducted three experiments to evaluate these contradictory results. In the first experiment, we assessed whether an altered three-choice MTS procedure (AMTS) that precluded the training of negative relations promoted the formation of equivalence relations in comparison with the standard MTS procedure (SMTS). In a training trial of the AMTS procedure, the correct comparison stimulus for each sample stimulus was the same as in the SMTS training trials, but the negative comparison stimuli were not correct to any sample stimulus (X1 and X2 stimuli), whereas in the SMTS procedure the incorrect comparison stimuli were positive to other sample stimuli. With the AMTS procedure we intended to yield exclusive conditional positive control. In Experiment 2, these two procedures were compared regarding the positive and negative control patterns that were produced and their relation with the symmetry and transitivity-equivalence performances, by presenting tests for the baseline sample-S+ and sample-S– relations. In Experiment 3, two variations of the AMTS and SMTS procedures were compared regarding the control patterns that were yielded by each and their probability for equivalence class formation.

Experiment 1

Method

To determine whether exclusively conditional positive control is sufficient for the emergence of equivalence relations we compared the performance of two groups trained and tested with a three-choice MTS procedure. The first group was trained with a standard MTS procedure (SMTS group). In the training trials for this group, the incorrect comparison stimuli for each sample stimulus were stimuli that would be correct to other samples. The second group was trained with an altered MTS procedure (AMTS group). For this group, the incorrect comparison stimuli in each training trial were the X1 and X2 stimuli, which were not correct for *any* sample stimulus.

For both groups the correct comparison stimulus for each sample stimulus was the same, and correct choices were reinforced. Both groups were then assessed for the probability of equivalence class formation by presenting symmetry and equivalence test trials. By using the X1 and X2 stimuli as incorrect comparisons in the AMTS procedure, we expected that the SMTS procedure would yield high positive *and* negative conditional control, whereas the AMTS procedure would yield high positive conditional control and low negative control. In this manner, any possible differences in the symmetry and equivalence performances between the SMTS and AMTS groups might be attributed to differences in the level of negative control.

Participants

Ten undergraduate psychology students from a private university in Bogotá, Colombia, who were awarded academic credits, agreed to participate in the experiment. The 10 students were randomly assigned to the SMTS and the AMTS groups, each with five participants.

Setting, Apparatus, and Stimuli

The experiment was carried out in a cubicle located in a psychology laboratory. Participants were seated in front of a portable computer with a 14-inch polychromatic monitor. Stimuli were presented and responses were recorded using a program designed in Visual Basic 2010.

Stimuli consisted of letters taken from three alphabets: Greek (Set A), Hebrew (Set B), and Arabic (Set C). The sets were established according to the phonological correspondence of the letters from the aforementioned alphabets, but their formal correspondence was not evident. Figure 1 shows the stimuli used in all the experiments. Stimuli from Sets A, B, and C were used for training in the standard MTS condition and for the symmetry and equivalence tests in all experiments. Stimuli X1 and X2 were used as negative comparisons in the altered MTS training

Stimuli A, B, and C, that were positively related during the training



Stimuli X, that only were related negatively in the training



Stimuli N, used in the negative control tests



Fig. 1 Stimuli used in all experiments

conditions. Stimuli were presented in black line drawn over a 4 × 4 cm white square on a gray background. In each trial the sample stimulus appeared at the horizontal center of the screen and 3.8 cm from the top of the screen. The comparison stimuli appeared in a horizontal row, with 2.5 cm between them and 3.5 cm below the sample stimulus.

Procedure

At the beginning of the experimental session, each participant read and signed an informed consent form and was assigned to an experimental group. Then, each participant filled out an initial form on the computer that asked for demographic information. After that, a form was presented on the screen with written instructions in Spanish, which read as follows, translated to English:

Read the following instructions carefully. If you have any questions, please ask the experimenter before you start:

You will be presented with a series of boxes containing letters from different alphabets. A letter will be

presented in the upper central part of the screen in each exercise. You must click on this letter with the mouse, and then three more letters will appear in the lower part of the screen. You must select one of these three letters by clicking on it. If you click the correct letter you will hear a tone indicating that it was the correct response. If you click the incorrect letter you will hear a bell indicating an error.

This study has several phases. You will finish a phase when you have performed well on all of the exercises in it. A message will appear indicating that you have finished the phase. The experimenter will then give you new instructions. You will get feedback regarding the correct and incorrect exercises with the tone and the bell during the first phases. You will receive no such feedback during the final phases. If you have no other questions, click the “Start” button to begin the exercises.

Each trial began with the appearance of the sample stimulus in the top central part of the screen. Three comparison stimuli appeared in the lower part of the screen when the participant made an observing response by clicking the mouse’s left button on the sample stimulus. The positions of the comparison stimuli were randomized across trials. If a participant clicked on the correct comparison stimulus, a “ta-dah” tone was played, indicating that the response was correct. If a participant clicked on one of the two incorrect comparison stimuli, a “chord” tone sounded, indicating that the response was incorrect. Stimuli then disappeared from the screen and there was a 1-s interval between trials started.

Training The experiment had four training phases. Phase 1 trained AB relations and Phase 2 trained AC relations. Each phase consisted of blocks of 15 trials, five for each trial type. A 100 % accuracy criterion had to be met to proceed to the following phase. All training and testing trial types are presented in Table 2. Training trials AB and AC were mixed in Phase 3, which had blocks of 24 trials, four of each trial type, and an accuracy criterion of 96 % (23 correct responses out of 24). Phase 4 consisted of 12 training trials, two of each type, but without feedback (so as to prepare the participant for the upcoming no-feedback test trials), and a 100 % accuracy criterion to proceed to the test phases.

Testing Following the four training phases described above, participants were presented with a test phase consisting of a single block of 48 randomly presented trials: 18 symmetry trials and 18 equivalence trials (three trials for each specific relation evaluated), and 12 baseline trials, two for each trained relation. The baseline trials differed between groups and were included to evaluate baseline maintenance during the tests.

Table 2 Training and Testing Trial Types for Experiment 1

Baseline	
SMTS	AMTS
A1-B1/B2, B3	A1-B1/X1, X2
A2-B2/B1, B3	A2-B2/X1, X2
A3-B3/B1, B2	A3-B3/X1, X2
A1-C1/C2, C3	A1-C1/X1, X2
A2-C2/C1, C3	A2-C2/X1, X2
A3-C3/C1, C2	A3-C3/X1, X2
Test trials for both groups	
Symmetry	Equivalence
B1-A1/A2, A3	B1-C1/C2, C3
B2-A2/A1, A3	B2-C2/C1, C3
B3-A3/A1, A2	B3-C3/C1, C2
C1-A1/A2, A3	C1-B1/B2, B3
C2-A2/A1, A3	C2-B2/B1, B3
C3-A3/A1, A2	C3-B3/B1, B2

Note. SMTS = standard MTS procedure, AMTS = altered MTS procedure.

