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The Formation of Equivalence Classes in Adults without Training in Negative Relations between Members of Different Classes

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Abstract

Research on the formation and properties of equivalence classes has been relevant in the Experimental Analysis of Behaviour for more than thirty years. However, the nature of this phenomenon is still debated. A great amount of investigations analyse the necessary conditions for its appearance and also its development in other species. The most widespread training procedure is "Match-to-Sample", a type of conditional discrimination task. These tasks require the participant to differentiate between reinforced stimulus relations (type S) and non-reinforced stimulus relations (type R). The approach to the study of these relations has been arguably flawed. The present work aims to develop a procedure that allows for their individual analysis, but still preserves the four term contingency of the operant conditional discrimination. Results suggests that type R relations need not be trained for the formation of equivalence classes as long as the conditionality is kept in the training.
Key words: matching-to-sample, negative relations, equivalence classes, conditional control, symmetry.

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Novelty and Significance

What is already known about the topic?

- The establishment of negative relations in the formation of equivalence classes has not been studied in depth.
- In addition, these studies present procedural limitations that do not guarantee that the task can be considered a conditional discrimination.

What this paper adds?

- Provides a procedure that preserves the contingency of four terms of the operant conditional discrimination without negative relations training.
- It provides data that support that negative relationships do not need to be trained for the formation of equivalence classes.

Equivalence classes have become one of the most productive fields of research of the last thirty years in the experimental analysis of behaviour. The main characteristic of this phenomenon is that stimulus control relations happen without explicit training (García & Benjumea, 2002). These new relations stem from the four elemental properties of the mathematical logic of set theory: Reflexivity, symmetry, transitivity and symmetric transitivity (Sidman, 1971; Sidman & Tailby, 1982).

The reflexivity relation is that in which each element is related to itself (A=A, B=B, C=C). The symmetry relation allows us to swap sample and comparison stimuli (if A=B, then B=A). The transitivity relation allows us to combine two conditional

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discriminations through a common element (if A=B and B=C, then A=C). Lastly, the symmetric transitivity relation is a combination of transitivity and symmetry relations (if A=B and B=C, then A=C; if A=C, then C=A). Out of these four, the main relation seems to be symmetry, with the other three stemming from it (Sidman, 1990). When diverse stimuli establish these four relations among each other, it is considered that they form an equivalence class.

The most widespread procedure to analyse the equivalence phenomenon is the conditional discrimination (Dube, Green, & Serna, 1993; Pérez & García, 2008), specifically the "Match-to-Sample" task (MTS, onwards) (García, 2002). This procedure develops as follows: first the participant is presented with a conditional stimulus (sample), and then several discriminative stimuli (comparisons) are shown, either simultaneously or successively. Depending on the sample, the choice of a particular comparison (Discriminative stimulus or S^+) is positively reinforced, while the choice of any of the other comparisons (Delta Stimuli or S^-) is punished or extinct.

For example, in order to train the A1-B1 relation, the participant is first exposed to the A1 stimulus (sample). Then the B1 and B2 stimuli (comparisons) are shown. The participant must choose between the two samples. The choice of B2 will be punished, while the choice of B1 will be reinforced (Carter & Werner, 1978; Cumming & Berryman, 1961; Pérez González, 1998).

Throughout the MTS task, participants are simultaneously exposed to several discriminative stimuli (comparisons). Some authors (Berryman, Cumming, Cohen, & Johnson, 1965; Carrigan & Sidman, 1992; Dixon & Dixon, 1978; Johnson & Sidman, 1993; Stromer & Osborne, 1982) argue that, in this kind of procedure, the participants' behaviour is controlled by two kinds of relations: 1) Positive relations, that control the "select" response sample-S^+ (Type S) and 2) Negative relations, that control the "reject" response sample-S^- (Type R).

