Revista Brasileira de Análise do Comportamento / Brazilian Journal of Behavior Analysis, 2006, Vol.2 nº. 1, 125-133

A FORMAÇÃO DE CLASSES DE EQUIVALÊNCIA VIA PAREAMENTO POR IDENTIDADE E DISCRIMINAÇÃO SIMPLES COM CONSEQÜÊNCIAS ESPECÍFICAS PARA AS CLASSES

EQUIVALENCE CLASS FORMATION VIA IDENTITY MATCHING TO SAMPLE AND SIMPLE DISCRIMINATION WITH CLASS-SPECIFIC CONSEQUENCES

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RESUMO

O desempenho de participantes humanos freqüentemente mostra aprendizagem de relações não diretamente ensinadas após o treino de discriminações condicionais entre estímulos fisicamente diferentes. Essas relações emergentes documentam a formação de classes de equivalência. O presente estudo investigou se conseqüências específicas paras as classes (i.e., reforçadores específicos usados para cada classe potencial durante o treino) também integram as classes de equivalência. Vários estudos anteriores sugeriram que as conseqüências específicas podem integrar as classes, entretanto, o treino nesses estudos inclui pareamento arbitrário e pareamento por identidade. No presente estudo, duas crianças autistas foram submetidas apenas a treino de reversões de discriminações simples e pareamento por identidade com conseqüências específicas paras as classes potenciais. Então, testes de pareamento arbitrário foram econduzidos. O desempenho das crianças evidenciou a formação de classes nestes testes, a despeito de elas não terem experiência de treino de pareamento arbitrário. Adicionalmente, um dos participantes mostrou evidência de formação de classes após treino de reversões de discriminação simples somente. Esses resultados tanto demonstram que as conseqüências reforçadoras de fato se tornam parte das classes de equivalência, quanto dão suporte à idéia de que equivalência surge das contingências de reforçamento e não é baseada em habilidades lingüísticas.

Palavras-chave: equivalência de estímulos, pareamento ao modelo, discriminação simples, reforçamento específico, efeito de conseqüência específica, retardo mental

ABSTRACT

Initially, this paper makes some distinctions between simple and conditional discrimination concepts and points to tHuman participant performances often show evidence of learning untrained relations when conditional discrimination training between physically dissimilar stimuli is conducted. These emergent relations document equivalence class formation. The current study investigated whether class-specific consequences (i.e. the specific reinforcers used for each potential class during training) also join the equivalence class. Several studies have suggested they do so. However, training in those studies typically included arbitrary matching and identity matching baselines. In the current study, two autistic children were trained on simple discrimination reversals and identity matching with class specific consequences. They were then given arbitrary matching probes. Performances of both children initially showed evidence of class formation on these tests, despite the fact that neither had received training on arbitrary matching. In addition, one of the participants showed evidence of class formation after simple discrimination reversal training alone. These results demonstrate that the reinforcing consequences do in fact become part of the stimulus equivalence class and provide support for the ideas that equivalence (1) arises from reinforcement contingency and (2) is not based upon language skills.

Key words: Stimulus equivalence, matching to sample, simple discrimination, outcome-specific reinforcement, differential outcomes effect, mental retardation

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This work was supported by CAPES and CNPq with financial help for a pos-doctoral fellowship at the University of Massachusetts Medical School for the first author under the supervision of the last author, and by NICHD Grant No. HD 39816. We thank "The New England Center For Children" (Southboro, Massachusetts, USA) for cooperation. We also thank Carol Pilgrim for doing a great job inspiring and encouraging the proposal of this research project. Correspondence should be addressed to Romariz Barros: *romarizsb@comcast.net* or *romariz@pesquisador.cnpq.br*.

Research on equivalence class formation investigates how dissimilar events become substitutable in the control of specific repertoires and in specific contexts (Sidman, 1994). A widely adopted experimental model to study this behavioral phenomenon (Sidman & Tailby, 1982) consists of initial conditional discrimination training with at least three stimulus sets. For example, the conditional relations AB and BC (where AB indicates selections of the comparisons B1 and B2 given samples A1 and A2, respectively, etc.) may be trained using the matching to sample procedure (MTS). Tests for the substitutability of the related stimuli present all possible recombinations of the stimulus sets: AA, BB, and CC (reflexivity tests); BA and CB (symmetry tests); AC (transitivity test), and CA (a combined symmetry and transitivity test).

One parsimonious explanation is that equivalence class formation results directly from exposure to reinforcement contingencies (Sidman, 1994, 2000). According to this theoretical position, equivalence class formation is a basic behavioral process (Sidman, 1990) and equivalence classes "consist of all ordered pairs of all positive elements that participate in the contingency" (Sidman, 2000, p. 128). If this position is correct, then equivalence classes may include not only antecedent stimuli, but also reinforcing stimuli and responses to the stimuli if they are both (a) specific to each class and (b) different for each class.

