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TRANSFER OF RELATIONAL STIMULUS CONTROL IN CONDITIONAL DISCRIMINATIONS

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Four adults were trained, using instructions and a matching-to-sample procedure, to select Stimulus B1 in the presence of Stimulus A1, B2 in the presence of A2, and B3 in the presence of A3 (the AB relations). Analogous PQ relations were trained. Afterwards, one stimulus in Set A and another stimulus in Set B appeared together as a sample, and novel Stimuli X1 and X2 were the comparisons. Responses to X1 were reinforced if the two stimuli in the sample had been related in the previous training (e.g., A1 and B1), and responses to X2 were reinforced if the two samples had not been related (e.g., A1 and B2). These were the ABX relations. In a test in which a stimulus of Set P and another of Set Q were the samples and X1 and X2 were the comparisons, 2 subjects selected X1 when the samples were P1 and Q1, P2 and Q2, and P3 and Q3, and selected X2 in the presence of the other six sample combinations (P1Q2, P1Q3, P2Q1, P2Q3, P3Q1, and P3Q2). Another subject showed the same responding after additional training. In the second experiment, 3 adults and an 11-year-old child were trained on AB, PQ, and ABX relations, and they showed the symmetrical relations BA and QP upon testing. Then all 4 of these subjects responded accurately to the PQX test. Results of Experiments 1 and 2 showed novel, consistent comparison selection based on the previously established relation between the two stimuli in the sample. In a third experiment, 3 of the subjects who had shown PQX relations were trained on EFX relations, with pairs of E and F stimuli as samples and X stimuli as comparisons. When the EF relations were tested, all 3 subjects consistently selected F1 in the presence of E1, F2 in the presence of E2, and F3 in the presence of E3 from the first trial. The results of Experiment 3 showed novel stimulus relations after training with a more complex conditional discrimination format.

Key words: stimulus-relation transfer, stimulus-relation relations, stimulus relations, conditional discriminations, matching to sample, symmetry, key press, adults, children

During the past 20 years, behavior analysts have become increasingly interested in stimulus control that emerges without direct training (e.g., Sidman, 1971; Sidman, Kirk, & Willson-Morris, 1985; Sidman & Tailby, 1982; Spradlin, Cotter, & Baxley, 1973). Typically, this emergent stimulus control has been studied with conditional discrimination procedures. One may train a human subject to select Comparison Stimulus B1 in the presence of Sample Stimulus A1 and Comparison Stimulus B2 in the presence of Sample A2, and then proceed to train the subject to select Comparison C1 in the presence of Sample B1 and Comparison C2 in the presence of Sample B2. Then, consistent conditional responding will be exhibited to a number of new arrangements and combinations of these stimuli, including conditional discriminations involving A stimuli as samples and C stimuli as comparisons, or C stimuli as samples and A stimuli as comparisons. Note that in this procedure A1 and C1 have been linked by common Stimulus B1, and A2 and C2 have been linked by common Stimulus B2. The stimuli A1, B1, C1 and A2, B2, C2 are said to be members of an equivalence class.

Emergent relations among stimuli can occur with stimuli that share no common samples or comparisons but that have been associated with the same consequence (Dube, McIlvane, Mackay, & Stoddard, 1987; Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989). In Dube et al.'s (1989) study, identity relations

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A1A1, B1B1, C1C1, and D1D1 and arbitrary relations A1B1 and B1C1 were trained with a particular reinforcer; identity relations A2A2, B2B2, C2C2, and D2D2 and arbitrary relations A2B2 and B2C2 were trained with a different reinforcer. After the subjects were tested for symmetry and transitivity (BA, CB, AC, and CA), Stimuli D1 and D2 were presented as samples or as comparisons with the other three pairs of stimuli. The subjects consistently selected the comparisons that had been associated with the same reinforcer as the current sample, even though Stimuli D1 and D2 had never been displayed together with the other stimuli in the previous training.

Other emergent relations among stimuli have also been demonstrated using procedures distinct from matching to sample, such as training to select a sequence of stimuli in a specific order (Lazar, 1977; Lazar & Kotlarchyk, 1986; Sigurdardottir, Green, & Saunders, 1990), and presenting complex samples in which one of several stimulus elements determines the correct comparison (Stromer & Mackay, 1990; Stromer & Stromer, 1990).

Studies on equivalence classes can be helpful for understanding linguistic relations such as the relations between a spoken word and an object or between an object and a written word (e.g., Sidman, 1971). However, relations other than equivalence are possible. For example, theoretical studies by Hayes (1991) and Hayes and Hayes (1989) expanded the analysis of relations to such nonequivalence relations as comparison, distinction, and opposition. Empirical research with conditional discrimination procedures showed that the relations of "same," "opposite," and "different" could be brought under contextual control (Steele & Hayes, 1991). This supports Sidman's (1986; also Bush, Sidman, & de Rose, 1989) contention that relations between environmental events vary according to the context. He suggested studies in which the relations among particular samples and comparisons could be determined by the presence of contextual stimuli. A recent demonstration of contextual control was made by Lynch and Green (1991).

It is apparent that humans perform in many other predictable ways when faced with novel combinations of stimuli in the environment, and they can show other types of relations besides the relations studied by Hayes, Sidman, and their associates. For example, there is a particular relation between Picasso and painting that is roughly the same as the relation between Shakespeare and literature. Those relations between particular arbitrary stimuli can be learned through specific training, and current research on stimulus equivalence can account for them. But there is a more complex relation when a person is asked if Picasso was a painter and responds "yes." In this case there is no particular stimulus that controls the response "yes," but it is the relation itself between Picasso and painting that controls the response. Because of that, if one is asked a different question, such as whether Shakespeare was a writer, the response would also be "yes." There is no substantial relation between the stimuli in the two questions (namely, between Picasso and Shakespeare or between painting and literature), but the stimuli share the particular relation of membership of a person to an art field, and this relation (plus the question) controls the same response in both cases. Conversely, when one is asked if Shakespeare was a painter, there is not a relation of membership, so the response would be different ("no").

Engelmann and others (Bereiter & Engelmann, 1966; Engelmann & Carnine, 1982) have studied procedures to teach children to say "yes" or "no" in the presence of pairs of stimuli having particular relations. They have shown that after children have been taught to say "yes" or "no" to some pairs of physically dissimilar stimuli depending on the relations between the members of the pair, they can respond correctly when presented to novel pairs bearing the same relations. However, research on stimulus control has not yet studied directly the problem of the relation between an arbitrary relation and a yes/no response. The current research was designed to study this type of relation with conditional discrimination procedures. Specifically, the research was designed to determine whether relations among sample and comparison stimuli that had been established in prior conditional discrimination training would control selection of comparisons in a new task.

