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ORIGINAL ARTICLE

Exploratory Study of Equivalence under Conjoint Select and Reject Control

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Abstract

Carrigan and Sidman *Journal of the Experimental Analysis of Behavior*, *58*, 183-204, (1992) proposed that *select* and *reject* arbitrary conditional relations are equivalence relations, each resulting in the emergence of alternative stimulus equivalence classes. The standard matching to sample (MTS) procedure can potentially teach both select and reject conditional relations, which apparently would prevent the emergence of equivalence relations, although there is extensive evidence for the emergence of equivalence with the standard MTS procedure. One possibility is that participants trained with the standard MTS procedure predominantly learn one type of control over the other. Experiment 1 explores the implementation of a *Detached-MTS* procedure, which separately trains the select and reject conditional relations involved in the *Standard-MTS* procedure. The results suggest that the emergence of equivalence relations may be compatible with conjoint select and reject conditional control. In Experiment 2, the Detached-MTS procedure succeeds in replicating the emergence of equivalence under exclusive select control but not under exclusive reject control, which conditions the findings of Experiment 1. The sources of control associated with the emergence of equivalence in the standard MTS procedure and some methodological issues of the Detached-MTS procedure are discussed.

Keywords Stimulus equivalence relations · Conditional discrimination · Select control · Reject control · Matching to sample

From a behavior analytic framework, the emergence of spontaneous accurate responses to arbitrary conditional relations is relevant to the study of symbolic behavior. One of the most important is the emergence of stimulus equivalence relations, which is considered to be related to linguistic behavior and several human cognitive abilities (e.g., Sidman, 1994). Stimulus equivalence relations emerge from the training of a series of conditional discriminations and the subsequent observation of responses that satisfy the properties of a mathematical equivalence relation: reflexivity, symmetry, and transitivity (Sidman & Tailby, 1982). For example, participants trained in the arbitrary conditional discriminations A-B and A-C, would show reflexivity when they conditionally relate each stimulus to itself (A-A, B-B, and C-C). They show symmetry when they conditionally relate the reverse of the trained relations (B-A and C-A). Finally, they show transitivity when they conditionally relate stimuli that were not directly related in training but were related to another stimulus in common (B-C and C-B). When these untrained relations emerge, it is said that some equivalence classes have been formed among stimuli A, B, and C (Green & Saunders, 1998; Sidman, 1994).

The matching-to-sample (MTS) procedure has typically been used to train arbitrary baseline conditional discriminations and to test emergent conditional discriminations used to assess the properties of an equivalence relation. In this procedure, a participant learns to respond to one out of two or more, comparison stimuli conditionally to a sample stimulus. For example, to train conditional discriminations between stimuli A and B in a standard two-choice MTS procedure, stimuli A1 and A2 are presented successively as samples across trials, whereas stimuli B1 and B2 appear simultaneously as comparisons on each trial. Responses to B1, but not B2, under A1; and responses to B2, but not B1, under A2 receive reinforcement (Carter & Werner, 1978).

The two-choice MTS trials potentially train two types of conditional relations between stimuli. First, *select* relations, which are established between the sample and the comparison whose choice is reinforced or S+ (i.e., A1-B1 and A2-B2).

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Second, *reject* relations, which are established between the sample and the comparison whose choice is not reinforced or S- (i.e., A1-B2 and A2-B1). Both conditional relations could be seen as consisting of a controlling comparison stimulus and a characteristic topographic component. In the case of the select control, the controlling stimulus is the S+, and its topographic component consists of responding to the controlling stimulus, either by touching, grasping, or clicking on it. In the rejection control, the controlling stimulus is the S-, and its topographic component consists of responding to the other available comparison, regardless of what it is (Carrigan & Sidman, 1992; McIlvane, 2013; Sidman, 1987).

In the two-choice MTS procedure, correct responses can be controlled by either the S+, the S-, or both. Because the opportunities to learn select or reject conditional relations are equal in the two-choice MTS procedure, even when the response criterion is met, we cannot identify which source of control (i.e., select or reject) is responsible. This indeterminacy of the sources of control makes it difficult to make accurate predictions about the formation of stimulus equivalence classes from the observed MTS performance (Carrigan & Sidman, 1992; Sidman, 1987). Sidman (1987) recommends the use of three or more choice MTS procedures to ensure the acquisition of select relations rather than reject relations. With three or more comparison stimuli per trial, there are more reject relations to learn than select relations, and acquisition of the select relations becomes more likely than acquisition of the reject relations. Carrigan and Sidman (1992) also proposed that select and reject stimulus conditional relations have different consequences for the formation of stimulus equivalence classes. According to their analysis, select and reject conditional relations are stimulus equivalence relations, but each determines the emergence of alternative stimulus equivalence classes that are incompatible with the emergence of the other. To say that the select conditional relations are equivalence relations is to say that selecting is also a reflexive, symmetric, and transitive relation. Considering a two-choice MTS format and a linear training structure (A-B, B-C), a participant might learn the select conditional relations “if A1, select (respond to) B1,” and “if B1, select C1”. Thus, responses in reflexivity test trials would include the relations “if A1, select A1,” “if B1, select B1,” and “if C1, select C1;” in symmetry test trials the relations, “if B1, select A1,” and “if C1, select B1”; in transitivity test trials, the relations “if A1, select C1”; and the equivalence test trials, the relation “if C1, select A1.”

On the other hand, to claim that baseline conditional reject relations are equivalence relations would mean that rejecting is also a reflexive, symmetric, and transitive relation. Under the same conditions as in the previous example, a participant could learn the reject conditional relations “if A1, reject B2,” and “if B2, reject C1.” Thus, in the reflexivity test trials such a participant would respond “if A1, reject A1 (responding to A2),” “if B2, reject B2 (responding to B1),” and “if C1, reject C1 (responding to C2);” in the symmetric test trials “if B2, then reject A1 (responding to A2),” and “if C1, reject B2 (responding to B1)”; and in the transitive and equivalence test trials “if A1, reject C1 (responding to C2),” and “if C1, reject A1 (responding to A2).” As can be seen, the responses recorded on the reflexivity test under reject control are the opposite of those under select control: Under select control, participants respond with identity matching, whereas under reject control, they respond with oddity matching. Instead, in symmetry test trials, responses under select or reject control would be the same, making this test unable to distinguish between the two types of control. In transitivity and equivalence tests, responses under select and reject control would again be the opposite, as in reflexivity tests. The same pattern will be similar for transitivity and equivalence tests with an odd number of nodes, but in tests with an even number of nodes, the select and reject controls would coincide in the responses like in the symmetry test. Exclusive select control, in which each baseline response is uniquely controlled by the S+ stimulus, yields the stimulus equivalence classes A1B1C1 and A2B2C2. In contrast, the exclusive reject control, in which baseline responses are controlled solely by the S- stimulus, yields classes A1B2C1 and A2B1C2. In consequence, exclusive select and reject control would determine the formation of different equivalence classes. A study by Johnson and Sidman (1993), which used a procedure to bias the acquisition of some of the conditional relations, confirmed predictions for exclusive reject control with three participants, whereas a study by Perez et al. (2015), which used a within-subject design, confirmed predictions for both select and reject control.

Carrigan and Sidman (1992) also argued against the use of novel stimulus tests (e.g., Spradlin & Saunders, 1986) for identifying the baseline select and reject controls because they cannot simultaneously probe the two types of controls and may inadvertently allow the strengthening of other relations that replace the original ones (Carrigan & Sidman, 1992, p. 186). In contrast, they suggested the use of equivalence class formation tests as the best alternative, so that responses to reflexivity and odd-node transitivity test trials can help identify the type of baseline control. They also analyzed in detail several cases of mixed control, in which some baseline conditional relations would be under select control and others under reject control, predicting indeterminacy and unpredictability in the responses of some reflexivity and one-node transitivity test trials, making the responses to these tests inconsistent and hence the emergence of equivalence unlikely (Carrigan & Sidman, 1992, pp. 195–198).