Results

Participants of the SMTS group needed a mean of four blocks (range: 3 - 6 blocks) in Phase 1 to reach the criterion, whereas the mean for participants of the AMTS group was 5.6 (range: 2–12 blocks). In Phase 2, the SMTS group required more blocks of training (mean=3; range: 1–5 blocks) than the AMTS group (mean=1.8; range: 2–3 blocks). Two participants of the AMTS group (P-9 and P-10) met the criterion of Phase 2 in a single trial block. In Phase 3, SMTS participants required a mean of 1.6 blocks, whereas all AMTS participants met criterion in a single block. All participants in both groups passed Phase 4 in a single block. Differences between groups were statistically analyzed using the Mann-Whitney U test, and no significant differences were found for any phase; for this reason, the data are not presented.

Figure 2 shows the results in the test trials of Phase 5. Baseline performances were relatively high for both groups – greater than 83 % accuracy for nine participants, with six achieving 100 %. The exception was P-8, who was 58 % accurate on the baseline trials. Participants of the SMTS group made at least 89 % correct responses on the symmetry trials, whereas accuracy in the AMTS group ranged from 56 % to 72 %. On the equivalence test trials, the SMTS group participants made at least 78 % correct responses with one participant at 100 %, whereas AMTS group participants were between 22 % and 50 % correct, around what would have occurred by chance alone.

Discussion

The standard MTS training procedure was superior to the altered procedure for establishing equivalence classes. The five participants trained on the altered MTS procedure averaged only about 51 % accuracy across symmetry and equivalences tests despite their accurate baseline performances. The altered MTS procedure was designed for establishing the positive conditional relations involved in the standard MTS procedure, but without training the negative conditional relations of this procedure, to test the suggestion of Carrigan and Sidman (1992). If the altered MTS procedure indeed trained only positive conditional relations, then the low results of participants of the AMTS group in the symmetry and equivalence tests would indicate that the positive relations involved in the standard MTS procedure by themselves do not promote the formation of equivalence relations. Nevertheless, in the altered MTS procedure as we designed it, conditional control was not necessary to meet the training criterion. Because the negative comparisons (X1 and X2 stimuli) were the same for each training trial, it is possible that the participants learned a simple negative discrimination and just responded to anything but X1 and X2, irrespective of the sample stimulus that was presented. Another possibility is that participants learned to select whichever of the B1, B2, B3, C1, C2, or C3 stimuli that was available, regardless of the sample. Furthermore, because these two options are not mutually exclusive, it is also possible that a combination of these possibilities contributed to the obtained differences.

There are two facts about the speed at which the mastery criteria were met during training that support the hypotheses that the participants of the AMTS group learned a simple negative discrimination. First, these participants required a larger number of training blocks in Phase 1 to meet the criterion, but the reverse was true in Phase 2, suggesting that the altered MTS procedure yielded more learning transfer from Phase 1 to Phase 2 than the standard MTS procedure. Second, two participants in Group 2 were correct on all trials in the first block of Phase 2, despite the fact that items in Phase 2 were distinct of those in Phase 1. If participants of the AMTS group learned to respond to anything but X1 and X2, they could have been able to pass Phase 2 in a single block, despite the fact that new positive comparison stimuli were presented.

In another experiment not reported here, participants were trained with the altered MTS procedure and, after meeting the training criterion, received a block of training trials on a standard MTS procedure, but without any feedback. These latter trials could be considered a test for positive control because they have the same positive comparison stimuli for each sample stimulus but different negative stimuli. These participants performed poorly on these trials, a finding that challenges the capability of the altered procedure to yield positive control. Experiment 2 was conducted to determine which kind of

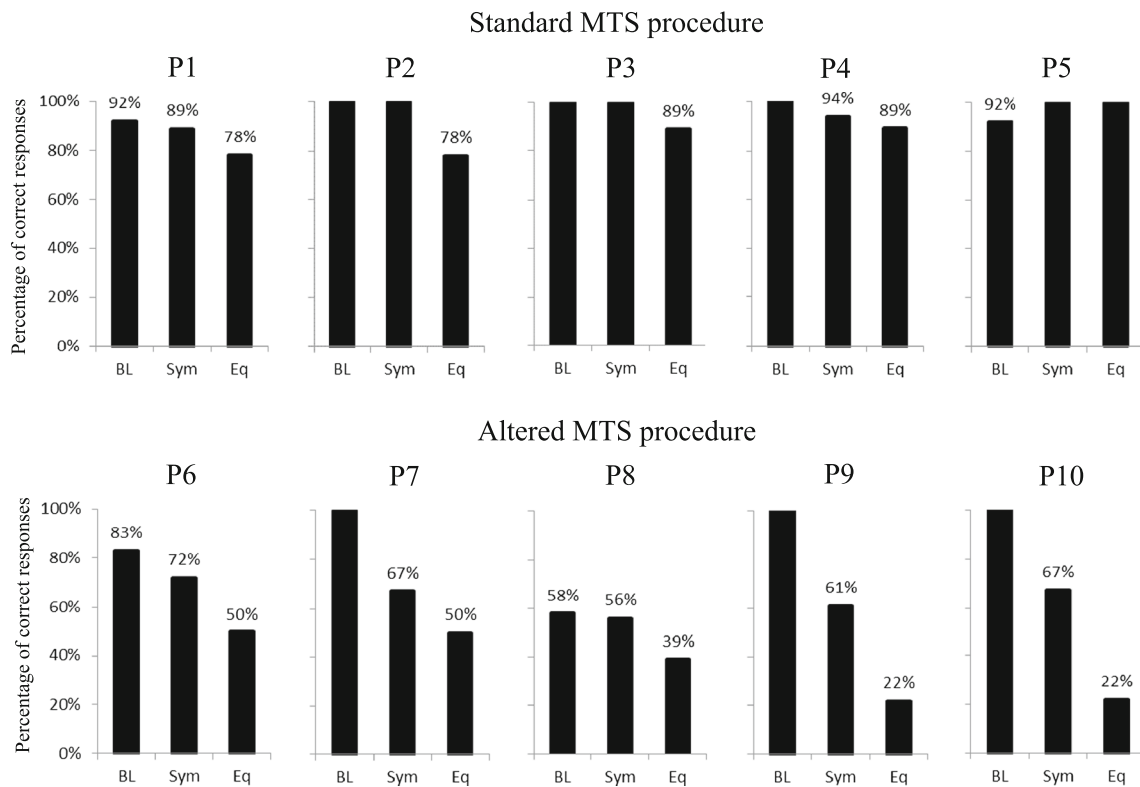


Fig. 2 Percentage of correct responses in test trials of the participants in Experiment 1. *Note.* The heading in each graph shows the number of the participant (preceded by the letter P). BL = baseline trials, Sym = symmetry, Eq = equivalence trials

control was established with the altered procedure and its relation to the emergence of equivalence relations regarding the standard procedure.