There is empirical support for the basic-process position. Several previous studies with human participants have documented equivalence classes that include class-specific reinforcers (Dube & McIlvane, 1995; Dube, McIlvane, Mackay, & Stoddard, 1987; Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989; Joseph, Overmier, & Thompson, 1997; McIlvane, Dube, Kledaras, de Rose, & Stoddard, 1992; Pilgrim, 2004; Schenk, 1994).

By contrast, equivalence class formation based on specific responses is hard to document because of procedural difficulties (see Sidman, 2000). Some relevant research has been reported by Lionello-DeNolf and colleagues with pigeon subjects (Lionello-DeNolf & Urcuioli, 2003; Urcuioli, Lionello-DeNolf, Michalek, & Vasconcelos, 2006). For example, Lionello-DeNolf and Urcuioli showed that pigeons were able to select A1 and B1 comparison stimuli conditionally upon two different behavior patterns (DRL and FR response patterns) that they had performed by responding to a blank key (so that the behavior patterns worked as conditional stimuli). However, recent follow-up work has indicated that pigeons do not seem to form acquired equivalence classes in which the behavior patterns become part of the class despite the success of the baseline training procedure (Urcuioli et al., 2006). This result may not be surprising given the difficulty of establishing stimulus equivalence in this population (e.g., Lionello-DeNolf & Urcuioli, 2002). A different outcome may occur if humans are tested using the procedure. Indeed, recent findings indicate that when humans are tested using a similar procedure, the defined responses do become, part of the equivalence class (Shimizu, in press).

Dube and colleagues (1987) were the first to demonstrate class membership based on the relation that antecedent stimuli have in common with specific reinforcers (stimulus-reinforcer relations) in adults with mental retardation. In that study, two adults were trained on matching-to-sample (MTS) with two sets of four stimuli (each stimulus set included one auditory stimulus, one printed visual stimulus, one 3-dimensional object stimulus, and one edible reinforcer). Training consisted first of MTS with the visual and object stimuli. Thereafter, MTS training was given with the auditory stimuli as samples and the visual and object stimuli as comparisons. For both identity and arbitrary MTS training, reinforcement for correct matching was class-specific (e.g., choices of Comparison 1 after presentation of Sample 1 were reinforced with Food 1 whereas choices of Comparison 2 after presentation of Sample 2 were reinforced with Food 2). In test, symmetry and transitivity probe trials were inserted into the baseline. Both participants passed these tests, indicating that training had established two 3-member equivalence classes. Then, reinforcer probe trials were presented. On these test trials, the class-specific food reinforcers were presented either as samples (with the visual or object stimuli as comparisons) or comparisons (with either the visual, object, or auditory stimuli as samples). Again, both participants matched accurately on these probes, indicating that the food reinforcers themselves had become members of the class. Moreover, follow-up work with these same participants indicated that class-specific reinforcement following identity MTS training with novel stimuli was sufficient to cause those stimuli to merge into the respective equivalence classes. Dube and colleagues (1989) later replicated Dube and colleagues (1987), showing that class-specific reinforcers could serve as the source of class expansion even when the reinforcers had no explicit MTS function (i.e., the food items never appeared as samples or comparisons in MTS).

The documentation of equivalence class formation based on stimulus-reinforcer relations further implies that equivalence classes could be established with procedures less elaborate (i.e. procedures involving fewer components such as simple discrimination procedures) than the widely used arbitrary MTS procedure (Sidman, 1994, 2000). Two procedural possibilities are identity MTS, in which sample and correct comparison stimuli are physically identical, and repeated reversals of simple simultaneous discriminations in which there is no sample and the same stimulus (or set of stimuli) is correct on every trial (cf. Vaughan, 1988).