EXPERIMENT 1

The initial goal of Experiment 1 was to design a conditional discrimination procedure that allows training comparison selection based on the previously established relations between two sample stimuli. This goal was achieved in two stages: First, relations between particular stimuli were established by training A-B relations through conditional discriminations. Second, an analogue of the yes/no response in the presence of particular relations was necessary. This was achieved with pairs of sample stimuli; the members of the pair had previously been related as sample-correct comparison or sample-incorrect comparison. The analogues of "yes" and "no" were two novel comparison stimuli, X1 and X2. The particular relations were trained as follows: Responses to X1 were reinforced if the two stimuli in the sample had had the sample–correct comparison relation, and responses to X2 were reinforced if the two stimuli in the sample had had the sample–incorrect comparison relation.

The second goal was to explore transfer of the relational control described above. After relations between novel stimuli were trained (P-Q relations), those stimuli were presented as paired samples and X1 and X2 were the comparisons in a test.

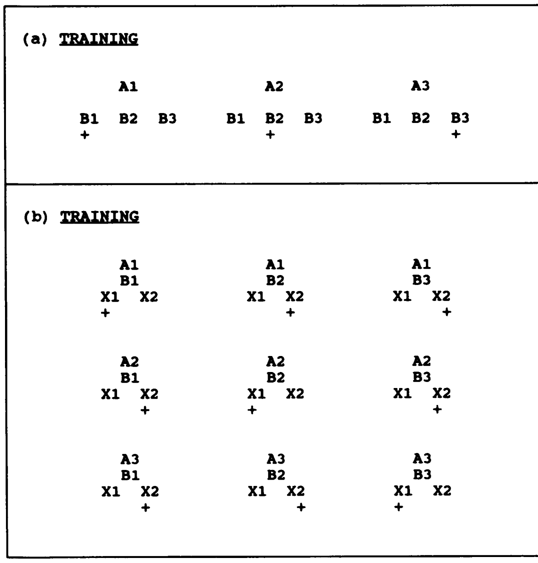

Fig. 1. Training configurations for the AB (a) and the ABX (b) relations. The stimuli in the upper part of each configuration were the samples; the two or three below were the comparisons. The plus signs indicate the correct comparisons.

Method

Subjects

Two adult Spanish-speaking males (LJS, age 33, and AUR, age 25) and 2 adult Spanish-speaking females (APS, age 23, and CRL, age 29), all friends or acquaintances of the experimenter, volunteered to serve as subjects. They were not given information concerning the goals or nature of the experiment prior to its completion, nor did they receive payment for serving in it.

Apparatus and Procedure

The experiment was carried out in a quiet room. A computer presented the stimuli and recorded the responses automatically. Subjects responded on the computer's keyboard.

After the subject was seated in front of the computer, the following instructions appeared in Spanish on the screen:

> Thank you for engaging in this game. Some pictures are going to appear on the screen, which may be accompanied by music. You can move this shape: "L." To do this, use the B, N and H keys.
>
> Moving this you can choose a picture. Most times, music will play, which will indicate you are correct. If a tone sounds, that means the response was incorrect. The game consists of responding correctly as much as possible. Press the space bar when you want to start.

If subjects asked which picture to select, they were told that they would learn this very easily. Only questions strictly related to the instructions were answered. The experimenter waited until the subject completed the first two or three trials before leaving the room. After the first session, the experimenter was not in the room with the subject. For each session, several phases were programmed in a sequence. The session ended after the completion of the last programmed phase or after 25 min, regardless of the number of responses.

Subjects came to the laboratory 3 to 5 days per week. Usually, one session was conducted each day. However, if the session was over within about 15 min, a second session was conducted.

Stimuli and types of stimulus configurations. The stimulus configuration for the first three baseline discriminations AB, PQ, and ABX and the tests for discrimination PQX are shown in Figures 1 and 2. The visual stimuli are shown in Figure 3. As can be seen in Figure 1a, the AB conditional discrimination was a three-choice discrimination in which A1, A2,

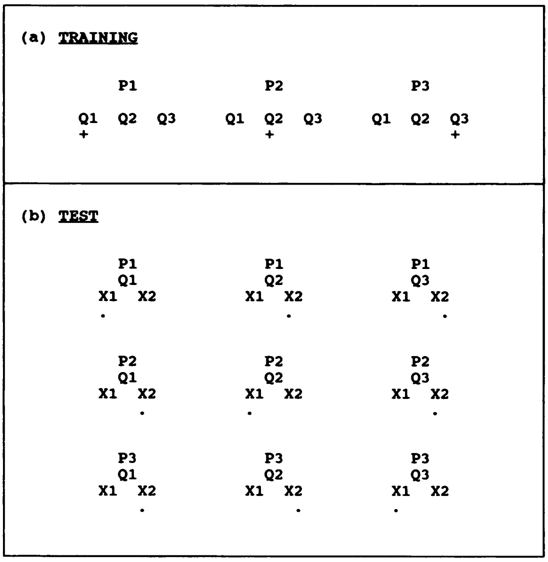

Fig. 2. Types of trials for training of PQ relations (a) and testing of the PQX relations (b). The stimuli in the upper part of each grouping are the samples; the two or three below are the comparisons. The plus signs indicate the correct comparisons for trained relations. The periods indicate the correct comparisons for the tested relations.

and A3 stimuli served as samples and B1, B2, and B3 as their respective related comparison stimuli. The PQ conditional discrimination was also a three-choice discrimination, with P1, P2, and P3 as sample stimuli and Q1, Q2, and Q3 as their related comparison stimuli (see Figure 2a). An additional EF conditional discrimination was analogous to AB and PQ. For the ABX discrimination training, the AB combinations served as samples for the selection of either X1 or X2 as comparison stimuli. As shown in Figure 1b, if one of the combinations A1B1, A2B2, or A3B3 was presented as the sample, then selection of X1 was designated as correct. If A1B2, A1B3, A2B1, A2B3, A3B1, or A3B2 was the sample, then X2 was correct. The EFX conditional discrimination was analogous to ABX. Finally, the test configuration consisted of the nine possible combinations of P and Q stimuli as samples and the X1 and X2 stimuli as comparisons (see Figure 2b). By analogy to ABX, responses to X1 in the presence of P1Q1, P2Q2, and P3Q3 and responses to X2 in the other cases were designated as correct.

Presentation of stimuli and consequences. The sample appeared in the center of the screen. When two stimuli comprised the sample (e.g., A1B1), they were displayed with one above the other. Comparisons appeared below the samples, from left to right. During AB, PQ, and EF training trials and BA and QP test trials, there were three comparisons. During ABX, PQX, and EFX presentations, there were two comparisons (X1 and X2). The position for each comparison varied randomly throughout the trials of all sessions. On each trial, the samples and comparisons were presented simultaneously (the subjects did not have to respond to the sample before presentation of the comparisons).

A cursor consisting of the symbol ⟂ appeared in the bottom left corner of the screen. An initial press to the B key moved the cursor to a position below the left comparison. An initial press on the N key moved the cursor to a position below the right comparison. When a trial involved two comparisons, additional presses on either the B or N key moved the cursor below the opposite comparison. When a trial involved three comparisons, pressing the B key moved the cursor one position to the left of the current position. If the cursor already was on the far left, pressing B moved it to the far right. Pressing the N key moved the cursor one position to the right, unless the cursor was at the far right, in which case it moved to the far left. The subject recorded selection of the comparison by pressing the H key, which resulted in the cursor moving upward towards the comparison, delivery of the consequence programmed for that trial, and advancement to the next trial.