Experiment 2

This experiment again consisted of two groups: Some participants were trained with the standard MTS procedure (SMTS group), and other participants were trained with the altered MTS procedure (AMTS group). Unlike Experiment 1, a phase with positive and negative control test trials was run before the symmetry and equivalence test phases. Trials used during the training phases for the SMTS group were used as positive control test trials for the AMTS group, and vice versa, insofar as they had the same baseline positive comparison stimulus but different baseline negative comparison stimuli. If participants systematically chose the correct comparison stimulus, this would show a “select” relation between each sample and its corresponding positive comparison stimulus. Table 3 shows the trial types used for testing positive control in both groups.

The negative control test involved trials in which the correct comparison stimulus was a *new* stimulus (N stimuli in Fig. 1), whereas the negative comparison stimuli were the same as in the training trials. For example, if the item A1-

B1/B2, B3 was trained, then the corresponding negative control trial would be A1-N1/B2, B3. In the SMTS group, if a participant systematically chose the new comparison stimulus, then a “reject” relation between each sample stimulus and its corresponding negative comparison stimuli would control his or her response. However, in the AMTS group, the negative control test trials could not evaluate a conditional relation

Table 3 Positive and Negative Control Test Trials in Experiment 2

Control +	Control –
SMTS group	
A1-B1/X1, X2	A1-N1/B2, B3
A2-B2/X1, X2	A2-N2/B1, B3
A3-B3/X1, X2	A3-N3/B1, B2
A1-C1/X1, X2	A1-N4/C2, C3
A2-C2/X1, X2	A2-N5/C1, C3
A3-C3/X1, X2	A3-N6/C1, C2
AMTS group	
A1-B1/B2, B3	A1-N1/X1, X2
A2-B2/B1, B3	A2-N2/X1, X2
A3-B3/B1, B2	A3-N3/X1, X2
A1-C1/C2, C3	A1-N1/X1, X2
A2-C2/C1, C3	A2-N5/X1, X2
A3-C3/C1, C2	A3-N6/X1, X2

Note. SMTS = standard MTS procedure. AMTS = altered MTS procedure.

because the negative stimuli were the same for all of the sample stimuli; hence, these trials only evaluate simple negative control in this group. The trial types used to assess negative control are also presented in Table 3.

Method

Participants

Twenty undergraduate psychology students were randomly assigned to two groups of 10 participants. As in Experiment 1, they received academic credit for their participation.

Setting, apparatus, and stimuli

The experiment was conducted in the same setting and with the same apparatus and stimuli as in Experiment 1.

Procedure

The general procedure was the same as in Experiment 1. There were seven phases for both groups. The first four were the same as in the previous experiment. In Phase 5, the positive and negative control tests were introduced (see Table 3). This phase consisted of 36 trials: 12 positive control test trials, 12 negative control test trials, and 12 baseline trials (two presentations of each item). Phases 6 and 7 were, respectively, the symmetry and equivalence test phases, each consisting of 18 trials, 12 test trials and six baseline trials. Unlike the previous experiment, Experiment 2 used a simple-to-complex testing protocol, which evaluates symmetry first, and then equivalence relations, for the purpose of improving the outcomes in these tests, as has been done in other studies (Adams, Fields, & Verhave, 1993; Fields, Adams, Newman, & Verhave, 1992; Smeets, Barnes, & Roche, 1997; Smeets, Dymond, & Barnes-Holmes, 2000), and which we expected would increase the probability of the altered MTS procedure to yield equivalence performances.

Results

Regarding the training phases, the AMTS group needed fewer training blocks than the standard procedure participants did in all phases, although the differences were significant only on the first two phases. In Phase 1, the SMTS group required a mean of 4.3 blocks to meet the criterion, and the AMTS group needed a mean of 2.5 blocks, $t(18)=2.557, p=.027$. In Phase 2, the SMTS group required a mean of 2.8 blocks and the AMTS a mean of 1.7 blocks, $t(18)=3.051, p=.007$. Four participants of the AMTS group (P-21, P-24, P-26, and P-30) met the criterion of Phase 2 in the first block. In Phase 3 the SMTS and the AMTS groups required a mean of 1.8 and 1.3 blocks,

respectively, and in Phase 4 they required a mean of 1.3 and 1.1 blocks, respectively.

Table 4 presents the percentage of correct responses of all participants in test trials. Figure 3 compares the mean of percentages of correct responses of both groups in each test. Baseline performances were high in both measurements for all SMTS participants and seven AMTS participants. In Phase 5, the baseline mean was 98.3 % for SMTS group and 93.3 % for AMTS group; in Phases 6 and 7, the mean for SMTS group was 95.8 % and 87.5 % for the AMTS group. The differences between groups were not statistically significant in Phase 5, $t(18)=1.053, p=.317$, and in Phases 6 and 7, $t(18)=1.195, p=.256$.

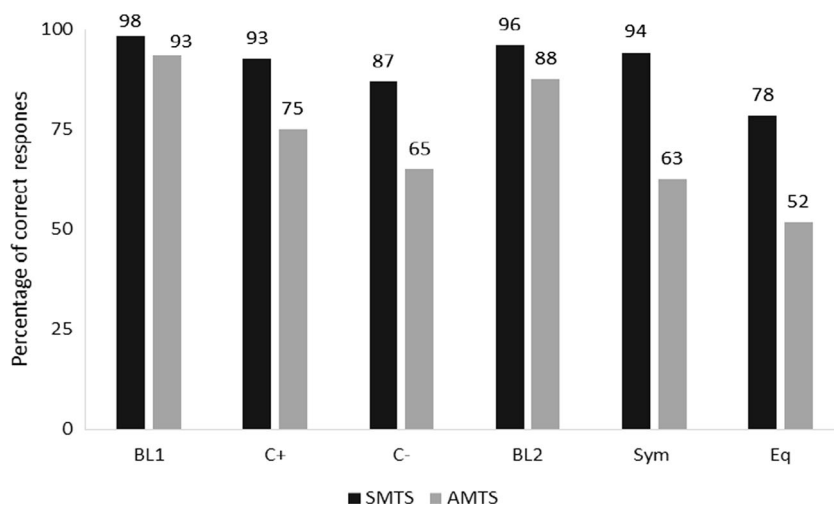
Regarding positive control test results, all SMTS participants had 75 % or more average number of correct responses, with six participants achieving 100 %. AMTS group results were more variable, ranging from 33 % to 100 %, and six participants matching at 75 % or greater accuracy. Performances for nine

