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Transfer-of-Function and Novel Emergent Relations Using Simple Discrimination Training Procedures

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Abstract The present study investigated whether simple discrimination procedures produce emergent relations that are consistent with functional and equivalence classes. In Experiment 1, 4 normally capable adults were exposed to simple successive discrimination reversal training. Responses to the S^+ (A1, B1, and C1) but not S^- (A2, B2, and C2) were reinforced. The participants were then exposed to repeated-reversal training, followed by tests of emergent equivalence relations. In Experiment 2, 4 additional adults were exposed to a simple successive discrimination training procedure using differential responses. Response 1 (R1) was reinforced only when emitted in the presence of A1, B1, or C1 (A1-R1, B1-R1, or C1-R1). Response 2 (R2) was reinforced only in the presence of A2, B2, or C2 (A2-R2, B2-R2, or C2-R2). A new response was then trained in the presence of 1 member of each class (A1-R3, A2-R4). A transfer-of-function test was then conducted to verify whether the new responses would be emitted in the presence of B1, B2, C1, and C2. In both experiments, emergent conditional relations were tested using a go/no-go procedure with compound stimuli. In Experiment 1, all of the participants showed functional classes, and 3 showed patterns that are consistent with the formation of equivalence classes. In Experiment 2, all 4 participants showed patterns that are consistent with functional and equivalence class formation. In these experiments, simple discrimination training generated a range of emergent stimulus relations that mirrored those that are indicative of equivalence class formation.

Keywords Functional classes · Equivalence classes · ?Go/no-go procedure · Compound stimuli · Button press · Humans

According to the definition by Sidman and Tailby (1982), equivalence classes can be identified when conditional discrimination training results in the emergence of new conditional discriminations that were not directly trained, in accordance with the three formal properties of equivalence: reflexivity, symmetry, and transitivity. Equivalence classes are typically established and tested using the matching-to-sample (MTS) procedure.

In accordance with the definition by Sidman (2000), “the equivalence relation consists of ordered pairs of all positive elements that participate in the reinforcement contingency” (Sidman 2000, p. 131). This expanded definition allows equivalence classes to be established using any procedure that yields relations that consist of ordered pairs of the reinforcement contingency (not only the MTS procedure).

Functional classes are sets of stimuli that occasion the same response (e.g., Goldiamond 1966). Functional class formation may be demonstrated when contingencies that are applied directly to one stimulus in the class also impact other members of the same functional class (Goldiamond 1962). For example, after a new response is reinforced in the presence of one stimulus of the class, tests can be conducted to evaluate whether the new response would also be controlled by the other stimuli of the same functional class. These tests have been described as transfer-of-control tests (e.g., Barnes and

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Keenan 1993) or transfer-of-function tests (e.g., Barnes et al. 1995).

Functional classes can be established using a simple discrimination reversal procedure, which was originally accomplished by Vaughan (1988) with pigeons. In this study, the reinforcement contingencies (i.e., to respond to one set of stimuli and not respond to another) were reversed and re-reversed several times until exposure to a few stimuli was sufficient to change performance with all of the stimuli, without experiencing the reversed contingency for all of the stimuli in each set. According to Vaughan, this performance indicated the partition of a set of stimuli into two subsets. Considering, mathematically, that partition implies equivalence, the performance obtained could also be interpreted as a demonstration of equivalence class formation, even without including the formal evaluation of reflexivity, symmetry, and transitivity.

According to Sidman (1994), a distinction between functional and equivalence classes based on different training and testing procedures does not necessarily indicate different behavioral processes. Studies have shown that MTS procedures that result in equivalence classes often also result in functional classes that are evaluated with simple discrimination tests (e.g., Barnes and Keenan 1993; Lazar 1977; Wulfert and Hayes 1988). Other studies have investigated whether simple discrimination reversal procedures that result in functional classes also result in equivalence classes evaluated with the MTS procedure (i.e., tests for reflexivity, symmetry, and transitivity; e.g., Kastak et al. 2001; Sidman et al. 1989).

In the experiment conducted by Sidman et al. (1989), three participants (a woman and two teenage boys with atypical development) who were exposed to a simple discrimination reversal procedure first demonstrated functional classes. The stimuli were then presented in an MTS context to evaluate whether functional class members would be matched to each other. When conditional relations emerged, the participants were exposed to conditional discrimination training between functional class members and new stimuli. Finally, the new stimuli were presented in the simple discrimination procedure to assess their inclusion in the functional classes. The results of two of the three participants were consistent with both functional and equivalence class formation.