In order to test this hypothesis, a modified MTS task can be used that replaces the comparison stimuli, both the discriminative stimulus (correct comparison) and the delta stimulus/i (incorrect comparison). A new stimulus, (with no previously trained function and thus not belonging to the trained equivalence classes) is used instead. For example, after the reinforcement of the choice of B1 (and not of B2) in the presence of A1, type S control could be tested by exposing the participant to type A1-B1/X trials. In this fashion, if the participant chose B1 in the presence of A1, the control of the positive relations over the participant's behaviour (for those specific stimuli) would be confirmed. Also, type R control could be tested with A1-X/B2 type trials: if the participant chose X in the presence of A1, the control of the negative relations over the participant's behaviour (for those specific stimuli) would be confirmed.

In investigations carried out with humans where this altered procedure was used, it was confirmed that the behaviour of the participants was under select and reject control. This is true with tasks where the response criterion was arbitrary (McIlvane, Withstandley, & Stoddard, 1984; McIlvane, Kledaras, Munson, King, de Rose, & Stoddard, 1987) as well as with tasks where the criterion was identity/difference (Dixon & Dixon, 1978).

Some works have studied the degree of importance of negative and positive relations in matching behaviour (arbitrary or not) and category formations, with promising results. However, it is still not clear whether or not the establishment of these relations is a necessary condition for matching behaviour.

Negative control affects the formation of equivalence classes, according to research. Carr, Wilkinson, Blackman, & Mcllvane (2000) carried out an investigation with five participants with mental retardation and deficient verbal repertoires, where they assessed the derivation of the relations that define equivalence classes and type S and type R relations. Only one participant failed to meet the established criterion for the formation of equivalence classes. The participants who performed well in the equivalence tests obtained positive results in type S and type R control tests as well. The only participant who did not pass the equivalence tests did not pass the type R control test. The authors concluded that negative control plays a significant role in the formation of equivalence classes.

Stromer and Osborne (1982) conducted two experiments: the first one showed that symmetry in four participants with delayed development was under type S and type R control; the second one, performed with twelve participants with developmental disorders, showed that the derived relations that define equivalence classes are under the control of positive and negative relations.

Only a few investigations have changed the MTS structure to identify the relevance that the establishment of negative relations (Harrison & Green, 1990; Plazas, 2012) and positive relations (Johnson & Sidman, 1993) have in the formation of equivalence classes. Furthermore, the modifications introduced in the training so as to prove the need for the establishment of negative relations are questionable. Harrison and Green (1990) exposed the participants (three adults and four children) to an MTS task with two comparisons. In each trial one of the comparisons always appeared when a specific sample was present, while the other comparison varied (A1-B1/X, for instance), so that no negative sample-comparison relation was trained (A1-notB2 type). The first experiment was conducted with three adults, and no explicit feedback was given after the participants' choice, simply going on to the next trial. Even though all of the participants acquired the matching behaviour for samples and comparisons that kept constant, none of them passed the equivalence tests. This training procedure without explicit reinforcement was later tested by Pérez and García (2010) with similar results. They considered those results to be the outcome of reinforcement by consistently applying the same rule.

Afterwards, Plazas (2012) followed Harrison and Green's study (1990) to analyse the formation of equivalence classes, but applying differential reinforcement this time. He carried out six experiments varying the procedure, yet still keeping the main characteristic of Harrison and Green's design (1990): the correct comparison was stable while the incorrect comparisons varied, thus not training negative relations. Just like in Harrison and Green's experiment (1990), the results of the two first tests of this study showed that the participants did not pass the equivalence tests, scoring low in symmetry, transitivity and symmetric-transitivity. However, a third test was conducted afterwards, with the same characteristics of the other two, but applying a within-participant design. It proved that the establishment of negative relations was not a necessary condition for the formation of equivalence classes. Nevertheless, the author suggests that the low score obtained in this procedure might be due to the nature of the training, which may not train conditional discriminations but simple discriminations. The poor performance of the participants in symmetry tests would be unsurprising then, taking into account that they imply the inversion of previously established conditional relations (which would not have been established in this case).