The standard two-choice MTS procedure has an equal probability of training select and reject stimulus conditional relations. However, Carrigan and Sidman (1992) claim that the select and reject controls yield stimulus equivalence classes that are alternative and incompatible with each other. This suggests that a participant who learns to both select and reject conditional relations using the standard two-choice MTS procedure may not be able to demonstrate the emergence of stimulus equivalence relations (Boelens, 2002). And Carrigan and Sidman's analysis of mixed control cases supports this suggestion. Nevertheless, there is considerable evidence that the likelihood of equivalence emergence with the two-choice MTS procedure is high (e.g., Fields et al., 1990; Grisante et al., 2014; Pilgrim & Galizio, 1990, 1995; Saunders, Saunders et al., 1988a, Saunders, Wachter et al., 1988b, Saunders et al., 2005, 1999; Spradlin & Saunders, 1986). One way to reconcile Carrigan and Sidman's analysis with this evidence is to assume that participants in the two-choice MTS procedure almost exclusively acquire select rather than reject relations (Boelens, 2002). However, some studies show that participants often acquire both select and reject relations with the two-choice MTS procedure (e.g., McIlvane et al., 1987, Exp. 1; Stromer & Osborne, 1982; Tomonaga, 1993, Exp. 2, with a chimpanzee), suggesting that conjoint select and reject control is compatible with the emergence of equivalence relations. Carrigan and Sidman (1992) did not explicitly consider the emergence of equivalence relations in the context of conjoint select and reject control, but their analysis seems to rule out this possibility initially.

The purpose of this exploratory study is to determine whether the acquisition of both the select and reject conditional relations involved in the two-choice MTS procedure prevents the emergence of stimulus equivalence relations. For this purpose, a new procedure is proposed, called *Detached-MTS*, which is characterized by training independently the select and reject relations involved in the two-choice MTS procedure, based on the same methodology of Carrigan and Sidman (1992) to bias the type of control (see the procedure section of Experiment 1 for a detailed description). The failure of stimulus equivalence relations to emerge with the Detached-MTS procedure would be evidence that the select and reject conditional relations in conjunction are incompatible with the emergence of equivalence, and that participants who demonstrate equivalence with the two-choice MTS procedure have acquired only one of these types of conditional relations. In contrast, the emergence of equivalence in the Detached-MTS procedure would show that the select and reject relations in conjunction are not incompatible with equivalence relations and raises the question of whether the emergence of equivalence in the two-choice MTS procedure is a direct function of the conditional relations acquired in the baseline.

Experiment 1

This experiment involved two conditions in which participants were exposed to the training of the same baseline select and reject conditional relations for the emergence of two three-member stimulus classes. The select relations A1-B1, A1-C1, A2-B2, and A2-C2, and the reject relations A1-B2, A1-C2, A2-B1, and A2-C1, were trained in the two conditions with a one-to-many training structure (e.g., Ayres-Pereira & Arntzen, 2021; Hove, 2003; Saunders & Green, 1999). The first condition, called the *Standard-MTS* condition, trained the select and reject relations on standard MTS trials, in which both types of control are involved together in the same trials. In these types of trials, it is possible for a participant to learn to respond exclusively to select relations, exclusively to reject relations, or to both types of relations, or to a particular mixture of some select or reject relations. The second condition, called the *Detached-MTS* condition, used an MTS procedure in which the same select and reject relations are trained, but separately, as shown in Fig. 1. In order to bias the development of the select and reject control, a procedure similar to that proposed by Carrigan and Sidman (1992) was used. To bias the control relations, six stimuli X of a null class were used as S− in select control training trials and as S+ in reject control training trials. This procedure was implemented to force the learning of both the conditional select and reject relations, rather than learning only one type or a mixture of the two.

Method

Participants

Sixteen first-year students of different undergraduate programs (Psychology, Marketing, International Business, and Computer Science) from a private university in Bogotá, Colombia, participated in the study. A block randomization procedure was used to assign participants to the two conditions. Each condition consisted of eight participants. There were eight females and eight males, ranging in age from 17 to 28 years (M = 19.4, SD = 3.5). The upper section of Table 1 shows the demographic information of the participants. Prior to training, participants signed an informed consent form. At the end of the experimental session, they received monetary compensation of approximately USD $4.57 (in Colombian pesos) for completing all phases, or one third of the amount if they dropped out before completion.

Setting, Apparatus, and Stimuli

The experimental sessions were conducted in a psychology laboratory. Participants sat in front of a computer with a 14-in screen. The computers were placed in cubicles with dark Plexiglas walls, to avoid visual contact with other participants' responses. A program designed in *Visual Basic* controlled the presentation of stimuli and recorded participants' responses on each trial. Participants received

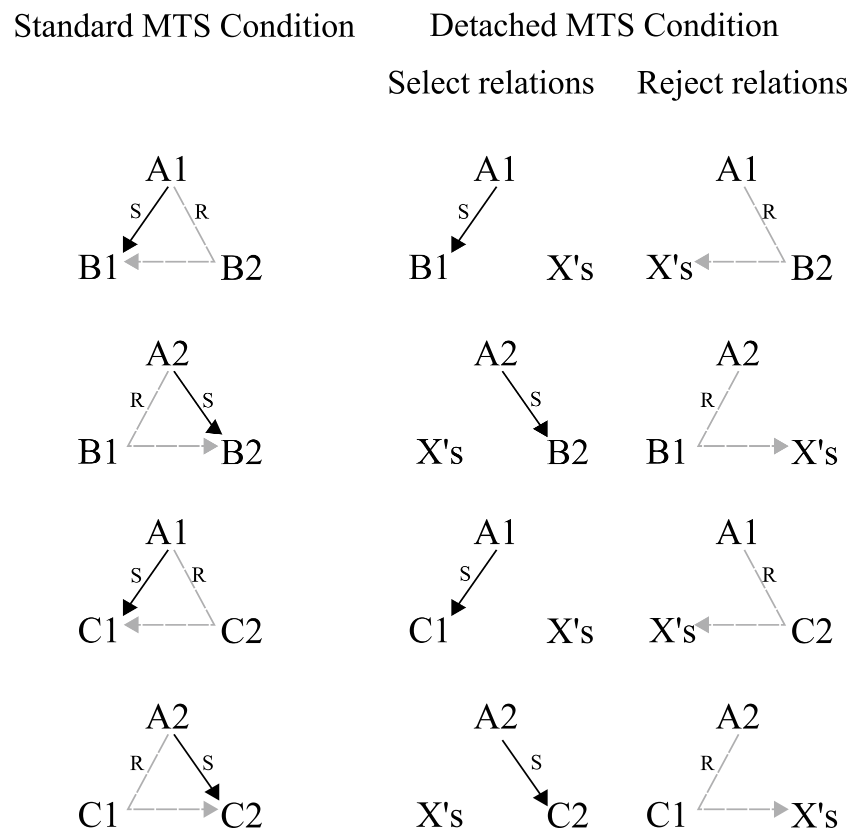

Fig. 1 Select and Reject Relations Trained in Experiment 1.*Note.* Unbroken black arrows are select relations, and dashed grey arrows are reject relation. Arrows point to the stimuli that would be selected. Arrows for reject relations are broken, because they first directed to the S− stimulus, and only then they are directed to the selected stimulus. S and R are for select and reject respectively

experimental instructions and feedback via headphones. Figure 2 shows the stimuli that were used. They consisted of abstract symbols without any conventional or similarity relation among them. All stimuli were figures drawn in a black outline over a white square of 3 x 3 cm. The stimuli appeared on a gray background on the screen. On each MTS trial, the sample stimulus appeared in the top center of the screen, 4.5 cm below the top edge of the screen. The comparison stimuli appeared in a horizontal row, 3 cm below the bottom edge of the sample, separated by 3 cm. All trials had a two-choice format, and the comparison stimuli appeared randomly on three possible squares, so that on each trial one of the squares was blank, and responding was ineffective.