Sidman (1994) later presented a critical analysis of experiments that used the MTS procedure to test for emergent conditional relations between members of a functional class that were established using simple discrimination reversals. According to his analysis, performance evaluated in tests that used the MTS procedure could have been directly reinforced during the repeated reversal training. In simple simultaneous discrimination training, for example, between pairs of stimuli A1/A2, B1/B2, and C1/C2, stimuli A1, B1, and C1 will always be the S^+ in some of the sessions. These functions are reversed only in different sessions. In these sessions, following a reinforced response to A1 (in a trial in which A1 and A2 were presented), for example, a response to C1 (and not C2) would be reinforced in the next trial. Conversely, in these same sessions, a response to C2 would never be reinforced following a response to A1. Thus, the sequence of reinforced responses during simple discrimination training would include responding to A1 and then responding to C1. In AC tests that use the MTS procedure, the participant must first respond to A1 (sample) and then select C1 ("correct" comparison). Similarly, the sample-comparison response sequences that are required in other tests with the MTS procedure could also have been directly reinforced during the simple discrimination reversal training. The same adventitious reinforcement of response sequences could occur in successive discrimination training, in which responses are reinforced only in the presence of the S^+. An alternative testing procedure would be required to avoid this potential confound.

One alternative to MTS is the go/no-go procedure with compound stimuli (Debert et al. 2007; Debert et al. 2009; Perez et al. 2009). Debert et al. used a go/no-go procedure with six adult human participants. Compound stimuli composed of two elements were presented in each trial. During AB and BC training, responses to the "related" compounds (A1B1, A2B2, A3B3, B1C1, B2C2, and B3C3) were reinforced, whereas responses to the "unrelated" compounds (A1B2, A1B3, A2B1, A2B3, A3B1, A3B2, B1C2, B1C3, B2C1, B2C3, B3C1, and B3C2) were not. During the tests, the stimuli were arranged into new compounds that were indicative of symmetry (BA and CB), transitivity (AC), and equivalence (CA) relations. Debert et al. reported equivalence class formation because the participants responded to related compounds and withheld responses to the unrelated ones. Tests that used the go/no-go procedure constituted true tests of symmetry and transitivity, and the findings were consistent with an analysis of compound separation and recombination (Stromer et al. 1993) and Sidman's (2000) definition.

Using the go/no-go procedure with compound stimuli for testing after the simple discrimination reversal procedure would avoid the problem presented by Sidman (1994). During go/no-go tests, the participants are required to respond to correct compounds and not respond to the incorrect ones. Therefore, the discriminative performance that was directly trained in the simple discrimination reversal procedure would be different from the performance required in tests that use the go/no-go procedure with novel compounds. In simple successive discrimination training, responses are emitted or not emitted in response to each stimulus that is presented alone. In tests that use the go/no-go procedure, responses are emitted or not emitted in response to the stimuli that are presented as novel compounds (i.e., involving stimuli not presented together during training). Furthermore, although adventitiously reinforced response sequences could be emitted in standard MTS tests (i.e., a response to the sample followed by a response to the comparison), no such sequences are required in tests with the go/no-go procedure with compound stimuli. Thus, Experiment 1 in the present study investigated whether a simple successive discrimination reversal procedure would generate functional classes and equivalence classes evaluated by the go/no-go procedure with compound stimuli.

Experiment 1

Methods

Participants The participants were four undergraduate students from the University of São Paulo (three males and one female), aged 19 to 49 years. Participants D and C were engineering students. Participants T and N were first-year psychology students. None of them had prior familiarity with the experimental analysis of behavior. The research was conducted according to the rules of the Ethics Committee on Human Research of the Psychology Institute, University of São Paulo (protocol no. 2010.028). The participants read and signed an informed consent form before beginning the procedure.

Apparatus The sessions were conducted individually in a laboratory room over 5 or 6 days. An HP Pavilion dv4-1120br notebook computer with a 14-inch screen was used. A program was developed in Visual Basic 6.0 to control stimulus presentation and record the data.

The stimuli were six abstract figures (Markham and Dougher 1993; see Fig. 1). During training, each figure was presented alone in the center of the screen within a rectangle. During the tests, two figures (two-element compounds) were presented within the rectangle. The figures were presented on a gray background (approximately 10 cm×5 cm) on the computer screen. The participants were seated facing the monitor and responded by positioning the mouse's cursor over the rectangle and pressing the mouse button.

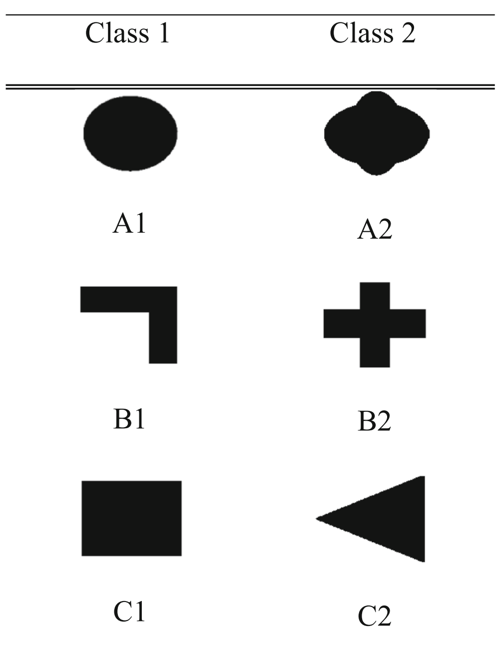

Fig. 1 Abstract stimuli developed by Markham and Dougher (1993) and their designation in the present study (A1, B1, C1, A2, B2, and C2)