Pérez and Polín (2016), point out that, in a series of trials of the type: A1-B1/X1, A1-B1/X2, A1-B1/X3, etc. and A2-B2/X1, A2-B2/X2, A2-B2/X3, etc., in which the choices of B1 and B2 are reinforced, the presence of A1 or A2 does not exert any conditional control over B1 and B2 as discriminative stimuli. Each time they are present, they serve as the correct comparison. According to this interpretation, the low scores in the subsequent equivalence tests cannot be definitely attributed to the lack of sample-comparison negative control, since there is no guarantee that a positive control exists. The study of the influence of type R control in the formation of equivalence classes requires, then, a procedure that ensures the training of conditional control. Furthermore, as Plazas (2012) notes, the standard MTS procedure is artificial to some extent. Most of the stimulus structures outside the laboratory do not include stimuli belonging to other classes as incorrect comparisons. That is why type R control relations are not so frequent.

In order to consider equivalence classes as an adequate explanatory model of certain complex behaviours (such as categorization), Fields, Doran, and Marroquin (2009) state that they have to appear after training procedures different to the MTS.

The aim of this work was, therefore, to design a procedure that trained positive conditional relations between members of the same class but not negative relations between members of a different class, so that we could later check whether, with those learning contingencies, participants responded under the derived control that defines equivalence classes.

Method

Participants

There were 12 participants (6 women and 6 men) in the present study, aged 18 to 34 (*M*= 23.43; *SD*= 4.72). All of them volunteered for the experiment, were unaware of its purpose and they did not have any experience as participants in psychological investigations. Informed consent was appropriately obtained.

Apparatus and Stimuli

The procedure was designed with Adobe Flash 10 and programmed with Action Script 2.0. Stimuli, consequences and participants' responses were automatically registered through this application. Tasks were performed in two computers of similar features in a quiet and well-lit room. Thirty categories of stimuli were used, four illustrations of each category. Stimuli were images of everyday domestic objects (cutlery, tools, silverware, makeup, food, sewing, etc.), in colour, of similar size and on a white background.

Three different triads of stimuli (A_1-B_1-C_1, A_2-B_2-C_2, A_3-B_3-C_3) were used in with each subject participant to train the three equivalence classes. Four different configurations of stimuli were designed so as to control the potential easiness of some associations compared to others (Figure 1). Each member of each trained equivalence class belonged to a category of stimuli different from the rest of the members of the same class. This way we controlled a possible interference in the training due to a probable physical or functional generalization.

The stimuli involved in the procedure which that were not used for the training of equivalence classes were randomly chosen between the images of the remaining 21 categories (in see tables Tables 1, 2 and 3, stimuli represented by the letter "X"). Thus the trained functional matching in the subjectparticipants' history did not interfere in with the arbitrary matching training we were implementing.

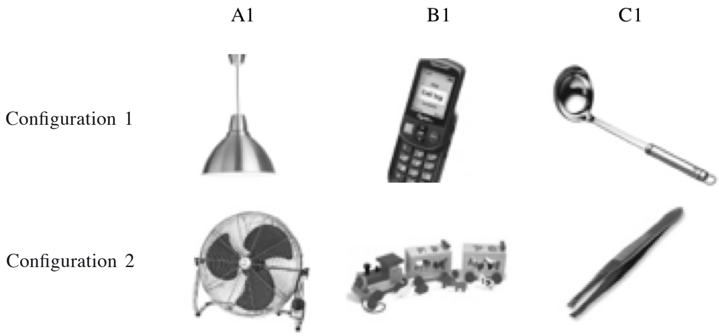

Figure 1. Stimuli composing the equivalence class 1 of stimulus configurations 1 and 4. In the experiment they were shown with their original colours.

Design

We worked with two independent variables, both present in the training, with two values each: terms in the reinforcement contingency (three or four) and trained relations (type S and R, or type S only). Although the resultant design would be 2x2, with an MTS procedure it is not possible to train type R relations without giving rise to conditionality. So three conditions were established and 4 participants were randomly assigned to each condition: Condition 1, where only positive sample-comparison relations (type S) were trained, with a procedure that required conditionality, that is, a four-term contingency (see Table 1); Condition 2, where positive relations (type S) and negative relations (type R) were trained, also through a four-term contingency (see Table 2); and Condition 3, where no negative relations were trained and there was no conditionality (see Table 3).