In the initial phases of training a conditional discrimination, correct responses resulted in the presentation of a sequence of four musical notes 2.35 s long, followed by a 2-s intertrial interval (ITI) with a blank screen. Each incorrect response led to the presentation of a low-frequency tone 1.41 s long, followed by a 3-s ITI (a 1-s timeout in addition to the usual 2-s ITI). It was assumed that the sequence of notes functioned as a reinforcer and the tone and timeout as a punisher; the subjects' responding was consistent with this assumption. In subsequent training phases, the probability of reinforcement was gradually reduced (see Succession of Trials, below), but the negative consequence was administered after every error throughout training. During the test phases, no differential consequences were presented, and the ITI was always 2 s.

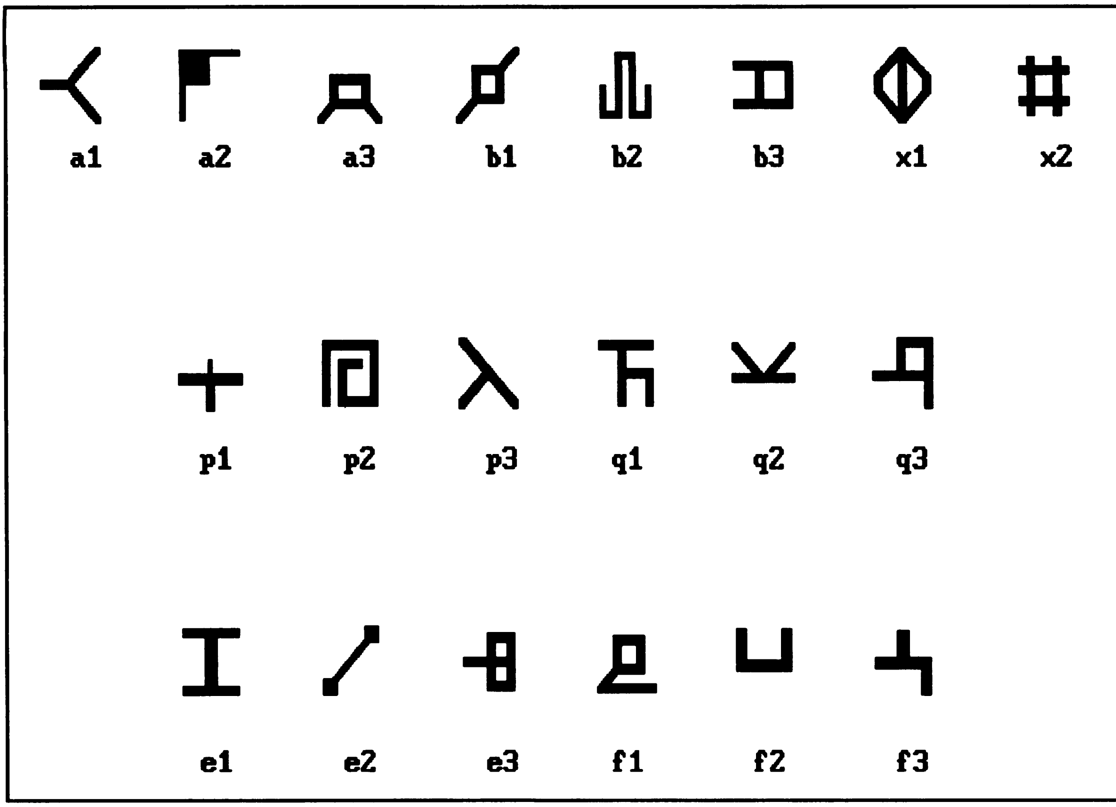

Fig. 3. Stimuli used in the experiments. Sets E and F were used only in Experiments 1 and 3.

Delayed prompt procedure. To facilitate training, a delayed prompt procedure (e.g., McIlvane & Dube, 1992; Touchette, 1971) was used in which the incorrect comparisons disappeared after being presented for 1 s during the first trial. When the response was correct, the interval during which the incorrect comparison was present was increased by multiplying the previous interval by 1.3. When the response was incorrect, the interval was decreased by dividing by 1.3. Responses after the incorrect comparison had disappeared increased the interval for the next trial but were counted as incorrect relative to advancement to the next phase of the experiment (see next section). They were also computed as incorrect in the results. The delayed prompt procedure was used only in the initial phases of training a conditional discrimination (see Table 1).

Succession of trials. The computer was programmed to present successive series of trials that are defined as phases. Table 1 shows the sequences of phases used in Experiment 1. In training phases, the same series of 24 programmed discriminations was repeated until the subject made correct responses in 8, 12, or 24 consecutive trials (the number depended on each phase; see Table 1 for details). Once the subject reached the criterion, a new phase followed. Each phase also varied in terms of the probability of reinforcement (for every response, the probability was 1.0; for every two responses, it was .5; and for every four responses, it was .25) or no reinforcement (test). Test phases ended after 24 trials, regardless of performance.

Specific Procedures

Table 1 summarizes the procedures, which are described below.

Identity matching. First, A1 and A2 were presented in a two-choice identity match-to-sample task. As shown in Table 1, the delayed prompt procedure was used, and the subjects received the consequences described above on each trial. This procedure continued until the

Table 1

Sequences of phases used in each session for each subject in Experiment 1. Shown are the phase, the stimulus relations, whether the delayed prompt procedure operated ("shaping"), the probability of reinforcement ("schedule"; "test" indicates no consequences), and the number of consecutive trials with correct responses needed to pass to the next phase. Lower case letters indicate the stimulus (or stimuli) in the relations that was (were) presented as sample(s). The numbers in the columns for Subjects APS, AUR, CRL, and LJS indicate the session(s) in which the phases were programmed.