Table 4 Percentage of Correct Responses in the Test Trials for the Participants in Experiment 2

Participant	Phase 5			Phases 6 and 7		
	BL1	C+	C-	BL2	Sym	Eq
SMTS group						
11	100	100	75	100	100	83
12	100	75	58	75	83	50
13	100	100	83	100	92	58
14	100	100	83	100	100	67
15	100	83	100	100	100	83
16	92	100	100	100	100	100
17	100	100	75	92	92	58
18	100	100	92	92	83	83
19	100	83	92	100	100	92
20	100	92	83	100	100	92
AMTS group						
21	100	100	75	100	83	67
22	100	100	75	92	75	92
23	75	100	100	92	67	25
24	75	75	33	58	67	58
25	83	50	83	100	67	33
26	100	33	100	100	42	58
27	100	100	25	92	83	67
28	100	58	50	92	67	33
29	100	92	33	100	75	50
30	58	67	75	42	33	33

Note. SMTS = standard MTS procedure. AMTS = altered MTS procedure. Part is the number of each participant. BL1 and BL2 are the baseline items in Phase 5 and 6, respectively. C+ and C- correspond to the positive control and negative control test items. BL2 is the baseline items in the Phase 6. Sym and Eq correspond to the symmetry the equivalence test items, respectively. Percentages equal or greater than 75 % are in boldface.

Fig. 3 Mean percentage of correct responses of SMTS and AMTS groups in the test trials of Experiment 2



participants of the SMTS group in the negative control test trials were equal to or greater than 75 % accuracy, with two of them reaching 100 %. Again, results of the AMTS group were more variable, with percentages ranging from 25 % to 100 %, and six participants matching at 75 % or greater accuracy. All SMTS participants correctly matched on 83 % (10/12 correct responses) or more trials on symmetry test trials, with seven subjects achieving 100 %. In contrast, only four participants from AMTS group correctly matched at 75 % or greater accuracy. Six participants of the SMTS group had 75 % or greater accuracy on the equivalence test, whereas only one participant of the AMTS group achieved this percentage.

To better analyze the types of control patterns showed in the positive and negative control tests trials and their relation with the performance on the symmetry and equivalence tests, we decided to classify as a high performance in each test a percentage of accuracy equal to or greater than 75 % (nine or more correct responses), because the probability of randomly choosing nine or more correct responses on 12 trials with three choice alternatives per trial is less than 0.01 in a binomial distribution. Performances lower than 75 % were considered inaccurate and demonstrative of a lack of control for the performance assessed by the test.

Nine participants of the SMTS group demonstrated a high performance in both the positive and negative control tests. All six participants of this group, which had a high performance in the symmetry and equivalence tests trials, and therefore formed equivalence relations, displayed this pattern of high positive and negative control. The remaining three participants showing this control pattern had a high performance in symmetry but inaccurate performance in equivalence test trials. P-12 had an inaccurate performance in negative control test trials, and showed the lowest result in the equivalence test.

The positive/negative control patterns were more varied for the AMTS group. Three participants (P-21, P-22, and P-23) exhibited a high positive and high negative control pattern.

Even though this pattern was the same for most participants in the SMTS group, it was not expected that their results in the symmetry and equivalence tests would be close to the results of the SMTS group because negative control in the SMTS group had to be conditional, but not so for the AMTS group, as was explained previously. The results of these three participants on the symmetry and equivalence test trials were unequal: P-22 had high scores on symmetry and equivalence tests, and this participant was the only one of this group who met the criterion for equivalence class formation; P-21 had high scores on symmetry and lower scores on equivalence; P-23 showed inaccurate scores on both test trials. Three other participants displayed a high positive control and inaccurate negative control pattern (P-24, P-27, and P-29). Participants who exhibited this pattern had to learn conditional relations between the sample stimuli and their corresponding positive comparison stimuli. This pattern was related to inaccurate to high performances on symmetry test trials and inaccurate performances on equivalence test trials. Three participants (P-25, P-26, and P-30) exhibited an inaccurate positive and high negative control pattern. Participants displaying this pattern did not learn any conditional relation but simple negative discriminations. This pattern was related to inaccurate scores on both symmetry and equivalence tests. P-28 had inaccurate results on positive and negative control tests, equally on symmetry and equivalence tests trials. This baseline performance could be explained by exclusive positive simple discriminations. The last participant, P-30, showed a deterioration of her baseline performance, associated with a high negative control and inaccurate positive control, symmetry, and equivalence performances.

Discussion

The standard MTS procedure promoted both high positive and high negative control, as has been found in other studies (Carr

et al. 2000; McIlvane, Withstandley, & Stoddard, 1984; McIlvane et al. 1987; Stromer & Osborne, 1982), so it is possible that both kinds of control are mutually strengthened with this procedure. The performance of P-12 shows that meeting the training criteria in a standard MTS procedure does not assure high positive and negative conditional control. Some authors, such as Sidman (1990, 1994) and McIlvane (2013; McIlvane & Dube, 1996), have suggested that equivalence relations between antecedent stimuli are a direct consequence of the establishment of four-term contingencies. However, the performances of P-13, P-14, and P-17 seem to show that the establishment of a series of four-term contingencies does not guarantee the emergence of equivalence classes.

The altered MTS procedure yielded great variability on control patterns, and, therefore, performance was less predictable. The use of the standard training trials as positive control tests seems to be an appropriate way to assess the conditional relations because all of the comparison stimuli in each test trial were correct in other training trials and, hence, the selection of the correct one in each test trial depends exclusively on the sample; in consequence, a high performance in the positive control test trials would be evidence of a reliable sample-S+ relation. Six participants showed conditional, sample-S+ (select) relations with this procedure. All four participants who exhibited high symmetry performance also showed high positive control, but the results of participants P-23 and P-24 show that a high “select” relation does not guarantee high symmetry performances. Only one participant met the criterion for the formation of equivalence relations, but five of the six participants who showed high positive conditional control (three of them with high symmetry performances) did not meet such criterion. In contrast, high negative control by stimuli that were not part of any of the classes which were pretended to form did not apparently interfere with equivalence class formation, as the results of P-22 indicate. This would suggest that the establishment of equivalence classes by positive conditional control alone is possible, but the probability of achieving it is much lower than with the concurrent training of negative conditional relations with stimuli that are positive to another sample stimulus and that would belong to alternative classes, as in the standard MTS procedure.

As expected, high negative control combined with inaccurate positive control was related to low performances in symmetry and equivalence test trials. In these three cases, it is possible to argue that participants learned in the baseline to respond to any comparison stimulus that was not X1 and not X2. Two participants required only one block to meet the criterion in Phase 2, which coincides with this pattern. As for the other two participants who completed Phase 2 in a single block, one of them (P-28) displayed inaccurate positive control and negative control, and the other one displayed high positive and high negative control. It is possible that in these cases

performances were controlled by a mixture of negative control and simple positive discrimination in the former, and by conditional positive discrimination in the latter.