Procedure

Participants first received instructions about the response feedback. A box displayed two buttons, one with the written word "CORRECT" and the other one with the word "INCORRECT" (both in Spanish). Participants were asked to click on the buttons. After clicking on the "correct" button, a "ta-da" sound was played, whereas a "chord" sound was played for the "incorrect" button. They then heard the following instructions (in Spanish):

> Hello, and welcome to this study. This study involves several phases. In each phase, you will make a series of exercises. In each exercise, a figure will be presented in the top section of the screen. You must click on it, and two figures will then appear in the bottom section of the screen. You must select one of the bottom figures. If you select the correct one, the computer will indicate this to you with the tone for correct responses. If you select the incorrect one, the computer will indicate this to you with the tone for incorrect responses. If you respond correctly to all exercises of a phase, you'll advance to the following one. If that is not the case, the phase will be repeated.

Each trial began with the presentation of the sample stimulus. Participants had to make an observing response to the sample stimulus by clicking on it, and then two comparison stimuli appeared below it while the sample disappeared (i.e., a 0-delay MTS). Participants had to click on one of the comparison stimuli, at which point the corresponding auditory feedback was played while the stimuli were removed, and a 1.5 s intertrial interval began. The order of the trials in each block, as well as the location of the comparison stimuli in each of the trials, was randomized.

Standard-MTS Condition Training Phases Participants in the Standard-MTS condition were exposed to eight training phases. The left panel of Table 2 shows the sequence of phases and their trial types for the Standard-MTS condition.

Table 1 Demographic Information of Participants

Participant	Age	Gender	Major
Experiment 1			
1	20	F	Computing Engineering
2	19	F	Marketing
3	28	F	Computing Engineering
4	17	M	Marketing
5	17	F	International Business
6	20	M	Computing Engineering
7	27	M	Computing Engineering
8	17	F	International Business
9	20	M	Computing Engineering
10	22	M	Computing Engineering
11	17	M	Computing Engineering
12	17	F	International Business
13	17	M	International Business
14	17	F	Psychology
15	17	F	Psychology
16	18	M	Psychology
Experiment 2			
17	20	F	Industrial Engineering
18	19	F	Industrial Engineering
19	17	M	Psychology
20	18	M	Industrial Engineering
21	17	M	Psychology
22	18	F	International Business
23	17	F	International Business
24	17	F	International Business
25	17	F	Marketing
26	18	F	Industrial Engineering
27	17	F	Psychology
28	17	F	Psychology
29	17	F	Marketing
30	17	M	International Business

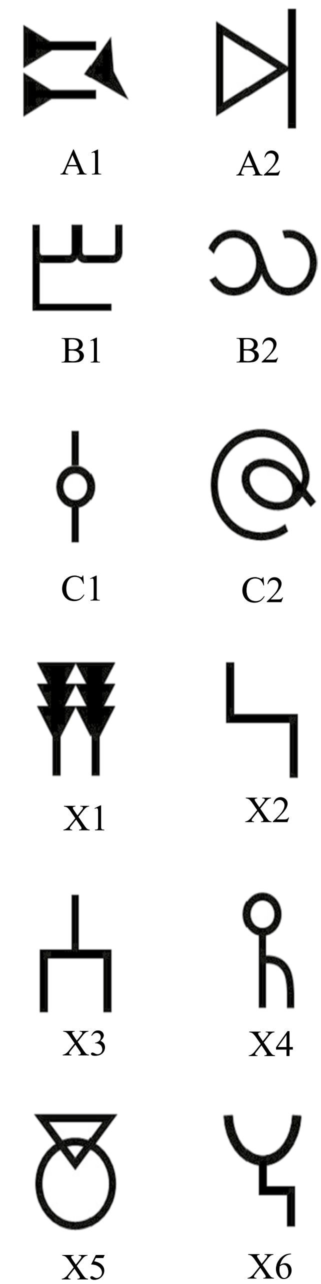

Fig. 2 Stimuli Used in the Study

Phase 1 consisted only of trial type A1-B1/B2 (corresponding to Sample-S+/S−, respectively), presented in blocks of 10 trials, with a mastery criterion of 100%. Phase 2 presented trial types A2-B2/B1 in blocks of 10 trials with a 100% mastery criterion. Phase 3 intermixed the trials from the previous phases in blocks of 12 trials (six for each type) and a mastery criterion of 11 correct responses. Phases 4 and 5 presented the A1-C1/C2 and A2-C2/C1 trial types, respectively, again with blocks of 10 trials and a mastery criterion of 100%. Phase 6 intermixed the trial types of the previous two phases, with blocks of 12 trials and with a mastery criterion of 11 correct responses. Phase 7 presented the four trial types intermixed in blocks of 24 trials with a criterion of 21 correct responses. Each response in phases 1 through 7 was followed by feedback. Phase 8 was a learning test in which the four baseline trial types were presented intermixed in a single block of 12 trials (three for each type) without feedback, with a mastery criterion of 100%. If participants met the criterion they proceeded to the test phases, but if they did not meet the criterion, they were returned to Phase 7. Baseline relations were trained in isolation rather than in a mixed block of trials, which is more common, in order to match the training schedule of the Detached-MTS condition.

Detached-MTS Condition Training Phases The Detached-MTS condition had 16 training phases. Each of the select and reject conditional relations was taught separately, using the procedure proposed by Carrigan and Sidman (1992), and

Table 2 Phases and Trial Types in Experiment 1

Standard-MTS				Detached-MTS			
Phase	Trial types	Trials per block	Mastery criterion (%)	Phase	Trial types	Trials per block	Mastery criterion (%)
1	A1-B1/B2	10	100	1	A1-B1/Xs	8	100
				2	A1-Xs/B2	8	100
				3	A1-B1/Xs, A1-Xs/B2	16	94
2	A2-B2/B1	10	100	4	A2-B2/Xs	8	100
				5	A2-Xs/B1	8	100
				6	A2-B2/Xs, A2-Xs/B1	16	94
3	A1-B1/B2, A2-B2/B1	12	92	7	A1-B1/Xs, A1-Xs/B2, A2-B2/Xs, A2-Xs/B1	16	94
4	A1-C1/C2	10	100	8	A1-C1/Xs	8	100
				9	A1-Xs/C2	8	100
				10	A1-C1/Xs, A1-Xs/C2	16	94
5	A2-C2/C1	10	100	11	A2-C2/Xs	8	100
				12	A2-Xs/C1	8	100
				13	A2-C2/Xs, A2-Xs/C1	16	94
6	A1-C1/C2, A2-C2/C1	12	92	14	A1-C1/Xs, A1-Xs/C2, A2-C2/Xs, A2-Xs/C1	16	94
7	A1-B1/B2, A2-B2/B1, A1-C1/C2, A2-C2/C1	24	88	15	A1-B1/Xs, A1-Xs/B2, A2-B2/Xs, A2-Xs/B1, A1-C1/Xs, A1-Xs/C2, A2-C2/Xs, A2-Xs/C1	32	94
8	Idem (Learning test)	12	100	16	Idem (Learning test)	20	100
9	Reflexivity: A1-A1/A2, A2-A2/A1, B1-B1/B2, B2-B2/B1, C1-C1/C2, C2/-C2/C1	12 BL 18 Test		17	Reflexivity: A1-A1/A2, A2-A2/A1, B1-B1/B2, B2-B2/B1, C1-C1/C2, C2/-C2/C1	20 BL 18 Test	
10	Symmetry: B1-A1/A2, B2-A2/A1 C1-A1/A2, C2-A2/A1	12 BL 16 Test		18	Symmetry: B1-A1/A2, B2-A2/A1 C1-A1/A2, C2-A2/A1	20 BL 16 Test	
11	Transitivity: B1-C1/C2, B2-C2/C1, C1-B1/B2, C2-B2/B1	12 BL 16 Test		19	Transitivity: B1-C1/C2, B2-C2/C1, C1-B1/B2, C2-B2/B1	20 BL 16 Test	