					Subject			
Phase	Relations	Shaping	Schedule	Trials	APS	AUR	CRL	LJS
Sequence A								
1	A-A	yes	1	8	1	1	1	1
2	a1-B	yes	1	12	1	1	1, 2	1
3	a2-B	yes	1	12	1	1	2	1
4	a3-B	yes	1	12	1	1	2	1
5	a1a2-B	yes	1	12	1	1	2	1
6	A-B	yes	1	24	1	1	2	1
7	A-B	no	.5	24	1	1	2	1
8	A-B	no	.25	24	1	1	2	1
9	p1-Q	yes	1	12	1	1	2	1
10	p2-Q	yes	1	12	1	1, 2	2	1
11	p3-Q	yes	1	12	1	2	2	1
12	p1p2-Q	yes	1	12	1, 2	2	2, 3	1
13	P-Q	yes	1	24	2	2	3	1, 2
14	P-Q	no	.5	24	2	2	3	2
15	P-Q	no	.25	24	2	2	3	2
16	A-B	no	.25	24	2	2	3	2
17	A-B-X	yes	1	24	2	2, 3([a]), 4	3, 4	2, 3([a]), 4
18	A-B-X	no	.5	24	2	4	4	4
19	A-B-X	no	.25	24	2	4	4	4
20	P-Q-X	no	test	24	2	4	4	4
Sequence B								
1	A-B	no	.25	24	—	5	5	5–9
2	P-Q	no	.25	24	—	5	5	5–9
3	A-B-X	no	.25	24	—	5	5	5–9
4	P-Q-X	no	test	24	—	5	5	5–9
Sequence C								
1	A-B	no	.25	24	—	—	8, 9	10–14
2	P-Q	no	.25	24	—	—	8, 9	10–14
3	A-B-X	no	.25	24	—	—	8, 9	10–14
4	Q-P	no	test	24	—	—	8, 9	10–14
5	A-B-X	no	.25	24	—	—	8, 9	10–14
6	P-Q-X	no	test	24	—	—	8, 9	10–14
Sequence D								
1	A-B	no	.25	24	—	—	6, 7	15, 16
2	P-Q	no	.25	24	—	—	6, 7	15, 16
3	A-B-X	no	.25	24	—	—	6, 7	15, 16
4	B-A	no	test	24	—	—	6, 7	15, 16
5	A-B-X	no	.25	24	—	—	6, 7	15, 16
6	P-Q-X	no	test	24	—	—	6, 7	15, 16
Sequence E								
1	A-B	no	.25	24	3	6	—	17
2	P-Q	no	.25	24	3	6	—	17
3	A-B-X	no	.25	24	3	6	—	17
4	B-A	no	test	24	3	6	—	17
5	Q-P	no	test	24	3	6	—	17
6	A-B-X	no	.25	24	3	6	—	17
7	P-Q-X	no	test	24	3	6	—	17

Table 1 (*Continued*)

Phase	Relations	Shaping	Schedule	Trials	Subject APS	AUR	CRL	LJS
Sequence J								
1	e1-F	yes	1	12	—	—	10, 11	18
2	e2-F	yes	1	12	—	—	10, 11	18
3	e3-F	yes	1	12	—	—	10, 11	18
4	e1e2-F	yes	1	12	—	—	10, 11	18
5	E-F	no	1	24	—	—	10, 11	18
6	E-F	no	.5	24	—	—	10, 11	18
7	E-F	no	.25	24	—	—	10, 11	18, 19
8	F-E	no	test	24	—	—	10–12	18, 19
9	P-Q	no	.25	24	—	—	10–12	18, 19
10	Q-P	no	test	24	—	—	10–12	18, 19
11	E-F-X	no	1	24	—	—	10–12	18, 19
12	E-F-X	no	.5	24	—	—	12	19
13	E-F-X	no	.25	24	—	—	12	19
14	P-Q-X	no	test	24	—	—	12	19

[a] Due to a programming error, the computer did not pass to the next phase, even when the subject achieved the criterion of correct responses for that phase before the end of the session.

subject made eight consecutive correct responses when both the correct and the incorrect comparisons were present. Then the program automatically moved on to the first AB training phase.

AB training. To minimize errors, the samples were introduced one at a time. During Phase 2 of Sequence A, for example, only A1 occurred as the sample while B1, B2, and B3 occurred as comparisons (see Table 1). The delayed prompt procedure was used. This phase continued until the subject made 12 consecutive correct responses. Phases 3 and 4 were conducted exactly as Phase 2, except that A2 and A3, respectively, were the samples. In Phase 5, Samples A1 and A2 occurred randomly across trials. In Phase 6, Samples A1, A2, and A3 occurred in random order across trials. Procedures were exactly as those described above, except that 24 consecutive correct trials were required prior to advancement to Phase 7. In Phases 7 and 8, the delayed prompt procedure was not in effect and the probability of positive consequences was .5 (Phase 7) and .25 (Phase 8).

PQ training. PQ training (Phases 9 through 15) was conducted exactly as in the seven phases of AB training, except that the stimuli used as samples were P1, P2, and P3 and the comparisons were Q1, Q2, and Q3.

AB review. Before the ABX training, the AB training was reviewed in Phase 16. It was identical to Phase 8.

ABX training. During the first phase of the ABX training (Phase 17), the nine combinations of stimuli shown in Figure 1b occurred randomly over trials. The delayed prompt procedure was used. After 24 consecutive correct responses, the program automatically progressed to the next phase. In the next two phases, the probability of reinforcement for correct responding was decreased to .5 and then to .25, and the delayed prompt procedure was not in effect.

PQX test. The PQX test consisted of randomly presenting the nine stimulus combinations of PQX. No differential consequences occurred, and the session ended after 24 trials. The 3 subjects who did not respond correctly the first time that the PQX test was conducted received a review of the AB, PQ, and ABX training (see Sequence B in Table 1) in the next session. The 2 subjects who responded correctly to the PQX relations (Subjects APS and AUR) were given an extra session in which the trained relations AB, PQ, and ABX were mixed with BA and QP symmetry tests (Sequence E in Table 1), to see whether they would also demonstrate symmetry for the AB and PQ relations.

The other 2 subjects (CRL and LJS) who did not demonstrate the expected PQX relations at this point were given additional sessions with the relations AB, PQ, and ABX, and were tested with PQX. Afterwards, with the aim of exploring whether symmetry testing at this point would help the PQX transfer, Subject LJS was tested with the QP relations (Sequence C, Table 1), and Subject CRL was tested with BA relations (Sequence D, Table 1), in both cases interspersed with the baseline relations. Thereafter, each subject was tested with the other symmetry, and then with both symmetries (Sequence E, Table 1). During the BA symmetry test, B1, B2, and B3 were used as samples and A1, A2, and A3 were used as comparisons. During the PQ symmetry test, Q1, Q2, and Q3 were the samples and P1, P2, and P3 were the comparisons. In these symmetry phases, 24 random trials of the BA or QP relations were presented with no programmed consequences.

When Subjects CRL and LJS did not demonstrate the expected transfer to the PQX stimuli after several sessions with the abovementioned procedure, they received EF and EFX conditional discrimination training.

EF training. The EF conditional discrimination was trained exactly like the AB and PQ conditional discriminations, except that E1, E2, and E3 were presented as samples and F1, F2, and F3 were presented as comparisons (see Sequence J in Table 1). After the subjects met the training criteria in Phases 1 to 8 of Sequence J, they were given the FE symmetry test. The FE symmetry test was conducted in exactly the same way as the BA and QP symmetry tests, except that the F and E stimuli were used. After the test, the PQ discrimination was reviewed, and the QP symmetry test was administered again.

EFX training. Training the EFX discrimination was conducted in the same fashion as ABX discrimination, except that combinations of EF stimuli, rather than AB stimuli, were presented as samples. After the subjects met the training criterion in Phase 13, they were again given the PQX test.