Procedure

Phase 1: Simple Successive Discrimination Training The participants underwent simple successive discrimination training using a go/no-go procedure. At the beginning of the session, each participant sat facing the computer screen, which presented the following instructions (translated from Portuguese):

> This study is not about intelligence testing and will not evaluate any aspect of your intellectual abilities. When it is finished, you will receive a full explanation. If any instruction is unclear, then you can click the "BACK" button to review it. Otherwise, you can click "NEXT." Your goal is to attain as many points as possible; these points will be shown on the upper left of the screen. In a defined area in the center of the screen, there will be figures. Your task is to click in this area using the mouse when correct figures are shown and not click when incorrect figures are shown. In the beginning, you will receive points whenever you click correct figures. Later, you will sometimes receive and sometimes not receive such points. The task will increase in difficulty as it goes along. Thus, pay attention even when the task seems very simple. Please repeat to the experimenter the instructions you just read. When the experimenter says you can start the task, click the "OK" button to start the experiment. Thank you for your participation.

The participants then completed sessions that were composed of 28 trials each. In each trial, one of six stimuli (A1, A2, B1, B2, C1, and C2) was presented for 4 s within the rectangle on the screen. The stimulus presentation order was random. As shown in Table 1, stimuli A1, B1, and C1 were designated as S$^+$ (correct), and A2, B2, and C2 were designated as S$^-$ (incorrect). During the first six trials, each response to the S$^+$ produced 10 points on a counter positioned in the top left of the screen. When points were added, the total flashed for 1 s. Thereafter, consequences occurred according to a conjunctive fixed-ratio 1 variable-time 2.5-s schedule (i.e., at least one response was made to the compound stimuli, and 2.5 s had elapsed). The intertrial interval was 2 s.

The criterion for mastery was 96.4 % correct responses. The percentage of correct responses was calculated by adding the number of trials that presented the S$^+$ for which there was at least one response to the number of trials that presented the

Table 1 Stimuli Presented in Each of the Phases in Experiment 1

TRAINING					TEST			
Phase 1		Phase 2			Phase 3		Phase 4	
Simple successive discrimination training		Repeated reversal training			BA/CB emergent relations test		AC/CA emergent relations test	
Correct	Incorrect	Correct	↔	Incorrect	Correct	Incorrect	Correct	Incorrect
A1	A2	A2	↔	A1	B1A1	B1A2	A1C1	A1C2
B1	B2	B2	↔	B1	B2A2	B2A1	A2C2	A2C1
C1	C2	C2	↔	C1	C1B1	C1B2	C1A1	C1A2
					C2B2	C2B1	C2A2	C2A1

S^- for which there were no responses. The sum was then divided by the total number of trials and multiplied by 100.

Phase 2: Repeated Reversal Training In this phase, repeated contingency reversals were programmed. The stimulus presentations, schedule of reinforcement, number of trials in a session, and mastery criterion were the same as the terminal procedures used in Phase 1. For each reversal, stimuli that were the S^+ in the previous phase were the S^- and vice versa. If accuracy was less than 96.4 % in a session, then the same session was repeated, usually on the same day. When the mastery criterion was achieved in a session, the function of the stimuli was reversed in the next session. Reversals were conducted until the participant achieved the mastery criterion in the first session of a reversal, with a minimum of three reversals required.

Phase 3: BA and CB Emergent Relations Test At the beginning of the session, the following instructions were presented on the computer screen:

> This is a new phase, and your task will be modified. Execute the task according to what you have learned. You will not know if you responded to the correct figures because the points will not be shown.

This phase tested for emergent relations (BA and CB) in a single session using the same go/no-go procedure but with compound stimuli under extinction conditions. The compound stimuli were B1A1, B2A2, C1B1, and C2B2 ("correct compounds") and B1A2, B2A1, C1B2, and C2B1 ("incorrect compounds"; see Table 1). Each compound was presented for 8 s (Debert et al. 2009; Perez et al. 2009). The session was composed of 12 blocks of eight trials (96 trials in total). The eight compound stimuli were presented in random order, with the constraint that each compound was presented once in a block.

Phase 4: AC and CA Emergent Relations Test This phase tested for emergent AC and CA relations in a single session using the go/no-go procedure with compound stimuli. The procedures were the same as in Phase 3, but the correct and incorrect compounds were changed (see Table 1), and the instructions were modified slightly to inform the participants that "other modifications would be presented."

Results

Table 2 shows the percentage and number of correct responses (numbers in parentheses) during the training and test sessions for each participant. The participants met the mastery criterion for Phase 1 (simple successive discrimination training) in four or five sessions.

In Phase 2 (Reversals 1–7 in Table 2), two participants (D and C) met the mastery criterion in four reversals, and the other two participants (T and N) required seven reversals to demonstrate functional class formation. After the first two reversals, the participants required only one or two sessions to achieve the mastery criterion, with the exception of Participant N, who required three sessions in Reversals 5 and 6.