The former procedural alternative has been explored experimentally (Dube & McIlvane, 1995; Schenk, 1994). Dube and McIlvane (1995), for example, carried out two experiments in order to examine emergent MTS based on stimulus-reinforcer relations in which participants were not trained on arbitrary MTS prior to testing. Eight young adults with mental retardation (four of whom had prior experience with arbitrary MTS) were trained on identity MTS (AA and BB) with outcome-specific reinforcement contingencies: selections of the comparisons A1 and B1, given samples A1 and B1, respectively, produced the reinforcer R1; selections of the comparisons A2 and B2, given the samples A2 and B2 respectively, produced the reinforcer R2. Tests for class formation assessed the emergent relations AB and BA. The performances of three of the experienced participants and one of the naive participants were consistent with equivalence class formation. Experiment 2 examined the matching performances of the four participants who did not show evidence of class formation. All four participants were given AB MTS training with outcome-specific reinforcement contingencies: all selections of comparisons B1 and B2 conditionally upon samples A1 and A2, respectively, were followed by the presentation of reinforcer R1 or R2, respectively. Only two of them mastered the arbitrary AB matching via direct training. These two participants also demonstrated emergent matching BA (symmetry), which could be based on sample-comparison relations and not necessarily on the stimulus-reinforcer relations. Both participants were given a CC identity MTS with outcome-specific reinforcement contingencies (all selections of comparisons C1 and C2 conditionally upon samples C1 and C2, respectively, were followed by the presentation of reinforcer R1 or R2, respectively). Then, both were given AC and CA tests. Only one of these two participants demonstrated AC and CA emergent matching based on stimulus-reinforcer relations.

Schenk (1994, Experiment 2) also examined the possibility of class formation in the absence of arbitrary MTS training. Eight typically developing 5-year old children were trained on identity MTS with four stimulus sets and outcome-specific reinforcement contingencies (as described above). Six of the eight children then showed evidence of class formation in testing with probe trials for each possible relation. Upon completion of probe tests for equivalence, the children were given a test in which pictures of the reinforcers (different colored beads that could be exchanged later for a favorite picture) were presented as samples and comparisons. The same six children who passed tests for equivalence also matched accurately on this test, indicating that the non-edible reinforcers had become members of the equivalence class.

To date, however, little work has been done investigating the second procedural alternative mentioned above: repeated reversals of simple simultaneous discriminations. In this procedure, participants are given a choice between two stimuli on every trial and choices of one of those stimuli are reinforced. Once the task is learned, the reinforcement contingencies are reversed until a high accuracy is re-established. Reversals continue until choices reverse in accordance with the changed reinforcement contingencies within the first few trials of the reversal session. For example, Vaughan (1988) trained pigeons on this procedure using 40 different slides of trees (20 slides for each stimulus set). After a series of repeated reversals, pigeons began to change their responses to the slides after experiencing just a few trials with the changed contingencies. This experiment was the first to document functional class formation in nonhuman subjects. More recently, Kastak, Schusterman, and Kastak (2001) have shown that stimulus equivalence classes can be established in California sea lions by training a series of simple discrimination reversals. The initial training was a systematic replication of Vaughan (1988). Interestingly, both sea lions did not show evidence of reversal learning (their performance was not accurate in the reversed contingencies after a large number of sessions) until the introduction of class-specific reinforcement. When class-specific reinforcement was removed, reversal performance deteriorated, and then improved again with its reinstatement. The sea lions were also able to match accurately when the stimuli from the simple discrimination were later presented as samples and comparisons in MTS.

The results from Kastak and colleagues (2001) are especially encouraging in the current context because they suggest that training with class-specific reinforcement may increase the likelihood of the emergence of equivalence in populations in which we would otherwise not observe it. This in turn provides further evidence that reinforcing stimuli do in fact become members of equivalence classes. The present work sought to bring together the training procedures used in both the human (Dube & McIlvane, 1995; Schenk, 1994) and animal paradigms (Kastak and colleagues, 2001; Vaughan, 1988) in order to demonstrate the inclusion of the reinforcer in stimulus class formation. Two autistic children were trained on simple simultaneous discrimination reversals with both food and visual stimuli prior to being given training on identity MTS with the visual stimuli (stimulus sets A, B, and C). They were then tested for equivalence class formation with arbitrary MTS probe trials. A final test for class formation was given after discrimination reversal training only, using a fourth set of stimuli (D; no identity MTS training was given with this set). To our knowledge, this is the first attempt to demonstrate class formation between reinforcing and visual stimuli solely after simple discrimination training in this population.

METHOD

Participants

Two 9-year old minimally verbal children (a boy, RBG, and a girl, COB) diagnosed with autism participated in this experiment. RBG's mental age equivalent scores were 2.33 years on the Peabody Picture Vocabulary Test (PPVT) and 2.0 years on the Expressive One-Word Picture Vocabulary Test (EOWPVT). COB's scores were 2.83 on the PPVT and 3.25 on the EOWPVT. Both had been trained previously to exchange plastic poker-chip tokens for food items. Neither participant had any prior experimental experience. Sessions lasted 15 to 20 minutes and were conducted three times per week in a laboratory located in their school building.

Apparatus

The laboratory consisted of two rooms: a programming area for the experimenters and a teaching area where the participants interacted with the apparatus (see Lionello-DeNolf & McIlvane, 2003 for additional details). The teaching area consisted of three walls, one directly in front of the participant, and two at 120-degree angles from the front panel. A countertop 75 cm above the floor and 20 cm deep spanned all three panels.