Note: Phases of the Standard-MTS and Detached-MTS conditions have been mapped according to the trained relations. The structure of trial types is: Sample-S+/S−. Xs is for the six X null class stimuli. BL is for baseline trials

used by Johnson and Sidman (1993) to bias learning toward a single type of control. This procedure is based on the principle that participants learn a task in a way that requires learning fewer discriminations. Each of the select control relations was trained in separate phases, in blocks of eight trials, with two standard trials as in the Standard MTS condition, and six trials with null-class X stimuli as S−. Likewise, each of the reject control relations was trained in phases with blocks of eight trials. Two of these were standard trials, whereas the remaining six contained X stimuli as S+. Standard trials were included to ensure the conditionality of the acquired relations (Carrigan & Sidman, 1992, p. 188). Six X stimuli were used in this training (see Fig. 2) and were distributed across trials so that they appeared randomly and the same number of times each. The right part of Table 2 shows the training phases of the Detached-MTS condition. Phase 1 trained the select relation A1-B1, in trials with A1 as the sample stimulus and B1 and an X stimulus as the comparisons. When a participant clicked on B1, the correct response tone sounded; and when the X stimulus was clicked, the incorrect response tone sounded. Phase 2 trained the reject relation A1-B2, in trials with A1 as the sample stimulus and B2 and an X stimulus as the comparisons. When a participant clicked on the X stimulus, the correct response tone sounded; and when B2 was clicked, the incorrect response tone sounded. Phases 1 and 2 had blocks of eight trials, with a mastery criterion of 100%. Phase 3 intermixed trial types of the two previous phases in blocks of 16 trials, with a criterion of 15 correct responses. Phases 4 and 5 trained the select relation A2-B2 and the reject relation A2-B1, respectively, with contingencies of reinforcement similar to the previous phases. Phase 6 intermixed the trial types of the previous two phases, in a single block of the same length and criterion as Phase 3. Phase 7 intermixed trials of the four previously trained conditional relations, in blocks of 16 trials (four standard and 12 null-class stimuli trials), with a criterion of 15 correct responses. Phases 8 through 10 trained the select relation A1-C1 and the reject relation A1-C2, whereas phases 11 through 13 trained the select relation A2-C2 and the reject relation A2-C1 in a similar way as in the training of the AB relations for the first six phases. Phase 14 intermixed the four conditional AC relations, in blocks of 16 trials and with a mastery criterion of 15 correct responses. Phase 15 intermixed the eight conditional AB and AC relations trained in all previous phases, in blocks of 32 trials (eight standard and 24 null-class stimuli trials), with a criterion of 30 correct responses. Participants' responses to all trials in Phases 1 through 15 received feedback. Phase 16 was a learning test, consisting of a single block of 20 trials (four standard and 16 null-class stimuli trials), without feedback, and with a mastery criterion of 100%. If participants met the criterion they advanced to the test phases, otherwise, they were returned to Phase 15.

Test Phases Participants in both conditions were exposed to three test phases: Phases 9 to 11 for the Standard-MTS condition and Phases 17 to 19 for the Detached-MTS condition. Participants were instructed that the following phases would present new exercises intermixed with previous ones and that they would not receive feedback on their responses. The bottom rows of Table 2 show the types of test trials used in both conditions. Each of these phases intermixed test trials among 12 baseline trials for the Standard-MTS condition or 20 baseline trials for the Detached-MTS condition. A simple to complex sequence of test presentation was used (Adams et al., 1993; Green & Saunders, 1998). The first phase of testing included 18 reflexivity test trials, testing six trial types (see Table 2) three times each. The reflexivity test is often omitted from equivalence studies because it is assumed to be present in the participants' repertory. However, it was included in this study to test some predictions about the difference between select and reject control. The second test phase consisted of 16 symmetry test trials, with each trial type presented four times. The third and final phase presented 16 transitivity trials, with each trial type was presented four times. Each of these phases was presented in a single block, without any mastery criterion, and no response was followed by feedback.

Results

Table 3 shows the number of blocks required by participants in the training phases, and the descriptive statistics of the phases by condition. Participants in the Standard-MTS condition required between one and five training blocks in Phase 1 to meet the mastery criterion, but required between one and two blocks in the remaining training phases. The sole exception was P1, who needed three blocks in Phase 2, and she did not meet the criterion in the first presentation of the Phase 8, being returned to Phase 7, needing three more blocks to progress to Phase 8 again. Participants in the Detached-MTS condition required between one and five blocks in Phase 1 and between one and four blocks in Phase 2. They required between one and three blocks throughout Phases 3 to 7, with the notable exception of P9 and P13, who required 40 and 10 blocks, respectively, in Phase 7. Throughout Phases 8 to 14, they ranged between one and two blocks, except for P15, who needed 4 blocks in the last of these phases. In Phase 15 they needed between one and three blocks, although P13 and P15 needed eight and nine blocks, respectively, to meet the criterion. In Phase 16, five participants successfully completed one block. However, P11, P12, and P13 did not meet the criterion and were returned to Phase 15. They required two, one, and six more blocks in Phase 7, respectively, before successfully completing Phase 16 in the second attempt. Finally, five participants passed the Phase 16 in a single block, whereas P11, P12, and P13 failed to meet the criterion in the first presentation, being returned to the previous phase, and meeting the criterion in the second presentation. Participants in the Standard-MTS condition completed the eight training phases in an average of 148.3 trials (range: 110–224), with an average total reaction time of 207.2 seconds (range: 132.9–334.9). In the Detached-MTS condition, participants required an average of 494.5 trials (range: 228–932), and an average total reaction time of 729.9 seconds (range: 328.4–1676.5).

In the test phases, participants in the Standard-MTS condition showed errorless performance on baseline trials, with the exception of P2 with 10 out of 12 correct responses in Phase 9, and P4 and P5 with 9 out of 12 and 11 out of 12 correct responses, respectively, in Phase 10. Participants in the Detached-MTS condition made between 17 and 20 correct responses in the baseline test trials of Phase 17. In Phases 18 and 19, participants made between 19 and 20 correct responses in these trials, with the exception of P13, who showed a deterioration from the baseline performance, with 14 and 12 correct responses in Phases 18 and 19, respectively.