During the tests of emergent relations (Phases 3 and 4), Participants C, T, and N showed the emergence of all relations (BA, CB, AC, and CA). Participant C exhibited 100.0 % correct responses in both tests. Participants T and N exhibited 97.9 % and 89.6 % correct responses, respectively, in the BA/CB emergent relations test and 100.0 % accuracy in the AC/CA emergent relations test. Participant D failed to show the emergence of any of the tested relations, scoring 75.0 % correct responses on each test.

Table 3 presents a detailed analysis of Participant N's performance during the BA and CB emergent relations test. The table shows the percentage of correct responses in each block of the test and the compounds for which the errors occurred. The percentages of responses to correct compounds were at chance level across the first five blocks of the test. When incorrect compounds were presented, accuracy was 100.0 % from the first block, but the correct response in these trials was to withhold a response. Thus, Participant N made few responses in the first blocks. In Blocks 6 to 12, performance was indicative of equivalence class formation (with the exception of 75.0 % in Block 8).

Table 2 Percentage and Number of Correct Responses in Each Session During Training and Testing Phases in Experiment 1

Phase	Participant			
	C	T	N	D
Simple successive discrimination training	57.1 (16/28)	17.9 (5/28)	53.6 (15/28)	67.9 (19/28)
	82.1 (23/28)	75.0 (21/28)	75.0 (21/28)	89.3 (25/28)
	89.3 (25/28)	67.9 (19/28)	71.4 (20/28)	89.3 (25/28)
	96.4 (27/28)	78.6 (22/28)	82.1 (23/28)	100.0 (28/28)
	—	96.4 (27/28)	100.0 (28/28)	—
Reversal 1	85.7 (24/28)	82.1 (23/28)	82.1 (23/28)	89.3 (25/28)
	85.7 (24/28)	100.0 (28/28)	100.0 (28/28)	100.0 (28/28)
	89.3 (25/28)	—	—	—
	89.3 (25/28)	—	—	—
	100.0 (28/28)	—	—	—
Reversal 2	96.4 (27/28)	85.7 (24/28)	89.3 (25/28)	89.3 (25/28)
	—	96.4 (27/28)	89.3 (25/28)	92.9 (26/28)
	—	—	96.4 (27/28)	100.0 (28/28)
	—	—	100.0 (28/28)	—
Reversal 3	92.9 (26/28)	78.6 (22/28)	89.3 (25/28)	82.1 (23/28)
	96.4 (27/28)	100.0 (28/28)	100.0 (28/28)	100.0 (28/28)
Reversal 4	100.0 (28/28)	78.6 (22/28)	89.3 (25/28)	96.4 (27/28)
	—	100.0 (28/28)	100.0 (28/28)	—
Reversal 5	—	89.3 (25/28)	67.9 (19/28)	—
	—	100.0 (28/28)	89.3 (25/28)	—
	—	—	100.0 (28/28)	—
Reversal 6	—	89.3 (25/28)	85.7 (24/28)	—
	—	100.0 (28/28)	89.3 (25/28)	—
	—	—	100.0 (28/28)	—
Reversal 7	—	96.4 (27/28)	96.4 (27/28)	—
BA/CB emergent relations test	100.0 (96/96)	97.9 (94/96)	89.6 (86/96)	75.0 (72/96)
AC/CA emergent relations test	100.0 (96/96)	100.0 (96/96)	100.0 (96/96)	75.0 (72/96)

The percentage and number of BA, CB, AC, and CA trials in which Participant D responded in the emergent relations tests are shown in Table 4. Participant D responded in 100.0 % of the trials for which correct compounds were formed by

Table 3 Percentage and Number of Correct Responses and the Compounds for Which Errors Occurred in Each Block (8 Trials) of BA and CB Emergent Relations Test for Participant N

Blocks	Percentage of correct responses		Errors in compounds	
	Correct	Incorrect	Correct	Incorrect
Block 1	75.0 (3/4)	100.0 (4/4)	B1A1	—
Block 2	75.0 (3/4)	100.0 (4/4)	B1A1	—
Block 3	25.0 (1/4)	100.0 (4/4)	B1A1, B2A2, C1B1	—
Block 4	50.0 (2/4)	100.0 (4/4)	B1A1, C1B1	—
Block 5	50.0 (2/4)	100.0 (4/4)	B1A1, C1B1	—
Block 6	100.0 (4/4)	100.0 (4/4)	—	—
Block 7	100.0 (4/4)	100.0 (4/4)	—	—
Block 8	100.0 (4/4)	75.0 (3/4)	—	B1A2
Block 9	100.0 (4/4)	100.0 (4/4)	—	—
Block 10	100.0 (4/4)	100.0 (4/4)	—	—
Block 11	100.0 (4/4)	100.0 (4/4)	—	—
Block 12	100.0 (4/4)	100.0 (4/4)	—	—

Table 4 Percentage and Number of BA, CB, AC, and CA trials in Which Participant D Responded in the Emergent Relations Tests