The front panel included a modified, automated Wisconsin General Test Apparatus that was used for discrimination training with food items. During trials, the participant obtained food and other items from two compartments *with transparent sliding doors. Each door was locked and unlocked by a controlling computer located in the programming area. The floor of each compartment contained a moving platform that was used to present or remove items. Two additional* food wells *without doors, located below the compartments described above, were used to dispense foods. The compartments were equipped with lights that were used to implement prompting procedures (described below). When the compartments were in use, two experimenters controlled the apparatus from the programming area, where they remained throughout training sessions. One experimenter entered commands into the controlling computer; the other experimenter loaded and unloaded the compartments and dispensed foods into the food wells as required. The participants' behavior was monitored at all times via television cameras in the teaching area.*

Each side panel of the teaching area contained speakers for auditory stimuli and a

17" LCD flat panel touch-screen connected to a networked Macintosh G4 computer (located in the programming area). In the present experiment, the right-side panel was used for visual discrimination training with two-dimensional visual stimuli presented on the touch-screen monitor.

Participant COB received outcome-specific tokens in some sessions. Prior to these sessions, a removable device containing two tubes was attached to the apparatus counter. COB used these tubes to sort black and pink tokens according to color (cf., Schenk, 1994).

Stimuli

Before the first experimental training session, a food preference assessment was conducted to select two highly preferred food items for each participant. Four different food items, recommended by the children's teachers, were presented on a tabletop in pairs for one 36-trial session, with an equal number of trials for each possible combination of food items and position (left and right). For RBG, Skittles (a sugar based fruit flavored and colorful candy) and potato chips were preferred. For COB, Snocaps (a milk chocolate candy shaped like bottle caps and covered with a white sugar toping) and Skittles were initially preferred. After 7 sessions, COB indicated a change of preference and small pieces of Slim Jim (a dried meat snack food) were substituted for Skittles.

The visual stimuli displayed on the computer screen were non-representative black shapes (geometric forms, etc.) superimposed on 5 x 5 cm white squares, with a light gray screen background. Each stimulus could be presented in any of nine positions of a 3 x 3 matrix centered on the screen. Four sets of two stimuli were used, here termed A (A1 and A2), B (B1 and B2), C (C1 and C2), and D (D1 and D2).

Procedure

After the food preference assessment, participants were given pre-training sessions in which they (a) explored the teaching area, and (b) learned to manipulate the compartment doors and to take foods from the compartments and food wells. Each step of the experimental procedure is listed in Table 1. Procedural details are presented in the text.

Simple discrimination with food items as stimuli. *Initially (Step 1 in Table 1) participants were given simple discrimination training with the food items identified in the preference assessments. Every session consisted of 30 trials. Each trial began with presentation of the two food items in the compartments. If the participant touched the door of the compartment containing the food designated as S+ for that session, the door was unlocked and s/he gained access to the S+ food item. If s/he touched the S- door, the foods were removed from both compartments. Left and right compartments were S+ equally often.*

A delayed cue procedure was used to reduce the number of errors during this initial food discrimination phase. Both compartments were lit as trials began, but, after a programmable delay, the light in the S- compartment was turned off to make it easier for the participant to discriminate the S+. As training progressed, the programmable delay was increased gradually to give the participant an opportunity to make his or her choice before the cue. Eventually, the delay was so long that every choice occurred before the cue. The acquisition criterion was selections of the S+ food before the cue on at least 14 of the final 15 trials in a session. In the session following acquisition, the reinforcement contingency was reversed: the former S+ food was designated S- and vice-versa. The same

Table 1

Each stage of training in chronological order. See text for details.

Step	Description
1	Simple simultaneous discrimination and reversals with food item in the compartments
2	Simple simultaneous discrimination and reversals with Set A visual stimuli on the touch screen
3	Identity matching to sample (MTS) with Set A stimuli (AA)
4	Simple simultaneous discrimination and reversals with Set B visual stimuli on the touch screen
5	Identity MTS with Set B stimuli (BB)
6	Identity MTS with Sets A and B stimuli intermixed (AA, BB)
7	Gradual introduction of intermittent reinforcement in AA and BB training
8	Tests for class formation: AB and BA MTS
9	Simple simultaneous discrimination and reversals with Set C visual stimuli
10	Identity MTS with Set C stimuli and tests for class formation: AC and CA MTS
11	Simple simultaneous discrimination and reversals with Set D stimuli and tests for class formation: AD and DA MTS (note: no training on identity MTS with Set D stimuli)

acquisition criterion was applied to the reversed discrimination. After reaching this criterion, another reversal of the contingencies presented the baseline discrimination once again. In all, there were three successive contingency reversals so that each stimulus functioned twice as S+ and twice as S-.