Table 4 shows the number of correct responses during the test trials for both conditions. To evaluate the emergence of a new conditional response under select control, a criterion of 87.5% or higher correct responses was used, requiring 16 or more correct responses in the reflexivity test trials, and 14 or more in the symmetry and transitivity test trials. Likewise, responses in reflexivity and transitivity were considered to be under reject control if they had 12.5% or less (i.e., two or

Table 3 Training Blocks per Phase in Experiment 1

Conditions	Part	Phases															
		1			2			3	4			5			6	7	8
Standard-MTS	1	2			3			1	2			1			1	1(3)	2
	2	2			1			1	1			1			1	1	1
	3	3			1			1	1			1			1	2	1
	4	5			2			2	2			1			1	1	1
	5	2			1			1	1			1			1	1	1
	6	4			2			1	2			1			1	1	1
	7	3			2			1	1			1			2	1	1
	8	1			1			1	2			1			1	2	1
	M =	2.8			1.6			1.1	1.5			1.0			1.1	1.6	1.1
	SD =	1.3			0.7			0.4	0.5			0.0			0.4	1.1	0.4
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Detached-MTS	9	2	2	1	1	2	1	40	2	1	1	1	1	1	1	3	1
	10	1	2	1	2	1	1	1	1	2	1	1	1	1	1	2	1
	11	4	2	1	1	2	2	1	2	1	1	1	1	1	1	1(2)	2
	12	1	1	1	2	3	1	3	2	2	1	2	1	1	1	2(1)	2
	13	3	3	2	2	2	3	10	2	1	1	1	1	1	1	8(6)	2
	14	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	15	5	4	2	1	1	1	2	1	2	1	2	2	1	4	9	1
	16	2	1	1	1	2	1	2	1	2	1	1	1	1	2	1	1
	M =	2.5	2.1	1.3	1.4	1.8	1.4	7.5	1.5	1.5	1.0	1.3	1.1	1.0	1.5	4.5	1.4
	SD =	1.4	1.0	0.5	0.5	0.7	0.7	13.5	0.5	0.5	0.0	0.5	0.4	0.0	1.1	4.6	0.5

Note: Phases of the Standard-MTS and Detached-MTS conditions have been mapped according to the trained relations. Part is for participants. The column for the Phase 7 in the Standard-MTS condition and the Phase 15 in the Detached-MTS presents some data between parentheses indicating to the number of blocks required for participants who returned after failing to meet the criterion during the first presentation of Phase 8 or 16. Statistical data in this column were calculated by adding data in parentheses

fewer correct responses). Seven out of the eight participants in the Standard-MTS condition exhibited the emergence of reflexivity, symmetry, and transitivity relations, thus forming stimulus equivalence classes in accordance with select control. Half of the participants in the Detached-MTS condition (P10, P12, P15, and P16) demonstrated the emergence of all three relations that were tested, which were in line with select control. P14 exhibited reflexivity comparable to reject control; however, transitivity was consistent with select control, and symmetry responses were aligned with both types of control. P9 demonstrated reflexivity and transitivity under reject control while transposed the majority of the responses in the symmetry test.

P11 displayed an interesting pattern of changes in response criteria throughout the tests. At the beginning, he responded with identity matching in the first 13 reflexivity test trials, then switched oddity matching for the final five. He responded correctly for the first nine symmetry trials but inaccurately for the last seven. And in transitivity, he responded in accordance with reject control in the first seven trials, and in accordance to select control in eight of the last nine trials. For its part, P13 showed consistent identity matching in the reflexivity test trials, but showed inconsistent responses in the symmetry and transitivity test trials, while exhibiting baseline deterioration during phases 15 and 16.

Discussion

As often reported in the literature, almost all the participants trained in the Standard-MTS condition showed emergence of equivalence in correspondence with select control. If the select and reject control promotes the emergence of incompatible stimulus classes and participants in the Detached-MTS condition learned conjoint select and reject conditional relations, inconsistent responses should be observed in the reflexivity and transitivity test trials and the emergence of equivalence relations should be unlikely. However, half of the participants in the Detached-MTS condition met the criteria for the emergence of equivalence under select control, and most of the participants responded consistently on reflexivity and transitivity tests under either select or reject control. Only two participants in the Detached-MTS condition (P11 and P13) showed inconsistent responses across the tests, as would be expected if the select and reject conditional controls were inconsistent, but P11 showed shifts

Table 4 Number of Correct Responses in Test Trials for Conditions in Experiment 1

Condition	Participant	Reflexivity (*n*/18)	Symmetry (*n*/16)	Transitivity (*n*/16)
Standard MTS	1	**18**	**16**	**15**
	2	**18**	**16**	**16**
	3	**18**	**16**	**16**
	4	**18**	12	**16**
	5	**16**	**16**	**16**
	6	**16**	**16**	**16**
	7	**18**	**16**	**15**
	8	**18**	**16**	**16**
Detached Control	9	**1***	3	**0***
	10	**17**	**16**	**15**
	11	13	9	8
	12	**18**	**16**	**16**
	13	**18**	13	12
	14	**1***	**16**	**16**
	15	**18**	**16**	**16**
	16	**18**	**16**	**16**

Note: Denominators in the fractions below the header of the tests are the total number of trials in its respective test. Results that meet the criterion for select or reject control for a test are in bold. * = results that meet the criterion for reject control

in response criteria, and P13 showed a deterioration in baseline. If we can assume that participants trained with the Detached-MTS procedure learn the select and reject conditional relations involved in the Standard-MTS procedure, then the conjoint learning of the select and reject conditional relations involved in the standard- MTS procedure seems consistent with the emergence of equivalence relations, especially under select control. These results suggest that the emergence of equivalence in the two-choice standard-MTS procedure is often not a direct function of the select and reject stimulus conditional relations acquired in the baseline.

Two participants in the Detached-MTS condition presented changes in their response criteria to the tests according to select and reject control, one of them (P14) from one test to another and the other one (P11) within the tests. This suggests that participants in the Detached-MTS condition learned both types of control, but also that the type of control may be shifted from one trial to trial. And, considering that one participant presented responses by reject control, what determines the type of control that controls responses in tests for participants in the Detached-MTS procedure? This question does not seem to be answerable uniquely by appealing to the select and reject conditional relations acquired in the baseline. If the baseline conditional relations of the Standard-MTS procedure are also under select and reject control, similar considerations would apply to the emergence of equivalence in that procedure.

However, to reach more compelling conclusions based on the Detached-MTS procedure, it would be desirable for this procedure to be able to replicate the expected results in stimulus equivalence formation under the exclusive select and reject control and obtained by Johnson and Sidman (1993) and Perez et al. (2015). Experiment 2 was designed to address this issue.

Experiment 2

This experiment compares *Exclusive-Select* and *Exclusive-Reject* control conditions in the emergence of equivalence, employing the Detached-MTS procedure of Experiment 1. For each of these conditions, participants were exposed to half of the conditional relations trained with the Detached-MTS procedure. In the Exclusive-Select condition, participants were trained only on select control relations, whereas in the Exclusive-Reject condition, participants were trained only on reject control relations involved in the Detached-MTS procedure (see Fig. 1). These conditions partially replicate the studies of Johnson and Sidman (1993) and Perez et al. (2015), except that in these studies, in addition to the procedure to bias the control toward the S+ or S- stimulus, a procedure to bias the attention toward the S+ or S- stimulus was also used in the training trials, increasing the number or duration of exposition to one stimulus over the other. According to the analysis of Carrigan and Sidman (1992), it would be expected that participants in the Exclusive-Reject condition reverse responses on reflexivity and transitivity trials compared to participants in the Exclusive-Select condition, but not on symmetry trials. Namely, in a reflexivity test trial with A1 as the sample and A1 and A2 as the comparison stimuli, participants in the Exclusive-Select condition should select A1 and respond to it; whereas participants in the Exclusive-Reject condition should reject A1, responding to A2. In a transitivity test trial with B1 as the sample and C1 and C2 as the comparison stimuli, participants in the Exclusive-Select condition should select and respond to C1, whereas participants in the Exclusive-Reject condition should reject C1 and respond to C2. However, in a symmetry test trial with B1 as the sample and A1 and A2 as the comparisons, a participant trained in the Exclusive-Select condition would select A1 and respond to it, and a participant trained in the Exclusive-Reject condition would reject A2 and also respond to A1. As a consequence, each condition should show the emergence of different stimulus equivalence classes.