Given the variability of control patterns that is yielded by the altered MTS procedure, and taking into account that this might have happened because the negative comparison stimuli were the same in all training trials, we decided to conduct another experiment in which one group was trained on the altered MTS procedure but with different X stimuli for each type of positive sample-comparison relation. With this procedural change we attempted to increase the number of participants displaying the high positive and low negative control pattern, insofar as the number of negative comparison stimuli associated with each sample would be greater, and they would be different for each sample. This procedure is similar to the one proposed by Carrigan and Sidman (1992) to bias the training to induce exclusively positive control, but with the difference that in Carrigan and Sidman’s procedure a baseline trial type was included for each sample stimulus, which had a negative comparison that was positive to different sample stimulus, in a two-choice MTS format.

Experiment 3

This experiment also had two groups. With the first group, a procedure similar to the altered MTS was implemented, with the exception that the particular pair of incorrect comparison stimuli differed across the types of training trials (see the upper panel of Table 5). We refer to this procedure as “varied altered MTS” (V-AMTS), which was aimed at increasing positive control and reducing negative control. The other group was trained with a new MTS procedure that we called “semi-standard” (S-SMTS) because, on each three-choice training trial, one of the incorrect comparisons was correct for another sample, but the other comparison stimulus was never correct on any trial (see the lower panel of Table 5). Thus, with this procedure, half of the negative conditional relations between each sample and comparison stimulus of alternative classes was trained as compared to the standard MTS procedure, with the possible outcome that this could result in lower scores, especially in equivalence test trials.

Method

Participants

Twenty students were randomly assigned to the V-AMTS and S-SMTS groups. Both groups contained two males and eight females. Ages of the V-AMTS group ranged from 17 to 30 years and from 17 to 28 years in S-SMTS group.

Table 5 Training Trials and Positive and Negative Control Test Trials for V-AMTS and S-SMTS Groups in Experiment 3

Training	Control +	Control –
V-AMTS group		
A1-B1/X1, X2	A1-B1/B2, B3	A1-N1/X1, X2
A2-B2/X3, X4	A2-B2/B1, B3	A2-N2/X3, X4
A3-B3/X5, X6	A3-B3/B1, B2	A3-N3/X5, X6
A1-C1/X3, X5	A1-C1/C2, C3	A1-N1/X3, X5
A2-C2/X1, X6	A2-C2/C1, C3	A2-N5/X1, X6
A3-C3/X2, X4	A3-C3/C1, C2	A3-N6/X2, X4
S-SMTS group		
A1-B1/B2, X1	A1-B1/B3, X2	A1-N1/B2, X1
A2-B2/B3, X2	A2-B2/B1, X3	A2-N2/B3, X2
A3-B3/B1, X3	A3-B3/B2, X1	A3-N3/B1, X3
A1-C1/C2, X4	A1-C1/C3, X5	A1-N4/C2, X4
A2-C2/C3, X5	A2-C2/C1, X6	A2-N5/C3, X5
A3-C3/C1, X6	A3-C3/C2, X4	A3-N6/C1, X6

Note. V-MTS = varied altered MTS. S-SMTS = semi-standard MTS.

Procedure

Just as in Experiment 2, both conditions involved passing through seven phases. The first four consisted of training phases, similar to those in previous experiments. Phase 5 involved evaluating positive and negative control, and Phases 6 and 7 were the symmetry and equivalence tests, respectively. The number of trials and the accuracy criteria in the training phases and the number of baseline and test items in the final phases were the same as in Experiment 2. Table 5 shows the configuration of training trials and positive and negative control test trials for both groups. Positive control test items for the V-AMTS group were the same as those for the AMTS group in Experiment 2 (cf. Table 3). In contrast, B, C, and X stimuli were used as negative comparison stimuli in the positive control test for the S-SMTS group. For both groups, items used on negative control test trials were N stimuli presented as positive comparisons (see Fig. 1), and the negative comparisons were the same as those appearing on baseline trials.

Results

In the first phase, the V-AMTS group required an average of 5.2 blocks (range: 2–13) to meet criterion, whereas the S-SAMTS groups needed an average of 4.5 blocks (range: 2–8). This difference was not statistically significant. In Phase 2, the V-AMTS group required a mean of 2.1 blocks (range: 2–3), whereas the S-SAMTS group needed a mean of 3.5 blocks (range: 2–5), and the difference was significant, $t(18) = 3.934$, $p = .003$. No one met the criterion on this phase in a single block. The mean number of blocks required in Phase 3 for

V-AMTS and S-SAMTS groups were 2.0 (range: 1–4) and 2.8 blocks (range: 1–10), respectively, and in Phase 4 it was 1.0 and 1.2 blocks (range: 1–2), respectively. In these last two phases there were no statistically significant between-groups differences.

Table 6 presents the percentage of correct responses of the V-AMTS and S-SMTS participants in the test trials, and Fig. 4 shows the mean of percentage of correct responses for each test trial. Participants in the V-AMTS group showed high baseline accuracy during testing, with the exception of P-33, who had 50 % accuracy on the first test but reached 100 % on the second. The S-SMTS group also showed high baseline accuracies during tests, except for P-46, who had 67 % accuracy in the first evaluation but reached 100 % on the second test. There were no statistically significant between-groups differences on the maintenance of baseline performances during testing. Seven participants of the V-AMTS group matched at 75 % or greater accuracy on positive control test trials. Positive control accuracies for all participants of the S-SMTA group matched at or above 75 % correct. Regarding negative control, in the V-AMTS group, only four participants matched at or above 75 % correct, and five participants matched at 50 % or less. On symmetry test trials, only three participants of the V-AMTS group and eight participants of the S-SMTS group matched at 75 % or greater accuracy. For the equivalence test trials, two participants of the V-AMTS group and seven participants of the S-SMTS group displayed performances at or above the 75 % correct. Taking as criterion of equivalence class formation a percentage of 75 % or greater in both the symmetry and equivalence test trials, only one participant in the V-AMTS group (P-37) and seven participants in the S-SMTS groups established equivalence relations.