Results

Baseline Training

The AB, PQ, and ABX discriminations constituted the baseline performances on which any transfer to PQX tests would be based. Trials to reach criterion on the AB conditional discrimination ranged from 216 for Subject APS to 350 for Subject CRL. The minimum was 128 trials (Sequence A, Phases 1 through 8). Trials to reach the criterion on the PQ discrimination ranged from 148 for Subject APS to 192 for Subject AUR. Subject APS required 86 trials to reach criterion on the ABX discrimination, and Subject CRL required 399 trials. Subjects AUR and LJS completed about 500 trials due to a programming error, although they reached the criterion in fewer trials (104 and 158, respectively).

Symmetry and PQX Relations

As shown in Figure 4, during the first PQX test session, 100% of Subject APS's selections were in line with predictions based on transfer of relational control; she selected X1 in the presence of P1 and Q1, P2 and Q2, and P3 and Q3 and selected X2 in the presence of P1 and Q2, P1 and Q3, and so on. The percentage of selections indicating such transfer was below 50% for the remaining 3 subjects. After a review of the trained relations, they were retested with PQX. Virtually all of Subject AUR's responses (23 of 24) were in line with predictions based on transfer. The performance of the remaining 2 subjects (CRL and LJS) remained below 50% in the first two tests (Sessions 4 and 5). Because LJS's performance showed a progressive increase, he was tested for additional sessions (6 to 9), but correct responses dropped to 58% in Session 9.

Subjects APS and AUR were given a session in which review of training phases was interspersed with tests for the BA and QP symmetries, followed by a PQX test. Their selections (95 to 100% correct) indicated that the AB and PQ relations were symmetrical, and PQX performance remained accurate.

Subjects CRL and LJS were presented in successive sessions with reviews of the trained phases, tests for BA and QP symmetries, and tests for the PQX relations. Results of symmetry tests ranged from 91 to 100% correct responses. However, the results on the PQX tests were about 50% in all sessions. After training with the EF and EFX relations, tests for the FE, BA, and QP symmetries yielded 95 to 100% correct responses. The final PQX test result for Subject LJS was 95%, consistent with transfer. Only 60% of Subject CRL's responses were correct in the final PQX test.

Discussion

Three of 4 subjects selected X1 in the presence of P1 and Q1, P2 and Q2, and P2 and Q3 and selected X2 in the presence of the other

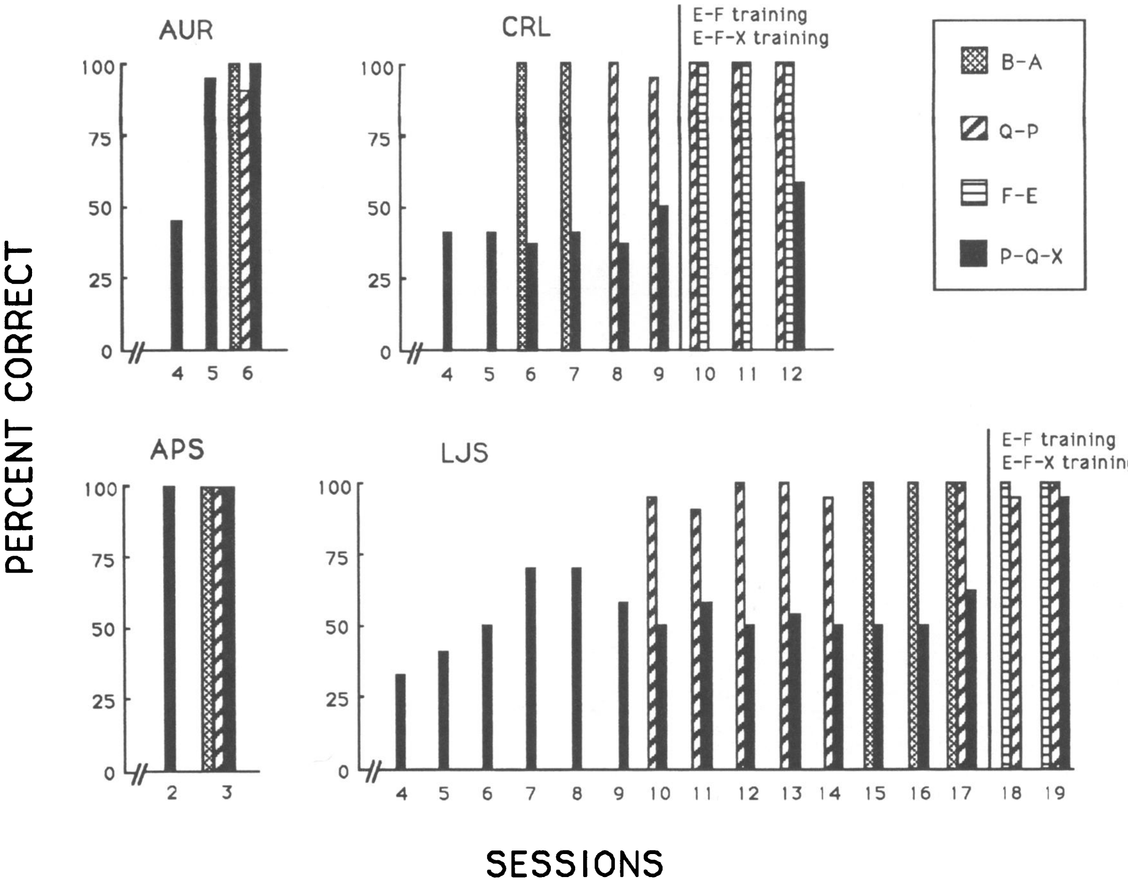

Fig. 4. Performance in the test phases of Experiment 1. Each bar represents the percentage of correct trials, typically in a block of 24 trials, for the BA, QP, FE, and PQX tests. Vertical lines indicate the introduction of training for the EF and EFX relations and the EF test for symmetry.

PQ sample combinations, demonstrating the PQX relational transfer. One subject showed the PQX relational transfer in the first test phase, and another subject showed it in the second. A 3rd subject did so after being trained with the EF and EFX relations and being tested for FE symmetry. This shows that the selections between two comparisons (here X1 and X2) may depend on the relation that two sample elements have had in previous training, even when the sample elements and comparisons are presented together for the first time.

Of the 3 subjects who showed the relational transfer, 2 (APS and AUR) did so before being tested for symmetrical relations BA and QP. In both cases, tests for these symmetries conducted during the sessions that followed the PQX transfer showed at least 91% correct responses. These results indicate that testing the two symmetrical relations before testing for PQX is not necessary for the PQX transfer. Emergence of the PQX relations was observed in a 3rd subject (LJS) after training with two new pairs of stimuli and testing for symmetry. Transfer may have been facilitated by the test for FE symmetry before training the EFX relations, the training with new sets of stimuli (EF and EFX relations), or both procedures.