These measures were taken in the design of the training trials in order to control for extraneous variables: The same number of sample-comparison pairings was programmed in each training block for all of the classes; The position of the correct comparison (left-right) was balanced, so that it appeared the same number of times in each position; The "X" stimuli were not repeated in the trials of the same block in any condition. Thus no "X" stimulus acquired the function of delta stimulus; In the second condition, the number of times each stimulus performed as an incorrect comparison was the same depending on position and sample stimulus.

The dependent variable we measured was the number of correct responses in a final test that assessed symmetry, transitive and symmetric-transitive relations separately, following a between-group comparison design.

Procedure

An MTS procedure was applied with the following features: (a) *Simultaneous*, sample and comparisons were present at the same time; (b) *Arbitrary*, sample and comparisons had no physical similarities; (c) *Required sample observing*, so that sample and comparisons appeared together. The participant had to press the sample before the comparisons were presented; an (d) *with correction trials*, after each incorrect choice the participant started that trial over again until the right comparison was chosen or the "next" button was pressed.

Table 1. Condition 1. Example of training of exclusively positive relations (A-B Block) with conditionality.

Sample	Comparisons	
A1	B1	X
A2	B2	X
A3	B3	X
X	B1	X
X	B2	X
X	B3	X
A1	X	X
A2	X	X
A3	X	X

Notes: Correct comparisons are in the uncoloured cells of the table, incorrect comparisons in the grey cells. The letter X represents the employed stimuli that did not belong to any of the three trained equivalence classes.

Table 2. Condition 2. Example of training of positive and negative conditional relations.

Sample	Comparisons	
A1	B1	B2 or B3
A2	B2	B1 or B3
A3	B3	B1 or B2
X	B1	X
X	B2	X
X	B3	X
A1	X	X
A2	X	X
A3	X	X

Notes: Correct comparisons are in the uncoloured cells of the table, incorrect comparisons in the grey cells. The letter X represents the employed stimuli that did not belong to any of the three trained equivalence classes.

Table 3. Condition 3. Training of exclusively positive relations without conditionality.

Sample	Comparisons	
A1	B1	X
A2	B2	X
A3	B3	X
X	X	X

Notes: Correct comparisons are in the uncoloured cells of the table, incorrect comparisons in the grey cells. The letter X represents the employed stimuli that did not belong to any of the three trained equivalence classes.

Each trial included a sample (in the upper central part of the screen) and two comparisons (lower part, left and right). There was a scoreboard always visible in the upper right part, and a button with an arrow, placed between the two comparison stimuli, used to proceed to the next trial without choosing any comparison.

Figure 2 shows an example of a sequence of a training trial. First the sample appeared alone. After the observing response the comparisons showed up, and the participant could choose between them or to go on to the next trial. Correct answers were reinforced by the appearance of the words "WELL DONE!" on a green background, recorded-audio congratulations in different voices (male and female) and the achievement of one point in the scoreboard. Incorrect answers were punished with the word "WRONG!" on a red background, an unpleasant sound and the loss of one point in the scoreboard. By pressing the "next" button, none of these consequences happened. A correct answer or a push on the "next" button led to the following programmed trial.

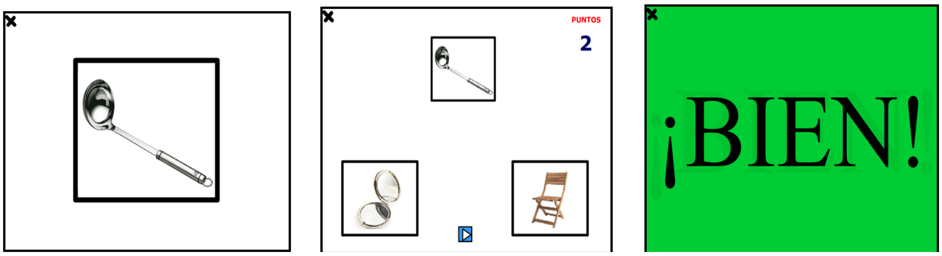

Figure 2. Example of a trial sequence.