Method

Participants

The experimenter implemented a block randomization procedure to assign 14 freshmen students to the two conditions, each with seven participants. Ten of them were females and four males, and their ages ranged from 17 to 20 years (*M* = 17.6, *SD* = 0.94). The bottom section of Table 1 presents the demographic information of the participants. Majors, informed consent, and payment conditions were the same as in Experiment 1.

Setting, Apparatus, and Stimuli

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

Procedure

The instructions and trial presentations were the same as in Experiment 1. The experiment consisted of 11 phases for both conditions. All participants were trained in a one-to-many matching-to-sample training structure, in four conditional relations, and tested for the emergence of two 3-member stimulus classes.

Table 5 shows the phases and trial types for each condition. Phase 1 trained the first AB relations for each condition in blocks of 12 trials. Phase 2 trained the second AB relation for each condition in blocks of 12 trials. These phases had a mastery criterion of 100%. Each block consisted of three standard trials and nine trials with stimuli X from the null class. X stimuli appeared as S− in trials training select relations, and as S+ in trials training reject relations. Stimuli X were assigned to the trials as in Experiment 1. In the Exclusive-Select condition, in a trial with A1 as the sample stimulus, clicking on B1 produced the correct response tone, and clicking on an X stimulus produced the incorrect response tone. In a trial with A2 as the sample stimulus, clicking on B2 produced the correct response tone, and clicking on an X stimulus produced the incorrect response tone. In the Exclusive-Reject condition, in a trial with A1 as the sample stimulus, to click on an X stimulus was followed by the correct response tone, and to click on B2 was followed by the incorrect response tone. In a trial with A2 as the sample stimulus, to click on an X stimulus was followed by the correct response tone, and to click on B1 was followed by the incorrect response tone (see Table 5). Phase 3 intermixed the trials from the first two phases in blocks of 16 trials, with four standard trials and 12 trials with stimuli X, and a mastery criterion of 15 correct responses. Phases 4 and 5 trained the AC relations indicated in Table 5, with similar differential contingencies, in blocks of 12 trials and a mastery criterion of 100%. Phase 6 intermixed the trials from the previous two phases, with blocks of 16 trials and a criterion of 15 correct responses. Phase 7 intermixed trials from all previous phases, in blocks of 32 trials and with a criterion of 30 correct responses. Phase 8 was a learning test that assessed the four learned conditional relations in a single block of 16 trials and with a criterion of 100%. Participants

Table 5 Phases and Trial Types in Experiment 2

Phase	Trial types		Trials per block	Mastery criterion (%)
	Exclusive-Select	Exclusive-Reject		
1	A1-B1/Xs	A1-Xs/B2	12	100
2	A2-B2/Xs	A2-Xs/B1	12	100
3	A1-B1/Xs, A2-B2/Xs	A1-Xs/B2, A2-Xs/B1	16	94
4	A1-C1/Xs	A1-Xs/C2	12	100
5	A2-C2/Xs	A2-Xs/C1	12	100
6	A1-C1/Xs, A2-C2/Xs	A1-Xs/C2, A2-Xs/C1	16	94
7	A1-B1/Xs, A2-B2/Xs, A1-C1/Xs, A2-C2/Xs	A1-Xs/B2, A2-Xs/B1, A1-Xs/C2, A2-Xs/C1	32	94
8	Idem (Learning test)	Idem (Learning test)	16	100
9	Reflexivity: A1-A1/A2, A2-A2/A1, B1-B1/B2, B2-B2/B1, C1-C1/C2, C2/-C2/C1	Reflexivity: A1-A1/A2, A2-A2/A1, B1-B1/B2, B2-B2/B1, C1-C1/C2, C2/-C2/C1	16 BL 18 Test	
10	Symmetry: B1-A1/A2, B2-A2/A1 C1-A1/A2, C2-A2/A1	Symmetry: B1-A1/A2, B2-A2/A1 C1-A1/A2, C2-A2/A1	16 BL 16 Test	
11	Transitivity: B1-C1/C2, B2-C2/C1, C1-B1/B2, C2-B2/B1	Transitivity: B1-C1/C2, B2-C2/C1, C1-B1/B2, C2-B2/B1	16 BL 16 Test	

Note: The structure of trial types is Sample-S+/S−. Xs is for the six X null class stimuli. BL is for baseline trials who met the criterion advanced to the test phases, otherwise they returned to Phase 7.

Phases 9 through 11 were test phases, assessing the emergence of reflexivity, symmetry, and transitivity respectively, with the test trials being the same as those in Experiment 1. Each phase had 16 baseline trials intermixed with the test trials. Phase 9 contained 18 reflexivity trials, whereas Phases 10 and 11 had 16 symmetry and transitivity test trials respectively. These phases were presented in a single block, without a mastery criterion, and no response was followed by feedback.

Results

Table 6 shows the number of blocks required to meet the criterion for each phase by participants in both conditions in the training phases. Throughout these phases, participants needed between one and three blocks to meet the criterion in all phases, with a few exceptions. In the Exclusive-Select condition, P19 required six, four, and nine blocks in phases 3, 6, and 7, respectively. He did not meet the criterion for Phase 8 on the first presentation and was returned to Phase 7, but dropped out after nine trials. In the Exclusive-Reject condition, P24 required four blocks in Phase 1, P28 needed five blocks in Phase 2. P 25 required four blocks in Phase 7, but did not pass Phase 8 on the first attempt; so she returned to Phase 7 and needed seven more blocks, and then passed Phase 8 on the second attempt. Participants in the Exclusive-Select condition completed the eight training phases in 229 trials on average (range: 140–545), with a mean total reaction time of 239.3 s (range: 157.8–487.4). In the Exclusive Reject condition, participants required an average of 245.1 trials (range: 152–524), and a mean total reaction time of 361.8 s (range: 243.3–767.1).

Maintenance of the baseline relations across Phases 9 to 11 was high for most participants in most phases, with a few exceptions. In the Exclusive-Reject condition, P28 presented a deterioration of the baseline performance across Phases 9 to 11, as did P24 and P25 in Phase 9.

Table 7 shows the number of correct responses for each of the test trial types for each participant. In the Exclusive-Select condition, half of the participants met the criteria for the formation of equivalence classes according to select control. The other half showed the emergence of symmetry and transitivity according to select control but did not show the emergence of reflexivity. P20 showed systematic oddity matching in all reflexivity trials, P23 in most of the trials with B and C stimuli, and P17 in the B2-B2 trial.