Patterns of control were reviewed using the same criteria as in Experiment 2. The V-AMTS procedure produced a variety of control patterns similar to that of the AMTS group in the previous experiment. Three participants (P-31, P-34, and P40) fell within the high positive and high negative control category. One of them (P-34) showed high scores in symmetry test trials, the remaining two had inaccurate performances in the symmetry test, and all three showed inaccurate scores in the equivalence test trials. Four participants (P-32, P-35, P-37, and P-38) fell within the high positive control and inaccurate negative control category. One of them (P-32) had high results in the symmetry test but low results in equivalence test. Another (P-35) had low results in both the symmetry and equivalence tests. P-38 showed inaccurate scores in the symmetry trials and high scores in the equivalence trials. The remaining one (P-37) had high scores in both the symmetry and the equivalence test trials and was the only one in this experimental group who met the criteria for the formation of equivalence relations. She also presented the lowest negative control within her control category. Only one participant

Table 6 Percentage of Correct Responses in the Test Trials for Participants in Experiment 3

Participant	Phase 5			Phases 6 and 7		
	BL1	C+	C-	BL2	Sym	Eq
V-AMTS group						
31	100	75	83	100	58	33
32	92	100	58	58	92	33
33	50	50	8	100	42	42
34	83	83	92	83	83	67
35	83	83	42	92	50	17
36	92	67	17	100	67	25
37	92	75	17	100	83	92
38	75	92	50	100	58	83
39	92	50	75	92	50	50
40	100	100	100	100	67	42
S-SMETS Group						
41	92	92	58	100	100	75
42	92	83	42	100	92	67
43	100	100	75	92	92	83
44	100	100	50	100	92	100
45	100	83	67	92	100	100
46	67	83	42	100	67	42
47	100	100	67	100	100	92
48	92	100	67	92	58	42
49	83	92	58	100	92	92
50	92	75	25	83	92	92

Note. V-MTS = varied altered MTS. S-SMETS = semi-standard MTS. The meaning of the headers is the same as in Table 4. Percentages equal or greater than 75 % are in boldface.

(P-39) was in the inaccurate positive and high negative control category, and he had equally inaccurate results in the symmetry and equivalence test trials. The remaining two participants (P-33 and P-36) had inaccurate performances in both positive

and negative control test trials, and their results in symmetry and equivalence trials were equally inaccurate.

Regarding the S-SMETS group control patterns, only one participant (P-43) was classified in the high positive and high negative control category. The remaining nine participants were placed in the category of high positive control and inaccurate negative control. Given that this group had high percentages of correct responses on the equivalence tests, these results seem to challenge the assumption that negative control by stimuli of alternative classes would be critical for the emergence of equivalence relations. We decided to analyze the types of errors presented by participants of this group in the negative control test in greater detail, as well as their relation to the performance on equivalence test trials.

Participants of the S-SMETS group were trained with a three-choice MTS format, with a negative comparison stimulus that would be positive to other sample (Stimulus B or C) and another comparison stimulus that would not be positive to any other sample (Stimulus X) in each trial. So, if the A1-B1/B2, X1 relation had been trained, then the configuration A1-N1/B2, X1 would have appeared in the negative control test. With such configuration, errors could be of one of two types: (a) the stimulus B2 would be selected, with this stimulus belonging to other alternative class, or (b) X1 would be selected, and this stimulus would not belong to any alternative class. If the error consisted in choosing B2, then this would be a problem related to the establishment of the equivalence relations, insofar as this selection is incompatible with the stimulus classes that were intended to form. However, if the error consisted of X1 being selected, this would not be incompatible with the intended classes and could indicate that B2 was exerting negative control. Thus, those participants who made more errors by selecting stimulus B or C in negative control test trials should also have made more errors in equivalence test trials than those incorrectly selecting stimulus X in negative control test trials. Table 7 shows the number of errors made by each participant on the negative control test, selecting either B/C

Fig. 4 Mean percentage of correct responses of V-AMTS and S-SMETS groups in the test trials of Experiment 3

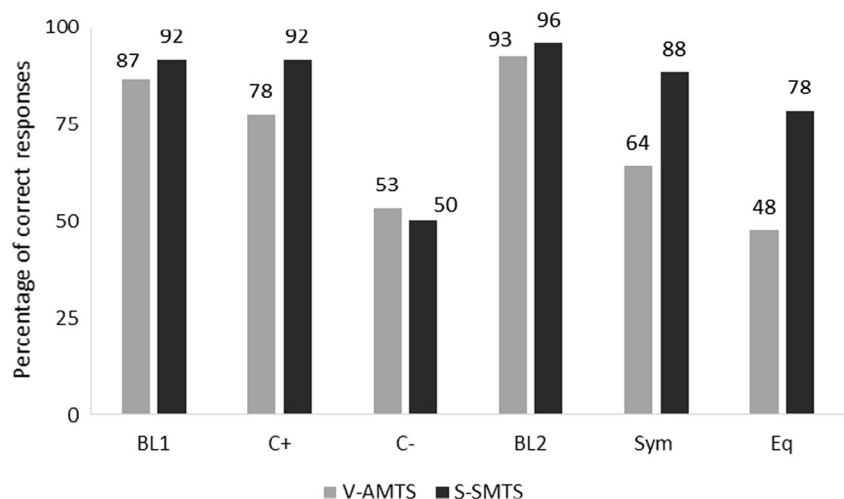


Table 7 Number of Errors in Negative Control and Equivalence Tests for the Semi-Standard MTS Group's Participants

Participant	Error type in negative control test trials		Errors in equivalence test trials
	B or C stimuli selection	X stimuli selection	
41	2	3	3
42	4	3	4
43	0	9	2
44	3	3	0
45	0	3	0
46	4	3	7
47	0	4	1
48	3	1	7
49	0	5	1
50	3	6	1

stimuli or X stimuli, and their relation to amount of errors on the equivalence test.

We were able to classify the participants of the semi-standard training group according to the type of error most frequently made on the negative control test trials. Three participants (P-42, P-46, and P-48) made most of their errors by selecting stimulus B or C. Six participants (P-41, P-43, P-45, P-47, P-49, and P-50) made most of their errors by selecting stimulus X. P-44 had an equal amount of both type of errors. Participants of the first set were the ones who did not meet the requirements for the formation of equivalence relation in the S-SMTS group. Using a Mann-Whitney test for comparing these two sets of participants regarding errors made on equivalence test trials, the mean rank for the former set was 8.0 and for the latter was 3.5 ($z = -2.374$, $p = 0.024$). This analysis clearly shows that those who made more errors by selecting stimuli positive for alternative classes in the negative control tests had worse performances on equivalence test trials than those who made more errors by selecting stimulus X on negative control test trials.

Discussion

In this experiment, negative comparison stimuli were varied for each type of training trial in the varied-altered MTS procedure as opposed to remaining constant across trials as in the altered MTS procedure in Experiment 2. As was expected, learning baseline relations was more difficult when the negative stimuli comparison varied across the training trials than when the negative stimuli were the same across the trial types. However, there was a greater positive learning transfer from Phase 1 to Phase 2 in both altered procedures than in both standard MTS procedures. This result suggests that learning that a stimulus may have different functions (positive and negative) is a more difficult task than learning that a stimulus has one and only one function (positive or negative).