Before the experiment started, participants registered their personal information (age and gender) and then read the following instructions:

> In the first place, we thank you for your participation in this study. We would like to remind you:
> - This is not an intelligence test
> - This is not a personality test
> - This is not a perception test
> - This is not a speed test
>
> This is a Learning task
>
> From this moment on, and until you are told otherwise, you cannot use the keyboard. You may only move the cursor and select by left-clicking on your chosen answer. We kindly ask you not to speak with your partners, should you have any, and not to ask about the task. If you have any technical problem, of course, notify the person in charge of the supervision of the study. It is very important that you make an effort and do your best, not only to get the best results, but also to later understand the phenomenon analysed.

Once the instructions were read, when the participant was ready, he/she clicked on an arrow to begin the experiment.

The experiment consisted of two phases:

Training Phase. In which the six matching responses needed for the formation of three equivalence classes (of three components each) were trained. Training was divided into nine independent blocks. The success criterion to go from one block to the next was to make no mistake for 10 consecutive trials in each of the three matchings. The following sequence was used: 1) A_1-B_1, 2) A_2-B_2, 3) A_3-B_3, 4) mixed trials of A_1-B_1, A_2-B_2 and A_3-B_3, 5) B_1-C_1, 6) B_2-C_2, 7) B_3-C_3, 8) mixed trials of B_1-C_1, B_2-C_2 and B_3-C_3, and 9) mixed trials of A_1-B_1, A_2-B_2, A_3-B_3, B_1-C_1, B_2-C_2 and B_3-C_3. Every session lasted thirty minutes maximum. The number of training blocks that each participant was exposed to depended on their performance in the tasks. If the participant did not reach the accuracy criterion, he/she had to repeat the same training block; if the participant reached the criterion, he/she went on to the next training block. After thirty minutes the session ended, to be resumed the next day.

Test Phase. When the whole training was completed, participants were exposed once to a test phase where the derivation of the relations that define equivalence classes was assessed. This phase consisted of twelve trials with one sample and two comparisons where no feedback was applied to the participant's responses. That is, the selection of any of the two comparisons always led to the next trial. Likewise, the "next" arrow to pass to the following trial without responding was not available in this phase. Four out of these twelve trials evaluated the derivation of symmetric relations (B-A and C-B), four the transitive relations (A-C) and four the symmetry-transitivity relations (C-A).

RESULTS

Tables 4, 5 and 6 show the number of trials each subject participant needed to pass the training phase, and the percentage of right answerscorrect responses in the tests of symmetry, transitivity and symmetric-transitivity.

Participants in condition 1 were the ones who needed the most trials (296.25) in the first phase (A-B), followed by those in condition 2 (289.75 trials) and condition 3

Table 4. Condition 1: Number of trials needed to pass the training phase and percentage of correct responses in the test phase.

Participants	Training Phase			Test Phase		
	A-B	B-C	AB/BC	Symmetry	Transitivity	Sym-Trans
1	405	148	54	100%	75%	75%
2	203	145	54	100%	100%	100%
3	164	154	56	50%	75%	50%
4	413	150	54	100%	100%	100%
Average	296.25	149.25	54.5	87.5%	87.5%	81.25%

Table 5. Condition 2: Number of trials needed to pass the training phase and percentage of correct responses in the test phase..

Participants	Training Phase			Test Phase		
	A-B	B-C	AB/BC	Symmetry	Transitivity	Sym-Trans
5	193	157	54	100%	100%	100%
6	247	196	54	100%	100%	100%
7	261	201	54	100%	75%	75%
8	458	335	54	100%	75%	75%
Average	289.75	222.25	54	100%	87.5%	87.5%

Table 6. Condition 3: Number of trials needed to pass the training phase and percentage of correct responses in the test phase.