	BA/CB emergent relations test		AC/CA emergent relations test	
Correct compound	B1A1	100.0 (12/12)	A1C1	100.0 (12/12)
	B2A2	0.0 (0/12)	A2C2	0.0 (0/12)
	C1B1	100.0 (12/12)	C1A1	100.0 (12/12)
	C2B2	0.0 (0/12)	C2A2	0.0 (0/12)
Incorrect compound	B1A2	0.0 (0/12)	A1C2	0.0 (0/12)
	B2A1	0.0 (0/12)	A2C1	0.0 (0/12)
	C1B2	0.0 (0/12)	C1A2	0.0 (0/12)
	C2B1	0.0 (0/12)	C2A1	0.0 (0/12)

elements of Class 1 (B1A1, C1B1, A1C1, and C1A1) and did not respond to correct compounds formed by elements of Class 2 (B2A2, C2B2, A2C2, and C2A2). This pattern may be attributable to the simple discriminative control established in the final reversal phase (Reversal 4), in which stimuli A1, B1, and C1 were the S^+. The participant did not respond to any incorrect compound.

Discussion

Experiment 1 investigated whether a simple successive discrimination-reversal procedure could generate functional and equivalence classes. Consistent with previous findings (e.g., Kastak et al. 2001; Sidman et al. 1989; Vaughan 1988) with sea lions, human participants and pigeons, the procedure generated functional classes. After training on a sufficient number of reversals, exposure to one trial of a reversal was sufficient to control the subsequent responding of all four participants.

The procedure could also be argued to have produced equivalence classes (BA, CB, AC, and CA emergent relations) in three of four participants evaluated using a go/no-go procedure with compound stimuli. Although future studies should test for the complete array of relations (AB, BC, BA, CB, AC, and CA), the relations assessed herein provided a reasonable sample. The results indicated that functional classes imply equivalence classes as suggested by Sidman (1994) and Vaughan (1988).

For the participant who failed to show patterns consistent with equivalence class formation (Participant D), responding appeared to be under the control of compounds that were formed by elements of the class (Class 1) that served as the S^+ in the last simple discrimination reversal prior to the tests. A simple discrimination procedure without reversals could avoid this source of competing control.

With the go/no-go procedure with compound stimuli during the tests, the participants did not emit the same sort of response sequences that may have been adventitiously reinforced during reversal training. However, this sort of sequence could also be identified in tests with the go/no-go procedure with compound stimuli in the present study. In these tests, the participant could respond to the compound A1C1, for example, because during training the chain "respond to A1 and then respond to C1" was reinforced in successive discrimination trials (i.e., if no S^- presentation intervened in the randomly determined order of stimulus presentations). Conversely, the participant would not respond to A1C2 because reinforcement never occurred for a chain "respond to A1 and then respond to C2" during training.

Thus, test performance, even with the go/no-go procedure, could have been based on directly reinforced sequences or conditional discriminations during the repeated reversal training. To verify whether functional classes are equivalence classes, it would be necessary to use a simple discrimination training procedure that could not inadvertently establish conditional discriminations or response sequences as proposed in Experiment 2.

Experiment 2

One possibility to avoid the adventitious control mentioned in the Discussion of Experiment 1 is to use simple discrimination training with differential responses that are trained to members of different functional classes (e.g., Barnes and Keenan 1993; Smeets et al. 1997; Smeets et al. 2001). In contrast to the simple discrimination reversal procedure, training differential responses would mean that a (correct) response to C1, for example, would no longer be reinforced only following a (correct) response to A1; it would also be reinforced following a (correct) response to A2, B2, or C2. Additionally, this procedure would avoid establishing control by compounds that are formed by elements from only one class, as observed in the test performance of Experiment 1's Participant D.

In a study by Smeets et al. (1997), for example, 20 preschool children were exposed to simple discrimination training using differential responses. A transfer-of-function test was then conducted to verify whether the new responses would be emitted in the presence of different stimuli.

Finally, tests of emergent conditional relations with the MTS procedure with two sets of stimuli (Sets A and B) were conducted. Eleven of the 20 participants responded consistently in the transfer-of-function tests and emergent conditional relations tests.

A replication of this procedure using at least three sets of stimuli (e.g., A, B, and C) would allow testing for a fuller array of emergent relations (testing for equivalence class formation). This was the purpose of Experiment 2. In contrast to previous studies, Experiment 2 involved testing a fuller array of emergent relations using a novel testing procedure (go/no-go procedure with compound stimuli).

Methods

Participants The participants were four additional undergraduate or graduate students, ages 20 to 28 years. None of the participants had prior familiarity with the experimental analysis of behavior. The ethical rules were the same as those described in Experiment 1.

Apparatus The apparatus and stimuli were the same as the ones used in Experiment 1 (see Fig. 1). In Experiment 2, the sessions were conducted on a single day, over 2–3 h.