Using different pairs of negative comparison stimuli in the training trials in the varied-altered procedure produced a level of positive control similar to that of the altered procedure, although the negative control was slightly lower, and the variety of control patterns with this procedure was similar to the ones obtained with the altered procedure. Positive control seems to have a direct relation to symmetry performances, but high negative conditional control by stimuli that were not positive to any sample had a negative relation with performances on the equivalence test trials and seemed to interfere with the formation of equivalence relations. As in Experiment 2, the emergence of equivalence classes was possible via exclusively positive conditional control, as the results of P-37 indicate, however, the probability of achieving this was much lower than with the training of negative conditional relations with stimuli that belong to alternative classes.

It was expected that intermediate results on the equivalence tests would be obtained by using the semi-standard MTS procedure, but the results were very similar to those for the standard procedure. This fact indicates that in three-choice MTS, the training of only one negative relation with a comparison stimulus that is positive to another sample on each trial is sufficient for the emergence of equivalence relations and that it is not necessary to train all the negative relations involved in the standard MTS procedure to achieve it.

In the semi-standard procedure, participants were trained with trials in which a negative comparison stimulus was positive to another sample, and the other negative comparison stimulus was not positive to any sample. There was a general tendency of participants trained with this procedure to have low scores on the negative control test trials. On these, both negative comparison stimuli were presented with their corresponding sample. Some participants selected the X stimuli that had been trained as a negative comparison rather than the novel stimulus, but these participants had high scores on the equivalence tests. The selection of X stimuli on the negative control test was, thus, not incompatible with the stimulus

classes that were expected to form. This fact suggests that, for these participants, attending to the positive comparison stimulus and the negative comparison that belonged to an alternative class was sufficient to learn the baseline conditional relations. In consequence, the X stimuli might have been irrelevant for the baseline criteria, so that the participants did not attend to them, which prevented discriminative control from developing, so they responded to the training trials as if it was a standard two-choice MTS.

General Discussion

This study explored some elements of the stimulus control involved in a standard three-choice MTS procedure for equivalence class formation. Particularly, we examined whether the training of exclusive positive conditional relations was sufficient for class formation, or whether the training of negative conditional relations with stimuli of alternative classes was necessary. Participants in the AMTS group in the second experiment and in the V-AMTS group in the third, who showed high conditional control but little conditional negative control by stimuli of alternative classes, had a low probability to meet the criterion for the formation of equivalence relations ($2/13 = 15.4\%$). Nevertheless, participants of the SMTS group in Experiment 2 who showed high negative control by stimuli of alternative classes, and participants of S-SMTS group in the third experiment, who made more mistakes selecting X stimuli in the negative control test trials, had a greater probability to meet the criterion for equivalence relations ($12/15 = 80\%$). These outcomes are consistent with some previous findings emphasizing the importance of negative relations for the emergence of equivalence relations (Carr et al., 2000; Harrison & Green, 1990; Saunders & Green, 1992; Tomonaga, 1993). These results also raise some doubts about the strength of the claim by Carrigan and Sidman (1992), that positive conditional control by itself readily yields equivalence relations.

In all groups of Experiments 2 and 3, participants who had a high performance in the symmetry test trials also demonstrated high positive control. This indicates that high positive conditional control between the stimuli that belong to the same class is a necessary condition for symmetry relations to emerge. However, as the performances of two participants of the AMTS group (P-23 and P-24), three participants of the V-AMTS group (P-31, P-35, and P-38), and two participants of the S-SMTS group (P-46 and P-48) show, high positive conditional control, by itself, did not guarantee high symmetry performances. The relation between positive conditional control and equivalence performances was weaker. Although all participants who had high scores in the equivalence test also had high scores in the positive control test, out of the 33 participants in Experiments 2 and 3 who showed high positive

conditional control, only 17 (51.5 %) demonstrated equivalence class formation.

One participant of the AMTS group in the second experiment met the criteria for the establishment of equivalence relations, although she demonstrated high negative control by stimuli that did not belong to any class. However, three participants from V-AMTS group with high scores in the negative control test had lower percentages in the equivalence test. Negative control in the AMTS group was not conditional, because the negative stimuli were the same for each sample, but in the V-AMTS group the negative control was conditional because negative stimuli were different and fixed for each sample. Negative simple control by stimuli that did not belong to any class seems to have an innocuous effect on equivalence class formation. Instead, conditional negative control for stimuli that were not positive to any sample, as apparently was the case for the V-AMTS group, seems to prevent the emergence of equivalence performances. This conclusion, however, needs further confirmation given the low number of cases for analysis.

It could be argued that the differences between the standard procedures and both of the altered procedures in equivalence class formation were because participants of the altered groups had to discriminate a greater number of stimuli than participants of the standard procedure, and this might have affected the results in the test for emergent relations. Yet, participants in the semi-standard MTS group had to discriminate the same number of stimuli as did participants of both altered procedures. In consequence, the key factor seems to be the type of positive and negative relations established rather than the amount of discriminations made.

The results of the semi-standard procedure seem to indicate that most participants respond to this configuration as a standard *two-choice* MTS task. Some authors have suggested that reinforcement contingencies determine the attending response of the subjects over stimuli (Dinsmoor, 1985; Nevin, Davison, & Shahan, 2005; Shahan, 2013). It is possible then that in this procedure participants neglected Stimuli X because attending only to stimuli that were positive to any sample was sufficient to accomplish the requirements of the task. This could explain the observation that in negative control test trials some participants selected the X stimulus more than the N stimulus, as if the X stimulus had not acquired any function in the baseline trials. Nonetheless, the selection by some participants of the X stimulus in the negative control test trials was similar to that made by most participants in a study conducted by Minster, Elliffe, and Muthujumaraswamy (2011). In this study, four of five participants showed the emergence of equivalence relations between the stimuli positively related in the training, and their respective class-specific *incorrect* comparisons. It is possible that the participants of the S-SMTS procedure who preferred the X stimulus over the N stimulus in the negative control test trials might have established untrained stimulus

relations including the X stimuli that were class specific, that is, by the mere fact that they were always present in the presence of the particular sample. However, the Minster et al. effect was found after a long overtraining, which was not the case here, and hence this possibility requires more research to be elucidated.