Participants	Training Phase			Test Phase		
	A-B	B-C	AB/BC	Symmetry	Transitivity	Sym-Trans
9	127	129	54	100%	75%	75%
10	155	129	54	0%	75%	75%
11	187	130	54	100%	100%	100%
12	153	200	54	75%	75%	75%
Average	155.5	147	54	68.75%	81.25%	81,25%

(155.5 trials). Participants in condition 3 needed the least trials to pass the first training phase (PA-9, PA-12 and PA-10). The greatest variability in the number of trials needed was in condition 1, and the participants in condition 3 presented the least variability.

In the second training sequence (B-C), participants in condition 2 needed the most trials (222.25), followed by the participants in condition 1 (149.25) and condition 3 (147). Just like in the first phase, in the second phase participants in condition 3 needed the least trials (PA-9, PA-10 and PA-11). The greatest variability was present in condition 2. Like in the first phase of the training, participants in condition 3 presented the least variability.

In general there was a transfer of learning from the first to the second phase in all of the conditions, excepts for PA-9, who needed more trials in the second phase than in the first. The greatest transfer of learning happened in condition 1, specifically for PA-4. This participant was the one who presented the greatest difference of trials between the two phases of training.

Results did not differ too much in the third phase of training (AB/BC). Generally, there was a transfer of learning from the second to the third phase in all of the conditions. Condition 2 presented the greatest transfer, mainly participants PA-8 and PA-7.

Regarding the test phase, under an arbitrary criterion (but strict and consistent with the literature) of 75% of correct responses, only the participants in condition 2 (traditional MTS format, conditional control and negative relations) passed the test of derived relations that define equivalence classes. Next were participants in condition 1 and those in condition 3. However, all of the participants in condition 1 reached the established criterion of 75% correct responses, except for PA-3. Furthermore, the total average performance in the derived relations test of condition 1 participants was better than the average performance of participants in condition 3.

If each derived relation is analysed separately (Figures 3 and 4), participants in condition 2 obtained a higher percentage of correct responses in symmetric-transitivity

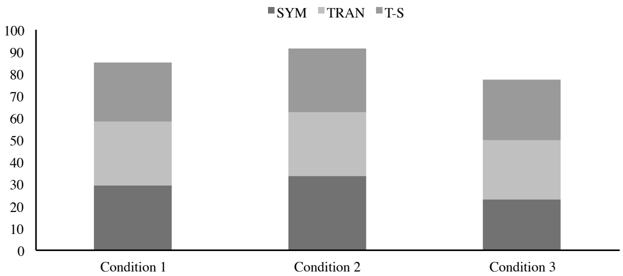

Figure 3. Percentage of correct responses in the test phase.