For the Exclusive-Reject Condition, only P27 clearly showed the emergence of reject equivalence relations, exhibiting the same learning pattern as most participants trained on exclusive reject relations in the studies by Johnson and Sidman (1993), and Perez et al. (2015). P26 responded under reject control on the reflexivity test and on half of

Table 6 Training Blocks per Phase in Experiment 2

Conditions	Part	Phases 1	2	3	4	5	6	7	8
Exclusive-Select	17	3	2	1	2	2	1	1	1
	18	1	1	1	2	1	1	1	1
	19	2	1	6	2	1	4	9(1)	1
	20	1	2	1	2	1	1	2	1
	21	2	2	1	1	1	1	1	1
	22	2	2	1	1	1	2	3	1
	23	2	2	1	2	1	1	1	1
	M =	1.86	1.71	1.71	1.71	1.14	1.57	2.71	1
	SD =	0.69	0.49	1.89	0.48	0.38	1.13	3.3	0
Exclusive-Reject	24	4	1	1	2	2	2	2	1
	25	1	1	3	2	1	2	4(7)	2
	26	2	2	1	2	2	1	1	1
	27	2	1	1	2	1	1	1	1
	28	3	5	2	2	2	1	1	1
	29	2	2	1	3	3	3	1	1
	30	1	2	2	1	1	1	1	1
	M =	2.14	2	1.57	2	1.71	1.57	2.57	1.14
	SD =	1.07	1.41	0.79	0.58	0.76	0.79	3.73	0.38

Note: Part is for participants. The column for the Phase 7 presents some data between parentheses indicating the number of blocks required for participants who returned after failing to meet the criterion during the first presentation of Phase 8. Statistical data in Phase 7 were calculated by adding data in parentheses

Table 7 Number of Correct Responses in Test Trials for Participants in Experiment 2

		Reflexivity							Symmetry					Transitivity				
		A1-A1	A2-A2	B1-B1	B2-B2	C1-C1	C2-C2	Total	B1-A1	B2-A2	C1-A1	C2-A2	Total	B1-C1	B2-C2	C1-B1	C2-B2	Total
Conditions	Part	*n*/3	*n*/3	*n*/3	*n*/3	*n*/3	*n*/3	*n*/18	*n*/4	*n*/4	*n*/4	*n*/4	*n*/16	*n*/4	*n*/4	*n*/4	*n*/4	*n*/16
Exclusive-Select	17	3	2	2	0	1	2	10	4	4	4	4	**16**	4	4	4	4	**16**
	18	3	3	3	3	3	3	**18**	4	4	4	4	**16**	4	4	4	4	**16**
	20	0	0	0	0	0	0	**0**	4	4	4	4	**16**	4	3	4	3	**14**
	21	3	3	3	3	3	3	**18**	4	4	4	4	**16**	4	4	4	4	**16**
	22	3	3	3	3	3	3	**18**	4	4	3	3	**14**	4	4	4	4	**16**
	23	3	3	1	0	0	1	8	4	4	3	4	**15**	4	4	4	4	**16**
Exclusive-Reject	24	0	1	2	2	2	1	8	0	2	2	3	7	2	0	1	3	6
	25	1	1	0	1	1	2	6	3	2	4	4	13	4	4	4	4	**16**
	26	0	0	0	0	1	1	**2**	4	4	2	2	12	1	0	2	2	5
	27	0	0	0	0	0	0	**0**	3	4	4	4	**15**	0	0	0	0	**0**
	28	0	0	0	0	0	0	**0**	2	0	0	3	5	2	1	1	3	7
	29	1	2	3	0	2	0	8	0	0	0	0	**0**	4	4	3	4	**15**
	30	3	3	3	3	3	3	**18**	4	4	4	4	**16**	4	4	3	4	**15**

Note: Part. stands for the participant number. Fractions below the header of the test trial types have in the denominator the total number of trials of each respective trial type. The total number of correct responses in a test that meet the criterion for either select or reject control is in bold the transitivity trial types. P28 responded in accordance with reject control on the reflexivity trials but not on the symmetry and transitivity trials; however, she showed a deterioration of the baseline performance in the last two tests. P30 consistently responded with the emergence of select equivalence relations. On the reflexivity test, three participants showed a consistent pattern of oddity matching (P26, P27, and P28) on all trials, and P25 on most of trials. P30 responded with identity matching, and P24 and P29 showed inconsistent responses. Two of the participants (P27 and P30) showed the emergence of symmetry. P29 showed systematic antisymmetry performance on all symmetry test trials, as did P28 on two specific trial types. On transitivity trials, three participants (P25, P29, and P30) showed the emergence of transitivity consistent with what was expected for the select control, and only P27 did so consistent with the reject control. The other three participants were inconsistent on these trials.

Discussion

Results from the Detached-MTS procedure employed in Experiment 1 are consistent with the expected results for the Exclusive-Select condition, but not for the Exclusive-Reject condition. This fact is relevant for interpreting of the results of Experiment 1 because if the Detached-MTS procedure did not provide sufficient control for the emergence of equivalence relations according to reject relations, then the fact that half of the participants in the Detached-MTS condition showed equivalence according to select control would not be an unexpected result. Thus, Experiment 1 results may be consistent with Carrigan and Sidman (1992) in suggesting that equivalence emerges only when learned conditional relations are under some type of control.

The employment of multiple null-class stimuli as S+ in the training trials to bias the reject control was only effective for the emergence of equivalence under reject control in one participant. Carrigan and Sidman (1992) proposed the employment of trials with null-class stimuli to bias the control toward selecting or rejecting during training. The studies by Johnson and Sidman (1993) and Perez et al. (2015) also employed a procedure to bias the attention toward some stimuli. In addition to using multiple null-class stimuli, Johnson and Sidman (1993) employed a delay-cue procedure based on Touchette's (1971) errorless learning procedure to teach new conditional discriminations. In the reject-control training trials, the S+ stimulus was initially presented for 0.1 s., and as the participants met some response criteria, exposure to the S+ gradually increased to 20 s. In the Perez et al. (2015) study, visualization of the S+ stimulus was restricted to half of the trials. This suggests that to obtain consistent responses in reflexivity, symmetry, and transitivity tests as those that characterize equivalence under reject control, according to Carrigan and Sidman (1992), it is necessary to implement an additional procedure to bias attention, in addition to employing null-class stimuli to bias the control.

General Discussion

The two-choice standard MTS procedure teaches conditional relations between stimuli that may be controlled by either the S+ or S- stimulus, or both. Carrigan and Sidman (1992) proposed that select and reject conditional relations are also equivalence relations, but each promotes the emergence of alternative stimulus equivalence classes. As a result, stimulus equivalence relations should be unlikely to emerge from the acquisition of both select and reject conditional relations. However, equivalence frequently emerges from the two-choice standard MTS procedure. In order to accommodate this finding, Carrigan and Sidman's (1992) analysis should suppose that participants acquire only the select conditional relations but not the reject ones. The Detached-MTS procedure in Experiment 1 aimed to evaluate the hypothesis that the acquisition of both select and reject conditional relations does not result in the emergence of equivalence. However, the results of Experiment 1 show that equivalence occurs more likely than expected in the Detached-MTS procedure, albeit still less frequently than with the Standard-MTS procedure. This suggests that the emergence equivalence relations may be compatible with conjoint select and reject conditional control. Now, several studies show that the Standard-MTS procedure also promotes the acquisition of both select and reject conditional relations (e.g., McIlvane et al., 1987, Exp. 1; Stromer & Osborne, 1982; Tomonaga, 1993, Exp. 2). Thus, the emergence of equivalence relations in the Standard-MTS procedure could occur under the conjoint action of select and reject control. This is remarkable because most of what we know about equivalence relations has comes from studies that used the Standard-MTS procedure.

A fundamental question is how equivalence may emerge under conjoint select and reject control. Carrigan and Sidman's (1992) analysis shows that a mixed select and reject control should lead to indeterminacy in reflexivity and odd-node transitivity tests, which may lead to inconsistent responses on these tests. However, they acknowledge that consistent responses to these tests should come from sources of control other than baseline conditional relations. But, what might these sources of control be? One possibility is that consistent responding on test is a consequence of generalized conditional responding (Saunders et al., 1988; Williams et al., 1995). Generalized conditional responding appears to be a basic mechanism that has been observed in participants with intellectual disabilities. However, generalized conditional responding does not appear to be sufficient to account for consistent responses across all tests and to meet the criteria for equivalence class formation. Furthermore, if equivalence often emerges in the Standard-MTS procedure under conjoint select and reject control, it does not appear that generalized conditional responding can account for the robust establishment of equivalence relations that is typically observed with this procedure.