Simple discrimination with visual stimuli presented on the computer screen. *Next, a procedure similar to that described above was used to train simple simultaneous discriminations with visual stimuli presented on the computer touch screen (Steps 2, 4, 9, and 11 in Table 1). Computer sessions were comprised of 36 trials. Each trial began with presentation of the two visual stimuli in any among nine possible positions on the computer screen. If the participant touched the stimulus designated as S+ for that session, a sound and a piece of food were presented. Sound 1 or Sound 2, as well as Food 1 or Food 2, were presented as consequences for correct responses to stimuli belonging to potential classes (? Ou retirar o do final1 or 2 respectively). So, when A1, B1, C1, or D1 functioned as S+, Food 1 and Sound 1 were presented as the consequence for selecting the S+. When A2, B2, C2, or D2 served* *as S+, Food 2 and Sound 2 were presented as the consequence for selecting the S+. If the participant touched S-, the trial ended without reinforcement. Each position on the computer screen was used to present S+ equally often. Different from the previous phase using food as stimuli, the delayed cue procedure was not used in this phase of training.*

With stimulus Set D (Step 11), seven (instead of three) reversals of the simple discrimination were conducted, in order to balance the amount of reinforcement with stimulus sets A, B, and C (which were presented in both simple and conditional discrimination). Two reversals occurred between sessions, as described above, and five reversals occurred within sessions, first with one reversal per session following at least 16 of 18 consecutive correct, and finally with two per session following at least 10 of 12 consecutive correct. In order to reduce the frequency of errors, the first trial of each within-session reversal presented only the S+ stimulus.

Identity MTS. *A zero-delay identity MTS procedure was used in Steps 3, 5, 6, 7, and 10 (see Table 1). Every trial started with the presentation of a sample stimulus in any of 9 positions of a 3 x 3 matrix on the computer screen. When the participant touched the sample, it disappeared and two comparison stimuli were presented immediately. The comparisons appeared in any of the nine positions except for the position that had just been used to display the sample stimulus on that trial. When the participant touched a comparison stimulus, both comparisons disappeared from the computer screen. If the participant touched the comparison that was identical to the sample, the consequence was Sound 1 and Food 1 if the correct stimulus was A1, B1, or C1; the consequence was Sound 2 and Food 2 if the correct stimulus was A2, B2, or C2. A 6 s inter-trial interval (ITI) followed the consequence. If the participant touched the non-matching comparison, the ITI began immediately and the session continued to the next trial. In Step 3, when the identity matching procedure was introduced, the trial sequence varied across sessions in the following manner. In the first session, A1 and A2 sample trials were presented in 6-trial blocks. In subsequent sessions, A1 and A2 sample trials were presented in 3-trial blocks, and finally A1 and A2 sample trials were presented in an irregular alternation pattern. In all subsequent MTS sessions (i.e., with other stimulus sets), sample stimuli alternated irregularly across trials*

Intermittent reinforcement. *The purpose of Step 7 was to prepare the participant for unreinforced test trials by gradually introducing non-reinforcement following correct responses on baseline trials. To maintain the average density of reinforcement, every unreinforced trial was followed by a* double-reinforcer trial *of the same potential class. For example, after an unreinforced A1A1 MTS trial, the next trial was always either an A1A1 trial or a B1B1 trial, and two reinforcers were delivered following a correct response on the second trial (no reinforcer was delivered if the participant made an incorrect choice on the second trial). The number of unreinforced baseline trials per session was gradually increased over three sessions until every session included eight unreinforced trials. The criterion to initiate testing was always correct responses on at least 35 of 36 trials for two consecutive baseline sessions with intermittent reinforcement.*

Class formation tests. *Emergent relations were then tested in a 36-trial block that included 28 baseline trials (4 unreinforced) and 8 tests trials (4 unreinforced) interspersed among the baseline trials (Steps 8, 10, and 11). A zero-delay arbitrary MTS procedure was used for all* *class formation tests. AB and BA relations, AC and CA relations, and AD and DA relations were tested in separate sessions. For example, in the AB test, there were 28 baseline AA and BB trials (7 A1A1, 7 A2A2, 7 B1B1, and 7 B2B2, one of each unreinforced) and 8 AB test trials (4 A1B1 and 4 A2B2, with the two first trials of each type unreinforced). In test blocks, unreinforced trials were always followed by double-reinforcer trials, regardless of whether the test-trial response was or was not consistent with class formation, and provided that the response on the following baseline trial was correct. The criterion to demonstrate each tested relation was 7 of 8 responses on test trials consistent with the experimentally defined classes.*

RESULTS

Table 2 shows, for each training session, the duration of the delayed cue and accuracy scores (number of correct choices / number of trials) for responses that occurred before and after the cue. The data presented in Table 2 show that both participants learned the Step 1 simple discriminations and reversals with the edible stimuli. The delayed cue procedure was apparently effective. Early in training, the number of responses after the cue was relatively high, but after a few sessions this number dropped considerably and the participants performed the discrimination accurately without the prompt (i.e., before the cue).