EXPERIMENT 2

The results of Experiment 1 indicated that 3 of 4 subjects showed transfer of control of a relation between two stimuli, presented as samples, over comparison selection. Although the results show that testing for symmetry may not be necessary for all subjects to respond appropriately in the PQX test, they do not

Table 2

Sequences of phases used in each session for each subject in Experiment 2. Shown are each phase, the stimulus relations, whether the delayed prompt procedure operated ("shaping"), the probability of reinforcement ("schedule"; "test" indicates no consequences), and the number of consecutive trials with correct responses needed to pass to the next phase. Lower case letters indicate the stimulus (or stimuli) in the relations that was (were) presented as sample(s). The numbers in the columns for Subjects GAB, MAR, CHU, and LET indicate the session(s) in which the phases were used.

					Subject			
Phase	Relations	Shaping	Schedule	Trials	GAB	MAR	CHU	LET
Sequence A								
1	A-A	yes	1	8	1	1	1	1
2	a1-B	yes	1	12	1	1	1	1, 3, 4
3	a2-B	yes	1	12	1	1	1	1, 3, 4
4	a3-B	yes	1	12	1	1	1	1, 3, 4
5	a1a2-B	yes	1	12	1	1	1	1, 2, 3, 4
6	A-B	no	1	24	1	1	1	4
7	A-B	no	.5	24	1	1	1	4
8	A-B	no	.25	24	1	1, 2	1	4
9	B-A	no	test	24	1	2	1	4
10	p1-Q	yes	1	12	1	2	1	4
11	p2-Q	yes	1	12	1	2	1	4
12	p3-Q	yes	1	12	1	2	1, 2	4
13	p1p2-Q	yes	1	12	1	2	2	4
14	P-Q	no	1	24	1	2	2	4, 5
15	P-Q	no	.5	24	1, 2	2	2, 4	5
16	P-Q	no	.25	24	2	2	2, 4	5
17	Q-P	no	test	24	2	2	2, 4, 5	5
18	A-B	no	.25	24	2	2, 3	2, 3, 4, 5	5
19	A-B-X	yes	1	24	2	2, 3	2, 3, 4, 5	5
20	A-B-X	no	.5	24	2	—	3, 4, 5	5
21	A-B-X	no	.25	24	2	—	3, 4, 5	5
22	P-Q-X	no	test	24	2	—	3, 5	5
Sequence B								
1	A-B	no	.25	24	—	4	—	—
2	B-A	no	test	24	—	4	—	—
3	P-Q	no	.25	24	—	4	—	—
4	Q-P	no	test	24	—	4	—	—
5	A-B	no	.25	24	—	4	—	—
6	A-B-X	yes	1	24	—	4	—	—
7	A-B-X	no	.5	24	—	4	—	—
8	A-B-X	no	.25	24	—	4	—	—
9	P-Q-X	no	test	24	—	4	—	—

rule out the possibility that symmetry testing may facilitate PQX performance for others. All the subjects demonstrated a high degree of control by symmetrical relations in the tests. Moreover, once a subject had established a pattern of responding that did not reflect control by the relation between the two sample stimuli, positive tests for symmetry did not appear to increase the probability of obtaining PQX transfer. However, prior to BA and QP symmetry testing, all the subjects had been exposed to repeated PQX tests. Breaking up established response patterns in the PQX test may have been difficult. Perhaps introduction of tests for symmetry would have had a different effect if they had been introduced prior to PQX testing. The goal of Experiment 2 was to see whether symmetry tests would facilitate correct responding to PQX. Therefore, Experiment 2 was a replication of the first phase of Experiment 1, with the exception that BA and QP tests were introduced prior to PQX testing.

Method

Subjects

Subjects were 4 Spanish speakers: CHU (a 23-year-old male), GAB (a 21-year-old male),

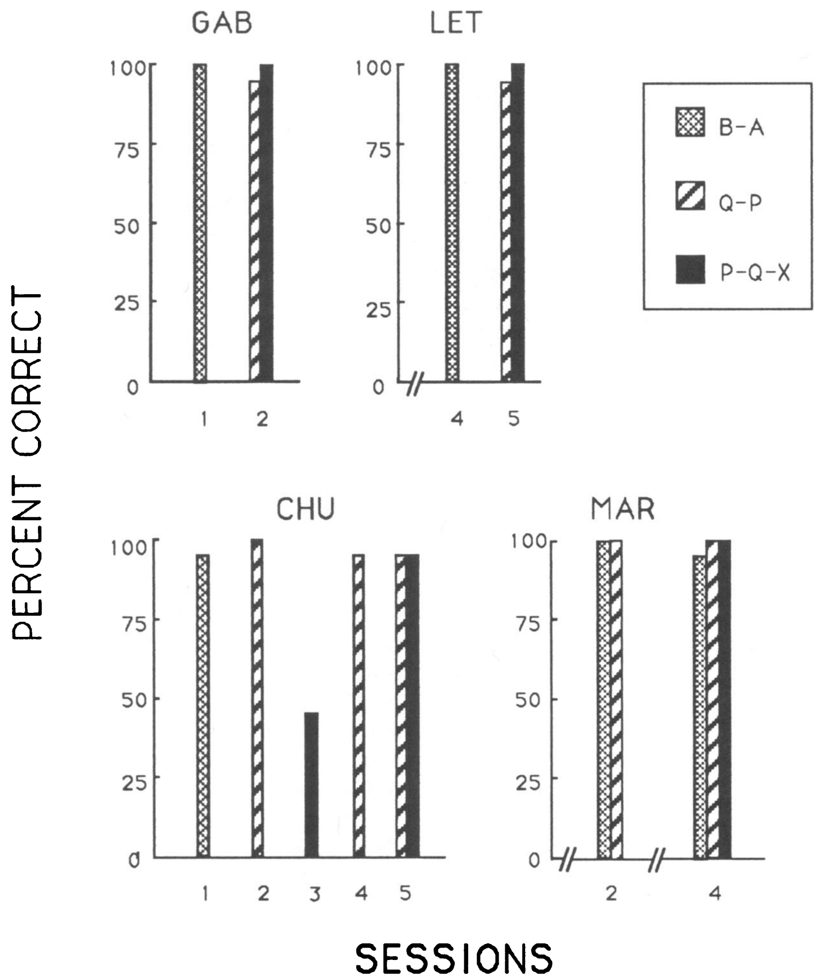

Fig. 5. Performance in the test phases of Experiment 2. Each bar represents the percentage of correct trials, typically in a block of 24 trials, for the BA, QP, and PQX tests.

MAR (a 25-year-old female), and LET (an 11-year-old female). They were recruited as in Experiment 1.

Apparatus and Procedure

The apparatus and stimulus configurations were the same as those used in the first part of Experiment 1. The sequences of training and testing phases are presented in Table 2. Sequence A, consisting of AB, PQ, and ABX training, was like that of Experiment 1, with two exceptions: Immediately after reaching the final criterion for AB discrimination training, BA symmetry tests were administered; immediately after meeting criterion for PQ training, QP symmetry tests were administered (see Table 2). In both symmetry tests, the subject was required to have 22 correct responses in 24 trials before moving on to the next phase. For Subjects GAB, LET, and CHU, the QP symmetry test was followed by an AB discrimination review session, ABX training, and PQX testing. Only 74% of subject MAR's responses were correct in 230 ABX training trials during Session 3, so she was given a review of the AB and PQ discriminations and of the BA and QP symmetry tests followed by the reintroduction of ABX discrimination training (see Sequence B of Table 2). After 24 consecutive correct trials in the last ABX review phase, the PQX test was introduced.