Procedure

Phase 1. Simple Successive Discrimination Training Using Differential Responses In this phase, the sessions consisted of 24 trials. One of the six stimuli (A1, A2, B1, B2, C1, and C2) was presented in the rectangle on the computer screen in each trial in a random sequence, with the constraint that each stimulus was presented four times. The presession instructions were identical to those in Experiment 1, with the exception that the participants were instructed to press either the “Y” or “B” key on the laptop keyboard. Pressing the “Y” key was defined as R1 and produced 10 points when A1, B1, or C1 was presented on the screen (A1-R1, B1-R1, C1-R1). Pressing the “B” key was defined as R2 and produced 10 points in the presence of A2, B2, or C2 (A2-R2, B2-R2, C2-R2). A stimulus remained on the screen until either key was pressed. When points were earned, they accumulated on the point counter as in Experiment 1. The intertrial interval was 2 s. Training continued until a session was completed with 100.0 % correct responses. Table 5 shows the stimuli that were presented in each phase in Experiment 2.

phase 2. Simple Successive Discrimination Training Using New Differential Responses In this phase, the procedures were the same as those in Phase 1, with the following exceptions. Only stimulus A1 or A2 was presented (12 trials each in the session). The participants were instructed to respond using the “Tab” or “Enter” key. Pressing the “Tab” key was defined as R3 and produced 10 points when emitted in the presence of A1 (A1-R3). Pressing the “Enter” key was defined as R4 and produced 10 points in the presence of A2 (A2-R4).

Phase 3. Transfer-of-Function Test At the beginning of the session, the following instructions were presented on the computer screen (translated from Portuguese):

> In this phase, you should continue to respond using the “Tab” and “Enter” keys. Try to respond according to what you learned in the previous phases. You will not know if you responded correctly because the points will not be shown.

This phase consisted of a test to verify whether the new responses, R3 and R4, would be emitted in the presence of B1, B2, C1, and C2 (B1-R3, C1-R3, B2-R4, C2-R4). Positive results would indicate functional class formation.

The four stimuli (B1, B2, C1, and C2) were presented one at a time in a random sequence. Each was presented six times in a session of 24 trials. No points were delivered during the session, but all of the other procedures were the same as those in Phase 2.

If accuracy was at least 91.6 %, then the participant was exposed to subsequent phases. If accuracy was less than 91.6 %, then the participant was reexposed to training and then to another test session.

Phase 4. AB and BC Emergent Relations Test Before the first test session, the following instructions were presented on the computer screen:

> In the following phases, your task will be modified. You should respond by clicking the mouse button. You should respond to figures you think are correct and not respond to figures you think are incorrect. Try to respond according to what you learned in the previous phases. You will not know if you responded correctly because the points will be not shown.

This phase tested for emergent relations AB and BC using the go/no-go procedure with compound stimuli under extinction conditions. The compounds were A1B1, A2B2, B1C1, and B2C2 (“correct compounds”) and A2B1, A1B2, B2C1, and B1C2 (“incorrect compounds”; see Table 5). The experimental conditions were the same as those described in the tests conducted in Experiment 1, with the exception that the session was composed of six blocks of eight trials (48 trials per session).

Phase 5. BA and CB Emergent Relations Test This phase tested for emergent relations BA and CB using the go/no-go procedure with compound stimuli. Correct and incorrect compounds are shown in Table 5. The procedures were otherwise the same as in Phase 4.

Table 5 Stimuli Presented in Each of the Phases in Experiment 2

TRAINING				TEST	
Phase 1		Phase 2		Phase 3	
Simple successive discrimination training (differential responses)		Simple successive discrimination training (new differential responses)		Transfer-of-function test	
A1→R1	A2→R2	A1→R3	A2→R4	—	—
B1→R1	B2→R2	—	—	B1→R3 ?	B2→R4 ?
C1→R1	C2→R2	—	—	C1→R3 ?	C2→R4 ?
TEST					
Phase 4		Phase 5		Phase 6	
AB/BC emergent relations test		BA/CB emergent relations test		AC/CA emergent relations test	
Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
A1B1	A1B2	B1A1	B1A2	A1C1	A1C2
A2B2	A2B1	B2A2	B2A1	A2C2	A2C1
B1C1	B1C2	C1B1	C1B2	C1A1	C1A2
B2C2	B2C1	C2B2	C2B1	C2A2	C2A1

Phase 6. AC and CA Emergent Relations Test In this phase, AC and CA emergent relations were evaluated. Correct and incorrect compounds are shown in Table 5. The procedures were otherwise the same as in Phase 4.

Results

Table 6 shows the percentage and number of correct responses during each training and testing session for each participant. In Phase 1 (simple successive discrimination training using differential responses), three participants (O, E, and I) required five sessions to meet the mastery criterion, and Participant A required six sessions. During Phase 2 (simple successive discrimination training using new differential responses), Participant O met the mastery criterion in a single session. Participants E and I met the mastery criterion in two sessions, and Participant A met the mastery criterion in three sessions. Although Participants E, I, and A underwent more than one session, they showed high accuracy even in the first session (95.8 %).