TABLE 2
RESULTS OF SIMPLE DISCRIMINATION TRAINING WITH FOODS

Participant	Session	Discrimination	Delay (seconds)	Correct /Total Before Cue	Correct /Total After Cue
COB	1	F1+, F0-	0.5; 0.75; 1.0	15/16	14/14
	2	F1+, F0-	1.0; 2.0	23/23	07/07
	3	F0+, F1-	0.25; 0.5; 1.0	03/03	25/27
	4	F0+, F1-	1.0; 2.0; 3.0	16/18	12/12
	5	F0+, F1-	3.0; 6.0	28/29	01/01
	6	F1+, F0-	6.0	30/30	0
	7	F0+, F1-	6.0	24/25	0
	8	F2+, F1-	6.0	11/15	0
	9	F1+, F2-	6.0	13/14	01/01
RBG	1	F1+, F2-	0.5	02/03	28/28
	2	F1+, F2-	1.0; 1.5	01/01	27/29
	3	F1+, F2-	1.5; 3.0;6.0	07/07	23/23
	4	F1+, F2-	6.0;	30/30	0
	5	F2+, F1-	0.5; 1.0; 2.0; 4.0; 6.0	03/03	27/27
	6	F2+, F1-	6.0	29/30	0
	7	F1+, F2-	6.0	29/31	0
	8	F2+, F1-	6.0	28/30	0

Note: Accuracy is shown as number of correct choices / number of trials both before and after the cue. Multiple delayed-cue delay durations reflect changes in the delay every 5 trials within the session. For COB, F0, F1, and F2 indicate Snowcaps, Skittles, and Slim Jims, respectively. For RBG, F1 and F2 indicate Skittles and potato chips, respectively.

No prompting procedures were used for training simple discriminations and reversals with the computer-presented visual stimuli. Data presented in Table 3 show that both participants, after learning the first discrimination in a few sessions, performed accurately on the reversals and return to baseline discriminations with all stimulus sets (A and B for COB and A, B, C, and D, for RBG). With stimulus Set D, RBG's accuracy on within-session reversals was high (Table 3, Set D, Sessions 4, 5, and 6). Due an experimenter error, no reversals of the discrimination B1+/ B2- were trained.

Table 3
Accuracy on Discrimination Training with Computer-Presented Visual Stimulus Sets

Participant	Session	Discrimination	Correct /Total
COB	1	A1+, A2- (Con1)	22/36
	2		34/36
	3	A2+, A1- (Con2)	28/35
	4		36/36
	5	A1+, A2- (Con1)	35/36
	6	A2+, A1- (Con2)	36/36
	1	B1+, B2- (Con1)	34/36
	2	B2+, B1- (Con2)	35/36
RBG	1	A1+, A2- (Con1)	18/35
	2		22/36
	3		29/36
	4		36/36
	5	A2+, A1- (Con2)	34/36
	6	A1+, A2- (Con1)	33/36
	7		36/36
	8	A2+, A1- (Con2)	34/36
	1	B1+, B2- (Con1)	22/36
	2	B1+, B2- (Con1)	35/36
	1	C1+, C2- (Con1)	33/36
	2	C2+, C1- (Con2)	35/36
	3	C1+, C2- (Con1)	35/36
	4	C2+, C1- (Con2)	18/20
	1	D1+, D2- (Con1)	33/36
	2	D2+, D1- (Con2)	35/36
	3	D2+, D1- (Con2)	18/18
	4	D2+, D1- (Con2)	18/18
		D1+, D2- (Con1)	17/18
	5	D1+, D2- (Con1)	10/12
		D2+, D1- (Con2)	12/12
		D1+, D2- (Con1)	12/12
	6	D2+, D1- (Con2)	11/12
		D1+, D2- (Con1)	12/12
		D2+, D1- (Con2)	12/12

Note: Accuracy is shown as number of correct choices / number of trials. Con1 and Con 2 indicate Food 1 with Sound 1 and Food 2 with Sound 2 as the consequence for correct responses.