Another possibility is that some participants of the Detached-MTS procedure showed emergence of equivalence according to select control because they mostly acquired select conditional control rather than reject control. This is suggested by the results of Experiment 2, which show that the Detached-MTS procedure has succeeds in replicating the expected results for the emergence of equivalence under select control but not under reject control. Although some studies have obtained equivalence under reject control as predicted by Carrigan and Sidman (1992; Johnson & Sidman, 1993; Perez et al., 2015), they required additional procedures to bias the attention. It is unclear why a procedure to bias the attention is needed to obtain equivalence under reject control, but not equivalence under select control. This is related to the issue that in the two-choice Standard-MTS procedure the emergence of equivalence is mostly in accordance with select control and not reject control, despite the likelihood of acquiring select and reject conditional relations is practically the same. Presumably, preexperimental learning history plays a role in favoring select relations. Carrigan and Sidman (1992) acknowledge that this may be the case in the identity matching in the reflexivity tests (p. 189). The participants in this study are college students, who have a lifelong training in problem solving that may require them to attend to the S+ in a variety of tasks. However, if this were the case in general, then the emergence of equivalence in the Standard-MTS procedure would not be a consequence uniquely of the stimulus conditional relations acquired in the training. Participants of the Detached-MTS procedure in Experiment 1 who changed their response criteria from one test to another or from one trial to another seem to provide additional evidence that factors other than the baseline acquired conditional relations determine the type of control that operated in the tests.

Although most participants of the Standard-MTS condition and half of the Detached-MTS condition demonstrated the emergence of equivalence under select control, this does not preclude the possibility of them to also acquiring reject conditional relations. The yet-cited studies that show the learning of reject relations with the Standard-MTS procedure and the maintenance of reject baseline relations in the Detached-MTS condition suggest this. A crucial problem is how to determine the conditional control of baseline relations that determine responses to tests. This study adheres to the rules of Carrigan and Sidman (1992) that the selecting and rejecting conditional relations are also equivalence relations, and that results in probes of equivalence can assess the type of conditional control acquired in the baseline. The latter point, however, is controversial. An anonymous reviewer of an earlier version of this article pointed out that a limitation of this study was the lack of independent tests of select and reject conditional relations because they did not believe that probes for equivalence were appropriate tests of conditional control. The results of half of the participants of the Exclusive-Select condition in the reflexivity tests do not conform to what was expected in accordance with Carrigan and Sidman's (1992) analysis. This raises doubts about the suitability of such tests for establishing the baseline conditional control. Carrigan and Sidman (1992) dismissed the employment of tests with novel stimuli that replace the S+ or S- stimulus, arguing that such tests might inadvertently promote the acquisition of control by the alternative comparison to that which originally controlled the response. An alternative may be to use of the blank comparison procedure, in which one of the comparison stimuli, the S+ or S-, is replaced by a blank stimulus in the test trials, and consistent responses to the black comparison in the presence of the S- would indicate a reject control (e.g., McIlvane, 2013; McIlvane et al., 1987; Plazas, 2021).

Carrigan and Sidman (1992) attributed the failure of the two-choice MTS procedure to produce equivalence to the reject control. They recommended training with multiple-choice MTS procedures to ensure the acquisition of select control and the emergence of equivalence under select control, on the principle that meeting the criteria of a multiple-choice MTS requires learning fewer select than reject relations. However, there appears to be no evidence that the likelihood of the emergence of equivalence relations is lower with the two-choice MTS procedure than with the multiple-choice MTS procedure, whereas there is evidence that this likelihood is not different (Saunders et al., 2005). In addition, there is evidence that in the three-choice MTS procedure, reject-control is also acquired (Plazas, 2019; Plazas & Villamil, 2016). Therefore, the recommendation in favor of a multiple-choice matching procedure does not seem to be sufficiently justified (see Boelens, 2002, for other considerations against this recommendation).

On the other hand, the high tendency of the emergence of equivalence for select control with the standard-MTS procedure does not imply that the same behavioral mechanisms are involved in the emergence of equivalence in the Exclusive-Select condition, despite the similarity of responses on the tests. Several studies have shown that the formation of select equivalence classes in the standard-MTS procedure can occur despite the acquisition of reject control (Arantes & De Rose, 2015; Carr et al., 2000; De Rose et al., 2013; Grisante et al., 2014; Harrison & Green, 1990; Kato et al., 2008; Plazas & Peña, 2016; Plazas & Villamil, 2016). Indeed, some evidence suggests that reject control may promote the acquisition of equivalence under select control (Plazas, 2019). These findings suggest that in the context of the standard-MTS procedure, select and reject control do not appear to be conflicting sources of control for the emergence of equivalence (Boelens, 2002; Saunders et al., 2005). Furthermore, it has been noted that in the standard-MTS procedure select conditional relations are associated with the training of intraclass relations, and reject conditional relations are associated with the training of between-class relations (Plazas & Villamil, 2016). The above suggests the presence of some behavioral mechanisms yet not identified that allow overcoming the initial conflict between select and reject control in the standard-MTS. This is contrary to the assumption that the emergence of equivalence in the standard-MTS procedure is a direct function of the stimulus conditional relations acquired in baseline, as Sidman claimed (Sidman, 1986, 1990, 1994, 2000). This observation supports the notion that participants learning history may contribute to the development of equivalence in the standard-MTS procedure, as posited by various theories including naming theory (Horne & Lowe 1996; Randell & Remington, 1999), the relational frame theory (Barnes-Holmes et al., 2004; Hayes et al., 2001), and the consideration of sorting behavior (Plazas & Peña, 2016). Further research is needed to clarify the behavioral mechanisms underlying equivalence in the standard-MTS procedure.

Limitations

In addition to the lack of an independent assessment of the conditional baseline control regarding the probes of equivalence, other limitations of this study should be mentioned. The first is the order in which the tests were presented. The simple-to-complex format employed may promote correct responses in the transitivity tests. It is possible that the likelihood of stimulus equivalence class formation with the Detached-MTS procedure would be different if the order of presentation of the tests were different; for example, if the transitivity test were presented first.

Second, the Detached-MTS procedure trains first select relations and then reject relations associated with each conditional discrimination, and this may influence the likelihood of presenting the emergence of equivalence under select control. For future studies using the Detached-MTS procedure, it would be recommended to balance the order of presentation of the selecting and rejecting relations.

Third, an anonymous reviewer noted some formal similarities between stimuli B1 and C2 and between A1 and X1. In the first case, similarity might have promoted correct responses in B2-C2 and C2-B2 transitivity test trials. In the second case, similarity might have induced incorrect responses in baseline trials under select control and correct ones in those under reject control. One possibility might be to implement the procedure of Dougher et al. (1994), where a pool of stimuli is used and the stimuli comprising each class are randomly varied across subjects. A simpler procedure would be to change the composition of the classes for different participants, so that, for instance, C1 and C2 will change roles for half of the participants.

Finally, the number of occurrences of each stimulus X was not equal in the phases that trained a unique relation in Experiment 2, because these phases had blocks of 12 trials. Participants who repeated one of these phases many times had more exposition to some X stimuli than others. It is difficult to predict how this might affect learning, but it would have been desirable for the number of occurrences of each X stimulus to be the same for each block.

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Data availability The datasets analyzed during the current study are available in the figshare repository (Plazas, 2020), https://doi.org/10.6084/m9.figshare.12490253.

Declarations

Conflict of interest Elberto A. Plazas states no conflict of interest exists.

Ethical approval All procedures performed in studies involving human participants were following the ethical standards of the institutional research committee and with the 1964 Helsinki declarations, and its later amendments or comparable ethical standards.

Informed content Informed consent was obtained from all individual participants included in this study.

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