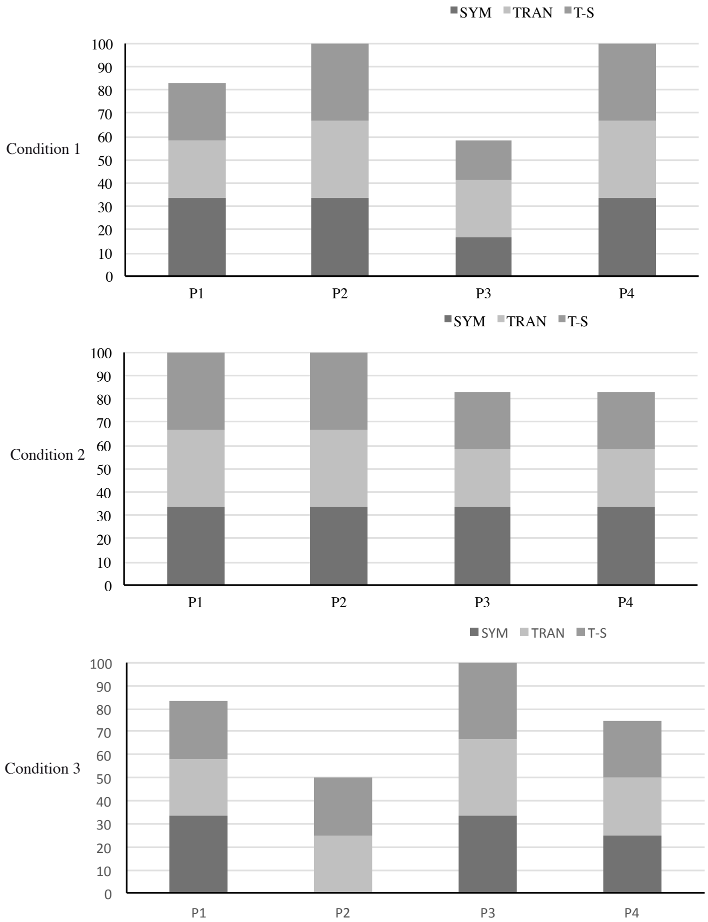

Figure 4. Percentage of correct responses for each participant in the test phase.

test (87.5%) compared to conditions 1 and 3, with both groups obtaining 81.25% correct responses. Likewise, participants in condition 2 had the highest percentage of correct responses (100%) in the symmetry relations test. The lowest percentage of correct responses (68.75%) in the symmetry test was scored in condition 3. In fact, the only participant who scored 0% correct responses in the symmetry test belonged to condition 3. The performance of participants in condition 1 and condition 2 in the transitivity test was similar, with both groups scoring 87.5% correct responses (see Tables 7 and 8).

Discussion

In summary, the data recorded from our participants support the initial hypothesis that considered that the kind of procedure applied in condition 3 (similar to the procedure employed by Harrison & Green, 1990, and Plazas, 2012) was a simple discrimination, even though its format was somewhat similar to MTS (which is a conditional discrimination).

Regarding the relevance that the establishment of negative relations has in the derivation of the relations that define equivalence classes, our results show that participants who learned with the standard MTS format (with negative relations and conditionality), as well as participants who learned with the newly designed procedure (where positive conditional relations between members of the same class were trained, but not negative relations between members of different classes), formed equivalence classes with both learning contingencies. That is, the exclusive establishment of positive conditional relations was enough for most of the participants (three out of four) to form equivalence classes.

These data contradict Plazas's results (2012), since most of the participants in that study did not pass the derived relations tests without previous training in negative relations training. This conflict may be mainly due to the altered MTS format Plazas (2012) applied in his investigation. Through that particular modification, his participants were trained exclusively in positive conditional relations, never in negative relations.

The main problem with this format (as we already pointed out in the introduction) previously used by Harrison and Green (1990), is that, like Pérez and Polín (2016) suggest, in a series of trials of the type: A_1-B_1/X_1, A_1-B_1/X_2, A_1-B_1/X_3, etc. and A_2-B_2/X_1, A_2-B_2/X_2, A_2-B_2/X_3, etc.; B_1 and B_2 choices are always reinforced, since these stimuli always appear in the presence of A_1 and A2, respectively. Thus, the sample stimuli are not exerting conditional control over the comparison stimuli, which would supposedly fulfil a discriminative function.

The results gathered in the present study support the hypothesis that the low scores Plaza's participants (2012) in equivalence tests are mainly due to the lack of conditional discrimination training, since the establishment of conditional relations is considered a requirement for the derivation of equivalence classes. The failure to establish conditional relations calls into question whether this kind of format is appropriate for the training of positive relations.

In fact, in our study, participants who were exclusively trained in the purportedly positive relations without conditional control did not pass the symmetry tests. This was probably due to the lack of training in conditional discrimination. However, they did reach the criterion to pass the transitivity and symmetric-transitivity tests. This means that the establishment of symmetric relations is not a necessary condition to pass transitivity and symmetric-transitivity tests, and that the lack of conditionality does not equally affect the relations that define equivalence classes, like Plazas (2012) defends. This brings us to suggest, like other authors did before (Pilgrim & Galizio, 1996; Pilgrim, Jackson, & Galizio, 2000), that the acquisitions of symmetric, transitive and symmetric-transitive relations are not dependent one upon another.

In conclusion, the new MTS format designed for the present study (which trains positive conditional relations without negative relations), seems to be an effective training procedure, necessary for the formation of equivalence classes in adults.

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