Table 4
Results of the Initial Identity MTS Training Sessions

Participant	Session	Trials Sequence	A1A1 Correct /total	A2A2 Correct /total
COB	1	6-trial blocks	17/18	18/18
	2	3-trial blocks	18/18	18/18
	3	random	18/18	18/18
	4	random	18/18	18/18
RBG	1	6-trial blocks	0/18	15/18
	2	6-trial blocks[a]	05/06	17/18
	3	3-trial blocks	18/18	18/18
	4	random	16/18	18/18
	5	random	18/18	18/18

Note: Accuracy is shown as number of correct choices / number of trials. [a] No S- was presented in the first two 6-trial blocks for the sample A1 only.

Table 4 shows the accuracy score for each sample stimulus during the initial sessions of AA MTS training. Accuracy was high after just a few training sessions. COB's accuracy was high from the beginning. RBG showed no conditional control in the first session, choosing A2 on almost every trial. In the second session, the S- (A2) was not presented for the first 12 A1A1 trials, so that there were no errors. When the S- was reintroduced in the thirteenth trial, the performance was very accurate.

Accuracy scores for both participants were always at least 95% in every baseline identity MTS block, including (a) all returns to baseline after tests and (b) when new identity MTS tasks were introduced (BB for COB and RBG, and CC for RBG). Thus, there was strong evidence of generalized identity matching. No disruption of the performance was found when the intermittent reinforcement was gradually introduced. The accuracy of all discriminations was always perfect for both participants.

Figure 1 presents the data for all class formation tests. Every test block was always preceded by return to baseline (data not shown in Figure 1). For both participants, there was strong evidence of class formation in the initial AB test (first pair of bars in each panel in Figure 1): COB and RBG made class-consistent choices on 8/8 and 7/8 trials, respectively.

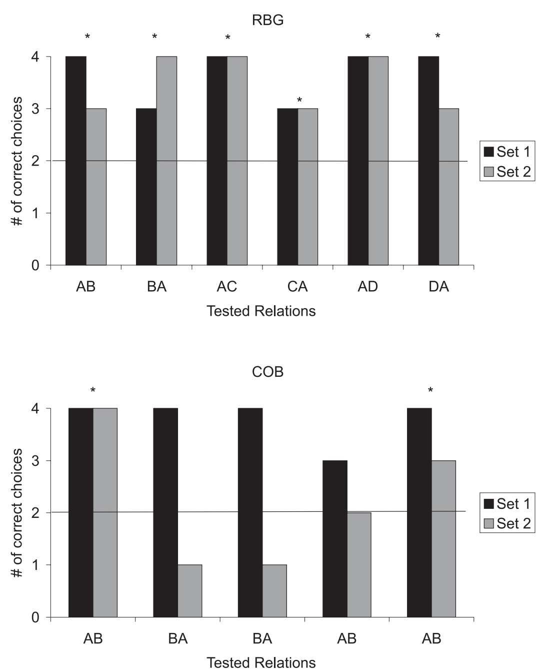

Figure 1. Number of correct choices for each participant on each relation tested (Steps 8, 10, and 11). * indicates accuracies that met the criteria for stimulus class formation. Chance performance line is placed at the level of two correct choices.

In the baseline sessions before COB's second test, she started tasting and then throwing away the foods instead of eating them. In addition, she began to demand alternative food items (such as pepperoni or Kit Kats) both during the session and after the session was completed. Her performance did not show any evidence of class formation in two repetitions of the second test (BA), nor in a re-presentation of the AB test that she had previously passed. To address the problem of throwing away foods (and of shifting reinforcer preferences), we introduced a token procedure. Correct choices of A1 and B1 stimuli produced pink tokens, and correct choices of A2 and B2 produced black tokens. Tokens were dispensed into the food wells below the compartments. After sessions, pink tokens were exchanged for a choice between Skittles, Snocaps (chocolate Non Pareils), or Kit Kat Bites, and black tokens were exchanged for a choice between pieces of pepperoni, beef jerky, or Slim Jims. When the AB test was again presented, there was strong evidence of class formation (final pair of bars in Figure 1). At that time, however, COB started presenting a variety of behavioral problems during sessions (e.g. climbing upon the apparatus countertop, spitting, shouting), as well as aggressive behavior in the classroom before and after sessions. We interpreted these behavioral problems as an indication that COB no longer wished to participate in the experimental sessions and her participation was suspended at that point.

In subsequent tests, RBG's performance was always highly consistent with class formation. The outcomes of his AD and DA tests (final two pairs of bars in Figure 1,) are especially interesting because RBG had never been exposed to any matching task with the Set-D stimuli. His only experience with these stimuli was in simple-discrimination reversals with outcome-specific consequences.