During the transfer-of-function test (Phase 3), three participants (O, E, and A) demonstrated 100.0 % correct responses in the presence of all of the stimuli (B1-R3, C1-R3, B2-R4, C2-R4). Participant I showed 83.3 % correct responses in the first session of the transfer-of-function test. This participant's responding was correct in all of the trials, with the exception of those in which C1 was presented (33.3 % correct responses). All of the errors occurred in the last four trials with

Table 6 Percentage and Number of Correct Responses in Each Session During Training and Testing Phases in Experiment 2

Phase	Participant			
	O	E	I	A
1. Simple discrimination training using differential responses (R1/R2)	62.5 (15/24)	33.3 (8/24)	54.1 (13/24)	50.0 (12/24)
	50.0 (12/24)	70.8 (17/24)	33.3 (8/24)	62.5 (15/24)
	45.8 (11/24)	75.0 (18/24)	79.1 (19/24)	54.1 (13/24)
	70.8 (17/24)	95.8 (23/24)	91.6 (22/24)	79.1 (19/24)
	100.0 (24/24)	100.0 (24/24)	100.0 (24/24)	91.6 (22/24)
	—	—	—	100.0 (24/24)
2. Simple discrimination training using new differential responses (R3/R4)	100.0 (24/24)	95.8 (23/24)	95.8 (23/24)	95.8 (23/24)
	—	100.0 (24/24)	100.0 (24/24)	95.8 (23/24)
	—	—	—	100.0 (24/24)
3. Transfer-of-function test	100.0 (24/24)	100.0 (24/24)	83.3 (20/24)	100.0 (24/24)
	—	—	100.0 (24/24)	—
4. AB/BC emergent relations test	100.0 (48/48)	100.0 (48/48)	95.8 (46/48)	100.0 (48/48)
5. BA/CB emergent relations test	100.0 (48/48)	100.0 (48/48)	100.0 (48/48)	100.0 (48/48)
6. AC/CA emergent relations test	100.0 (48/48)	100.0 (48/48)	100.0 (48/48)	100.0 (48/48)

C1. After this test session, Participant I completed an additional Phase 1 training session and then a second transfer-of-function test session. In the second session, Participant I showed 100.0 % correct responses.

During the remaining emergent relations tests (Phases 4, 5, and 6), with one exception, participants responded correctly in 100.0 % of the trials. Participant I made two errors in the first block of Phase 4.

Discussion

Consistent with previous findings (e.g., Barnes and Keenan 1993; Smeets et al. 1997, 2001), a simple discrimination training procedure that used differential responses generated functional classes for all of the participants. Only Participant I made errors during the first test session in the presence of C1. After one additional training session, the participant made all correct responses in the second transfer-of-function test session.

In the emergent relations tests, all of the participants showed the emergence of the tested conditional relations (AB, BC, BA, CB, AC, and CA). These findings extend the literature on increasing the number of stimuli and number of emergent conditional discriminations following simple discrimination training with differential responses (c.f., Smeets et al. 1997). Considering that Sidman's (2000) account holds that equivalence relations consist "of ordered pairs of all positive elements that participate in the reinforcement contingency" (Sidman 2000, p. 131), equivalence classes can be established and tested by any reinforcement procedure that involves ordered pairs of related events. In the present study, the ordered pairs of the reinforcement contingency included the differential, or class-specific, responses. According to Sidman, the response that was held in common across the A1, B1, and C1 training contingencies, for example, allowed those stimuli to merge as one equivalence class. The test performance demonstrated the interchangeability of the stimuli, given that all of the elements of the compounds could be "separated" and "recombined" into new and untrained compounds (e.g., Stromer et al. 1993). This performance was similar to the study by Debert et al. (2007), in which the participants were also exposed to training that involved compound stimuli.

General Discussion

The present results appear to demonstrate the formation of equivalence classes based on three-term contingencies, as described by Sidman (1994, 2000). The results also support the argument that the current differences in the definitions of functional and equivalence classes do not necessarily indicate different behavioral processes (Sidman 1994). The present findings support Sidman's hypothesis that functional classes can imply equivalence classes. One implication of this hypothesis would be to either abandon or expand the original behavioral definition of equivalence based on the properties of reflexivity, symmetry, and transitivity (e.g., Sidman and Tailby 1982), which can be assessed only via four-term contingency procedures (Sidman 1994). Therefore, the present findings also call for adopting Sidman's (2000) definition, which permits the use of different training and testing procedures to establish and evaluate the emergence of equivalence relations.

The literature on stimulus equivalence with nonhumans has also developed training and testing procedures that are different from the usual MTS procedure to demonstrate the interchangeability between stimuli (e.g., Frank and Wasserman 2005; Sweeney and Urcuioli 2010; Urcuioli 2008, 2011). Alternative procedures to matching-to-sample have also been investigated in applied research (e.g., Critchfield 2014). Collectively, the positive results generated across distinct training and testing procedures may corroborate the generality of the processes that yield stimulus equivalence and emergent relations (Sidman 1994, 2000). As training and testing procedures develop beyond the standard MTS procedure, contributions to our understanding of the phenomena that are involved in stimulus equivalence and emergent behavior in different species and under different experimental conditions will consequently increase. Conversely, a failure to consider the findings from these disparate procedures as potentially related, whether through single or multiple behavioral processes, would seem shortsighted.