RESULTS

Baseline Training

The number of trials to reach criterion for AB training ranged from 163 for Subject MAR to 577 for Subject CHU. The number of trials to reach criterion for PQ training ranged from 151 for Subjects LET and CHU to 220 for Subject GAB. The number of training trials for the ABX discrimination ranged from 76 for Subject CHU to 292 for Subject MAR. Subject MAR was given 77 additional ABX trials.

Symmetry and PQX Tests

As shown in Figure 5, all 4 subjects responded to the BA and QP symmetry tests with over 90% accuracy. The results of the PQX test are also shown in Figure 5. Subjects GAB, LET, and MAR made selections on 100% of the PQX trials that were congruent with predictions based on transfer from the ABX task. Subject CHU performed at less than 50% on the first PQX test, but he achieved 100% accuracy on the second test.

DISCUSSION

All 4 subjects showed systematic transfer to the PQX relations after the BA and QP tests for symmetry. Experiments 1 and 2 differed as to when the symmetrical relations were tested. In Experiment 2, the symmetrical relations were tested right after the training of each simple conditional discrimination, but in Experiment 1, they were tested during several sessions after unsuccessful tests for the PQX relations. Two subjects in Experiment 1 showed the transfer to PQX before being tested for the BA and QP symmetries; 1 subject showed the transfer to PQX after those tests and extra training with new sets of stimuli (EF relations) plus the test for symmetry with the new relations (FE); the remaining subject did not show the PQX relational transfer. On the other hand, all subjects in Experiment 2 showed the transfer to PQX in either the first (3 subjects) or second (1 subject) session in which these relations were tested. These results suggest that even though tests for symmetry are not necessary for PQX transfer, administering the tests for symmetry before ABX training may facilitate it. Systematic replications of the results obtained in Experiments 1 and 2 are necessary to clarify the influence of symmetry in the transfer to PQX.

EXPERIMENT 3

The main characteristic of ABX training and PQX tests in Experiments 1 and 2 is that responses to X1 and X2 depended upon the relation that the two sample stimuli have had with each other. Comparisons X1 or X2 were selected depending on preexisting relations between the sample stimuli. One might wonder if X1 and X2 could be used to bring about the relation between two novel stimuli presented as a sample.

For the present experiment, subjects who had been tested successfully on the PQX relations were directly trained to select X1 or X2 in the presence of novel pairs of stimuli: E1, E2, or E3 with F1, F2, or F3, as shown in Figure 6a. Because all sample stimuli were novel and arbitrary, these EFX discriminations can be learned only by means of differential consequences.

In a posterior EF test (Figure 6b), given that selections of X1 were reinforced when E1 and F1 formed the sample in the EFX training, the subject may select F1 when E1 is the sample and F1, F2, and F3 are the comparisons in a conditional discrimination. Similarly, if E2 and F1 formed the sample in the EFX training and selections of X2 were reinforced, then responses to F1 in the presence of E2 should not occur; instead, another comparison should be selected.

The aim of the present experiment, then, was to find out whether EFX training might establish an EF conditional discrimination.

METHOD

Subjects

Subjects APS and AUR (from Experiment 1) and LET (from Experiment 2) participated. All had passed the PQX test of transfer.

Apparatus and General Procedure

All experimental conditions were the same as in the previous experiments. Stimulus Sets E and F (Figure 3) were used. These stimuli had not been used before with these subjects.

Specific Procedures

The specific procedures are summarized in Table 3. Sequence A was used with LET, and Sequence B was used with APS and AUR.

EF pretest. Given that some people respond in a conditional manner even before training (R. Saunders, Saunders, Kirby, & Spradlin,

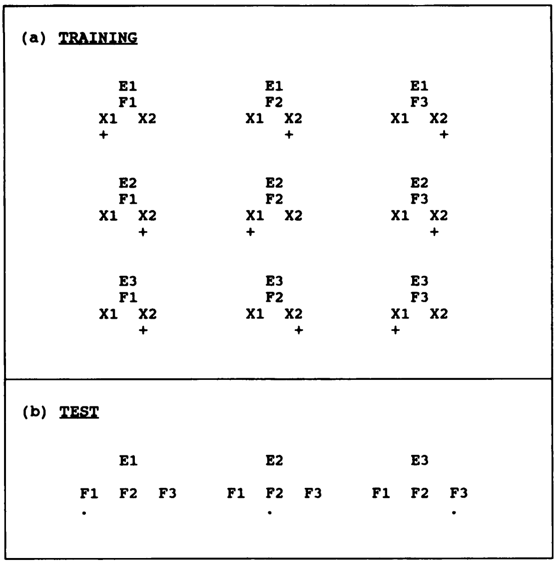

Fig. 6. Discriminations trained (a) and tested (b) in Experiment 3. The plus signs indicate the correct comparisons for trained relations. The periods indicate the correct comparisons for the tested relations.

Table 3

Sequences of phases used in Experiment 3 (Sequence A was used with LET and Sequence B with APS and AUR). Shown are each phase, the stimulus relations, whether the delayed prompt procedure operated ("shaping"), the probability of reinforcement ("schedule"; "test" indicates no consequences), and the number of consecutive trials with correct responses needed to pass to the next phase. Lower case letters indicate the stimulus (or stimuli) in the relations that was (were) presented as sample(s).

Phase	Relations	Shaping	Schedule	Trials
Sequence A				
1	E-F	no	test	24
2	e1-F-X	yes	1	12
3	e2-F-X	yes	1	12
4	e3-F-X	yes	1	12
5	e1e2-F-X	yes	1	12
6	E-F-X	yes	1	24
7	E-F-X	no	.5	24
8	E-F-X	no	.25	24
9	E-F	no	test	24
Sequence B				
1	E-F	no	test	24
2	E-F-X	yes	1	24
3	E-F-X	no	.5	24
4	E-F-X	no	.25	24
5	E-F	no	test	24

1988), it was possible that a subject would respond correctly in the test for the first-order conditional discrimination just because each comparison is arbitrarily assigned to a given sample. To rule out the possibility of arbitrary assignment before training, a test for the EF relations was conducted first. About 100% accuracy on the test would indicate arbitrary sample-comparison assignments coincident with the ones to be established by EFX training. Other assignments would result in 33% or 0% correct responses. Random selection among the three comparisons would lead to 33% correct responses.