DISCUSSION

Two autistic children were taught a series of simple discrimination reversals and identity matching problems with class-specific consequences for correct (experimentally defined) choices. Both of the participants showed strong evidence for equivalence class formation on subsequent arbitrary matching probes that involved two of the stimulus sets (i.e., AB matching), despite not having been given training on arbitrary matching. Participant RBG also showed evidence of class formation with all the trained stimuli (i.e., AB, BA, AC, CA matching). He also showed strong evidence for class formation after being trained solely on the simple discrimination reversal procedure (i.e., AD and DA matching). These data corroborate findings of previous studies suggesting that equivalence class formation can be obtained in a set of simple discrimination training and reversals (Kastak,et al., 2001; Sidman, Wynne, Maguire, and Barnes, 1989; Vaughan, 1988).

These results extend the findings of Dube and McIlvane (1995) and Schenk (1994). In those studies, adults with mental retardation and typically developing 5-year old children, respectively, showed evidence of class formation after identity matching training with specific consequences. In neither study, however, were the participants trained on simple discrimination reversals. In addition, some of those participants had had pre-experimental training on arbitrary matching. By contrast, neither participant in the current study had been explicitly taught arbitrary matching before beginning this study. The present results confirm the findings of the aforementioned studies, namely that arbitrary matching training is not necessary for class-formation. The results from RBG further indicate that identity-matching experience with the stimuli is also not necessary if simple discrimination training with class-specific consequences is trained. The current study also replicates the work of Kastak and colleagues (2001), which showed that training simple discrimination reversals to sea lions was sufficient in creating a stimulus equivalence class.

Interestingly, COB's accuracy on arbitrary matching became disrupted at the same time that she began indicating a change in food preference. That matching performance experienced a disruption at this time is consistent with an interpretation that Foods 1 and 2 were the salient elements of the compound consequences for her. When she began to simply throw both foods on the floor, the consequences became the same for all trials — they were all items to throw. This situation can be compared to that of the sea lions in Kastak and colleagues (2001). In that study, simple discrimination reversals were first trained with non-differential reinforcement for correct choices (two types of fish were given in every session, regardless of the reinforced stimulus set). The sea lions did not learn the reversal task until reinforcement became class-specific: a different type of fish was used depending on which stimulus set was positive for that session. When the class-specific reinforcement was discontinued (i.e., non-differential reinforcement), the sea lions' accuracy on the task also fell. Both the data from COB and that of the sea lions strongly indicate that the food consequences had become part of the stimulus class.

These data also provide strong evidence that class-specific reinforcing stimuli can serve as nodal stimuli in equivalence classes. A nodal stimulus is one that is related to two or more other stimuli that, in turn, have not been directly related to each other (Fields & Verhave, 1987). For example, when AB and BC matching problems are trained, the B stimulus serves as the nodal stimulus. In the current experiment, the stimuli A1 and B1 (and also C1 and D1 for RBG) were related to the compound Consequence 1 (Sound 1 and Food 1), and A2 and B2 (and also C2 and D2, for RBG) were related to the compound Consequence 2 (Sound 2 and Food 2). Emergent AB relations are possible if the trained relations A1 – Consequence 1 and B1 – Consequence 1 are symmetric (Consequence 1 – A1, Consequence 1 – B1) and transitive (if A1 – Consequence 1 and Consequence 1 – B1, then A1 – B1). The same logic applies to the A2 – Consequence 2 and B2 – Consequence 2 relations. These emergent AB matching relations were initially found in the performances of both participants and provide evidence for the formation of two stimulus equivalence classes {A1-B1-Consequence 1} and {A2-B2-Consequence 2}, with the consequences functioning as the nodal stimuli. For RBG, the emergent relations BA, AC, and CA indicated that these classes also included C1 and C2, respectively.

Finally, the AD and DA emergent matching relations for Participant RBG provide experimental evidence that supports Sidman's (2000) proposal that matching to sample training may not be necessary to create equivalence relations. The simple discrimination procedure for Set D did not include stimulus-stimulus (sample-comparison) relations as part of the reinforcement contingency (i.e., because matching relations were not trained with the D stimuli prior to test). Rather, it was based on the three-term operant contingency (stimulus-response-reinforcer). All possible emergent relations, however, were not tested. Future studies need to further explore the potential for generating equivalence classes from the three-term contingency. Nonetheless, this finding is consistent with the theoretical position that equivalence relations arise from experiencing reinforcement contingencies (Sidman, 1994, 2000). The alternative theoretical approaches on the origin of equivalence class formation claim that equivalence is based on language skills (e. g. Dugdale & Lowe, 1990; Hayes, 1991; Horne & Lowe, 1996). Since the participants of the current study had almost no language skills, their performance is unlikely to have been based on such skills. Also, equivalence class formation in an identity matching to sample and simple discrimination context, as a result of using training contingencies with class-specific consequences, is one of the possible predictions directly derived from Sidman's theory (see Sidman, 2000).

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