Future research should investigate simple discrimination procedures that involve defined responses and specific reinforcers. Additional research should also investigate whether simple discrimination procedures can produce equivalence classes in specific populations for whom MTS procedures have proven insufficient (e.g., young children and individuals with atypical development; e.g., Devany, Hayes, and Nelson 1986).

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References

Barnes, D., & Keenan, M. (1993). A transfer of functions through derived arbitrary and nonarbitrary stimulus relations. *Journal of the Experimental Analysis of Behavior, 59*, 61–81.

Barnes, D., Browne, M., Smeets, P., & Roche, B. (1995). A transfer of functions and a conditional transfer of functions through equivalence relations in three- to six-year-old children. *The Psychological Record, 45*, 405–430.

Critchfield, T. S. (2014). Online equivalence-based instruction about statistical inference using written explanation instead of match-to-sample. *Journal of Applied Behavior Analysis, 47*, 606–611.

Debert, P., Matos, M. A., & McIlvane, W. J. (2007). Conditional relations with compound abstract stimuli using a go/no-go procedure. *Journal of the Experimental Analysis of Behavior, 87*, 89–96.

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

Devany, J. M., Hayes, S. C., & Nelson, R. O. (1986). Equivalence class formation in language-able and language-disabled children. *Journal of the Experimental Analysis of Behavior, 46*, 243–257.

Frank, A. J., & Wasserman, E. A. (2005). Associative symmetry in the pigeon after successive matching-to-sample training. *Journal of the Experimental Analysis of Behavior, 84*, 147–165.

Goldiamond, I. (1962). Perception. In A. J. Bachrach (Ed.), *Experimental foundations of clinical psychology* (pp. 280–340). New York: Basic Books.

Goldiamond, I. (1966). Perception, language and conceptualization rules. In B. Kleinmuntz (Ed.), *Problem solving: Research, method and theory* (pp. 183–214). New York: Wiley.

Kastak, C. R., Schusterman, R. J., & Kastak, D. (2001). Equivalence classification by California sea lions using class-specific reinforcers. *Journal of the Experimental Analysis of Behavior, 76*, 131–158.

Lazar, R. (1977). Extending sequence-class membership with matching to sample. *Journal of the Experimental Analysis of Behavior, 27*, 381–392.

Markham, M. R., & Dougher, M. J. (1993). Compound stimuli in emergent stimulus relations: Extending the scope of stimulus equivalence. *Journal of the Experimental Analysis of Behavior, 60*, 529–542.

Perez, W. F., Campos, H. C., & Debert, P. (2009). Procedimento go/no-go com estímulos compostos e a emergência de duas classes de equivalência com três estímulos (Go/no-go procedure with compound stimuli and the emergence of two equivalence classes with three stimuli). *Acta Comportamentalia, 17*, 191–210.

Sidman, M. (1994). *Equivalence relations and behavior: A research history*. Boston: Authors Cooperative.

Sidman, M. (2000). Equivalence relations and the reinforcement contingency. *Journal of the Experimental Analysis of Behavior, 74*, 127–146.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*, 5–22.

Sidman, M., Wynne, C. K., Maguire, R. W., & Barnes, T. (1989). Functional classes and equivalence relations. *Journal of the Experimental Analysis of Behavior, 52*, 261–274.

Smeets, P. M., Barnes, D., & Roche, B. (1997). Functional equivalence in children: Derived stimulus–response and stimulus-stimulus relations. *Journal of Experimental Child Psychology, 66*, 1–17.

Smeets, P. M., Barnes-Holmes, D., & Roche, B. (2001). Derived stimulus–response and stimulus-stimulus relations in children and adults: Assessing training order effects. *Journal of Experimental Child Psychology, 78*, 130–154.

Stromer, R., McIlvane, W. J., & Serna, R. W. (1993). Complex stimulus control and equivalence. *Psychological Record, 43*, 585–598.

Sweeney, M. M., & Urcuioli, P. J. (2010). Reflexivity in pigeons. *Journal of the Experimental Analysis of Behavior, 94*, 267–282.

Urcuioli, P. J. (2008). Associative symmetry, antisymmetry, and a theory of pigeons' equivalence-class formation. *Journal of the Experimental Analysis of Behavior, 90*, 257–282.

Urcuioli, P. J. (2011). Emergent identity matching after successive matching training: I. Reflexivity or generalized identity? *Journal of the Experimental Analysis of Behavior, 96*, 329–341.

Vaughan, W. (1988). Formation of equivalence sets in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 14*, 36–42.

Wulfert, E., & Hayes, S. C. (1988). Transfer of a conditional ordering response through conditional equivalence classes. *Journal of the Experimental Analysis of Behavior, 50*, 125–144.