Theoretical Implications

Results of these experiments seem to pose problems for the main theoretical accounts of equivalence class formation insofar as all of them emphasize the role of the positive relations trained. According to the Pavlovian account of equivalence relations (Clayton & Hayes, 1999; Tonneau, 2001), attention to the sample-S+ correlation in the training trials would be sufficient for the participants to display accurate performances in symmetry and equivalence test trials. Similarly, relational frame theory (Hayes, Barnes-Holmes, & Roche, 2001; Barnes-Holmes, Barnes-Holmes, Smeets, Cullinan, & Leader, 2004) assumes that the coordination frame involved between the sample-S+ baseline relations yields the conditions for the emergent performances of the equivalence relations. However, both theories have problems to explain the fact that most participants of the altered groups who showed high sample-S+ conditional relations did not readily display the emergence of symmetry and equivalence relations. Sidman's (1986, 1990) contingency approach takes into account both positive and negative conditional relations for a description of the four-term contingency. However, Sidman (1994; Carrigan & Sidman, 1992; Johnson & Sidman, 1993) has admitted that equivalence relations could be the product of exclusively positive or negative control, and in this sense this theory faces the same problem the other ones face. A theory of equivalence class relations should account for the differences found in this study between the standard and the altered procedures for the emergence of equivalence relations.

A difference between the standard and semi-standard procedures regarding both of the altered procedures was that each of the training trials of the former presented two or three B or C comparison stimuli, establishing simultaneous discriminations between them, while in each training trial of the altered procedures only one B or C comparison stimulus was presented, and simultaneous discriminations between them were not trained. However, because the training structure used in these experiments was a *one-to-many* (AB and AC), the equivalence test trials (BC and CB) presented either the three B or the three C stimuli as comparisons in each trial. So, for both of the altered groups, the equivalence test trials were more distinct from the baseline trials than was the case for both standard groups. It is possible, then, that the superiority of both standard MTS procedures over the two altered procedures was related to the simple simultaneous discriminations established in the training. Saunders and Green (1999) have predicted the

superiority of the *many-to-one* training structure over the *one-to-many* and *linear series* structures on the formation of equivalence relations in the grounds that only the first one trains all of the possible simple discriminations between the stimuli during training. This hypothesis has some empirical support (Fields, Hobbie-Reeve, Adams, & Reeve, 1999; Hove, 2003; Saunders, Chaney, & Marquis, 2005; Saunders, Wachter, & Spradlin, 1988). Thus, it is possible that the differences between standard and altered procedures were largely due to the use of a *one-to-many* training structure, and if participants of both procedures were to be trained with another structure, these differences could be reduced.

For all of the experiments, most cases of either establishment or not of equivalence classes seemed to be accounted by some pattern of positive and negative control (simple or conditional). There are a number of participants, however, who showed exceptional performances, either demonstrating equivalence class formation without high negative conditional control for stimuli of alternative classes or displaying high positive conditional control and negative conditional control by stimuli of alternative classes and yet not forming equivalence relations. For those authors who claim that equivalence class formation is a consequence of the four-term contingencies only (e.g., Sidman, 1990, 1994, 2000; McIlvane, 2013), the latter case is specially challenging. How can these cases be explained?

Some authors have proposed the perspective that equivalence class formation is to be understood as the partition of a series of physically dissimilar stimuli in sets that are mutually excluding, whose members share certain functions under some contexts (Saunders & Green, 1992; Urcuioli, 1996, 2013; Vaughan, 1988). Some experiments with nonhuman subjects have showed this partitioning effect (e.g., Wasserman, DeVolder, & Coppage, 1992; see Urcuioli, 2013), without testing for symmetry or equivalence relations. Arguably, it is possible that in the case of human subject performance, the standard arbitrary MTS training procedure, and especially the negative relations therein established among stimuli from alternative classes, would be a critical antecedent condition to control partitioning performances throughout the symmetry and equivalence tests.

How are the negative relations between stimuli of alternative classes related to the formation of equivalence classes? One possibility is that most human participants in these experiments have been exposed to a history of learning in which they are trained to sort stimuli within categories that are mutually excluding, and that this learning involves the training of negative relations between stimuli belonging to different sets. In the training with the standard MTS procedure, the learning of negative relations between stimuli belonging to different classes along with the format of presentation of the test trials sets the occasion for the presentation of sorting behavior, so that a participant behaves in the equivalence test trials by

selecting the comparison stimulus that belongs to the same set that the sample stimulus does, in the context of the other stimuli that belong to the other sets. In contrast, none of the altered MTS procedures trains between-classes stimuli relations, and, in consequence, the probability that the experimental situation will set the occasion for the application of sorting behavior to the overall set of stimuli is lower.

Why did some participants trained with the altered procedures reach the criterion of the equivalence class formation, then? It is possible that these few participants had a history of learning in which sorting has been trained more frequently or is under the control of more subtle series and complex of stimuli, so that when they were exposed to the altered procedure the positive relations were sufficient to show the sorting behavior. The contrary could be the true for those participants trained with the standard procedure who exhibit low performances in equivalence tests. It is possible that their learning history of sorting behavior might have been more limited. A piece of evidence supporting this interpretation is the observation reported by Pilgrim and Galizio (1996) that most of college students trained with the standard procedure could sort the stimuli involved in the training even without having been exposed to the probe trials (see Fields, Arntzen, & Moksness, 2014; Hove, 2003; Lian & Arntzen, 2013, for similar results).

One methodological limitation in Experiments 2 and 3 was the use of novel stimuli on positive and negative control tests trials. The novel stimulus methodology has been used on some studies to evaluate positive and negative control on identity matching (Dixon & Dixon, 1978) and arbitrary matching (Carr et al., 2000, Study 2; Stromer & Osborne, 1982). However, there are concerns about its utility because a bias to select the novel comparison stimulus on these type of test trials is possible (Carrigan & Sidman, 1992; Johnson & Sidman, 1993; McIlvane et al., 1987; Stromer & Osborne, 1982). There are other procedures to assess positive or negative control. Johnson and Sidman (1993), for example, used the outcomes on reflexivity and transitivity tests as indicators that learned relations were either S+ or S− relations. However, this procedure was relevant only for their experiment, given that they assessed a teaching procedure to generate exclusively control by the “reject” relation, and hence it would not be applicable to the experiments reported here because it was expected that performances trained with standard and altered MTS procedures were controlled by both “select” and “reject” relations. Another alternative procedure is the use of a blank comparison rather than a novel stimulus. This procedure has been developed and used to assess the exclusion or emergent symbolic “mapping” performance (Costa, McIlvane, Wilkinson, & De Souza, 2001; McIlvane, Bass, O’Brien, Gerovac, & Stoddard, 1984; McIlvane et al., 1987; McIlvane, Kledaras, Lowry, & Stoddard, 1992; Wilkinson & McIlvane, 1997; Wilkinson, Rosenquist, & McIlvane, 2009),

but its use to assess positive or negative control on arbitrary conditional relations has been very limited. McIlvane and colleagues (1987, Experiment 1) used a blank comparison procedure to assess positive and negative control for arbitrary two-choice matching. Their study found control by either “select” and “reject” relations, but it is not clear if those results would be different with the novel stimuli procedure that we employed here. This is an empirical issue and subsequent research must clarify the validity of using novel comparison procedures on positive and negative control test trials for these sort of studies.

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Compliance with Ethical Standards

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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