EFX training. Subject LET, the 11-year-old, received different training from that of the adults, because previous experiments have shown that more detailed training may be necessary for children (see Sequence A in Table 3). In Phase 2, sample E1 was present in all the trials, and F1, F2, and F3 alternated as the second sample stimulus in the pair; X1 and X2 were the comparisons; and the delayed prompt procedure was in effect. After 12 consecutive correct responses, the next programmed phase began. Phases 3 and 4 were identical to Phase 2, except that E2 (Phase 3) or E3 (Phase 4) instead of E1 was present as the first sample stimulus. In Phase 5, E1 and E2 alternated as the first sample stimulus; other aspects of the procedure were identical to the previous phases.

In Phase 6, all nine combinations of E1, E2, and E3, as the first sample stimulus, and F1, F2, and F3, as the second sample stimulus, were used, while X1 and X2 were used as the comparisons in all the trials. The delayed prompt procedure was also in effect, and the next phase occurred after 24 consecutive correct responses. Phases 7 and 8 differed in that the delayed prompt procedure was no longer in effect, and the probability of reinforcement was .5 (Phase 7) or .25 (Phase 8).

The adult Subjects APS and AUR received only the three last training phases mentioned above (Phases 2 to 4 shown in Sequence B in Table 3).

EF test. The EF test consisted of random presentations of E1, E2, and E3 as single sample stimuli in successive trials, while F1, F2, and F3 served as comparisons. Twenty-four trials with no differential consequences were presented, and the experiment ended.

Results

All subjects completed the experiment in one session. Data from the test phases appear in Figure 7.

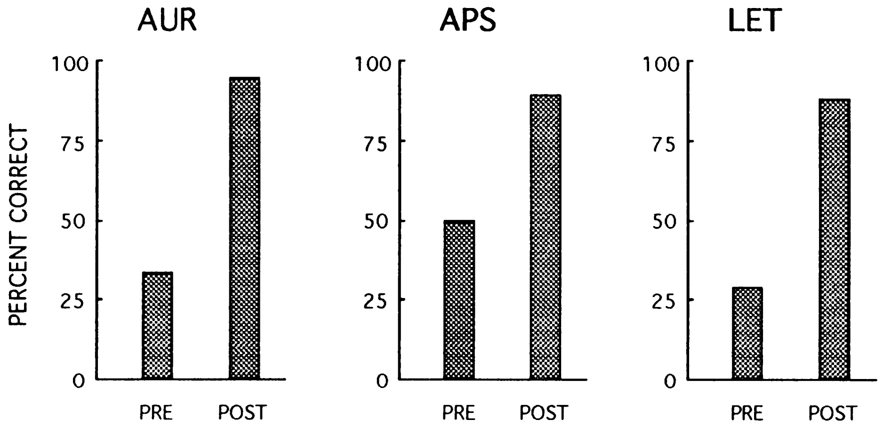

Fig. 7. Performance in the tests for the EF relations in Experiment 3. Each bar presents the percentage of correct trials in a block of 24.

EF pretest. All subjects responded at about chance level (33%) in the control test in Phase 1 for the EF relation (correct responses were 33% for AUR, 50% for APS, and 29% for LET).

EFX training. Subject LET reached criterion on the EFX phases in 194 trials (the minimum number was 120), Subject AUR reached criterion in 80 trials, and Subject APS reached criterion in 112 trials (the minimum number for AUR and APS was 72).

EF posttest. The subjects selected F1 in the presence of E1, F2 in the presence of E2, and F3 in the presence of E3 on 90% (Subject LET) to 95% (Subject AUR) of the test trials. All subjects responded correctly on the first eight trials of the EF test. The first error was in Trial 9 for AUR, in Trial 14 for APS, and in Trial 10 for LET.

Discussion

The 3 subjects who participated in this experiment responded according to the predictions on the final EF test. Selection of F1 in the presence of E1, F2 in the presence of E2, and F3 in the presence of E3 was due, in part, to previous EFX training in which E and F stimuli, presented together, controlled the selection of X1.

Stimuli X1 and X2 had served as comparisons in the EFX training, as in the previous ABX training and PQX testing. In ABX training and PQX testing, X1 or X2 were selected in the presence of a sample composed of two stimuli with a previously established relation (e.g., selections of X1 in the presence of P1 and Q1). In EFX training, X1 or X2 were selected in the presence of novel pairs of stimuli (e.g., selections of X1 in the presence of E1 and F1). As the setting in the ABX and PQX conditions was the same as in EFX, it is very likely that EFX training produced the relations among the E and F stimuli (e.g., E1 and F1) as a result of the previous ABX training and PQX testing.

There are several variables that could be studied more extensively. For example, all nine sample combinations of the EFX discrimination shown in Figure 6a were used in training. It is not clear whether training with fewer of these discriminations would suffice for the EF relations to emerge. In fact, many of the trained discriminations were redundant, given that, for example, E1F1X1, E1F2X2, and E1F3X2 discriminations were trained. The training of the E1F1X1 discrimination may be enough to produce the E1F1 relation; alternatively, training E1F2X2 or E1F3X2 might produce the E1F1 relations through exclusion (McIlvane et al., 1987; Stromer & Osborne, 1982).

GENERAL DISCUSSION

Experiments 1 and 2 showed transfer of control based on the relation between the two stimuli comprising the sample in a conditional discrimination task. The relation between the stimuli depended upon previous matching-to-sample training in which one of them had been the sample and the other had been either the correct comparison or the incorrect one. Responses to Stimulus X1 followed presentations of samples that had the sample–correct comparison relation in the previous training; responses to Stimulus X2 followed presentations of samples that had the sample–incorrect relation in the matching-to-sample training. Correct responding on the PQX tests demonstrated that selections of X1 and X2 transferred from the ABX training to new pairs of stimuli (PQ) that had the same relations as the trained AB stimuli (sample–correct comparison or sample–incorrect comparison). But there were no relations between particular stimuli and X1 or X2. So, the PQX test showed novel relations between a relation (e.g., the P1Q1 relation) and a comparison stimulus (X1 or X2).

Two of the 4 subjects in Experiment 1 demonstrated the PQX transfer (in the first or second test) before being tested for BA and QP symmetrical relations. The 4 subjects in Experiment 2 demonstrated transfer after the tests for symmetrical relations. Thus, Experiment 1 shows that tests for symmetry are not necessary for the PQX transfer, but Experiment 2 suggests that those tests can facilitate PQX transfer. Symmetry may be necessary for transfer because it is one of the requisites for stimulus equivalence (Sidman & Tailby, 1982). It is likely that only stimuli that belong to a class (here, a reduced two-element class) may control the selection of X1 (and stimuli that do not belong to a class control selections of X2). This speculation about the role of symmetry, and about the conditions for the PQX transfer in general, needs experimental clarification.

Results apparently were not affected by the fact that a 2-s ITI and no sound followed some of the correct responses during training as well as all responses during the test. The consequences were the same in both cases. It is possible that the combination of a 2-s ITI and the absence of sound reinforced responses in the test. This possibility is remote, however, given the pattern of test responses actually observed. Five of 8 subjects in Experiments 1 and 2 obtained four correct responses in the first four trials of the first test, as did all subjects in the symmetry tests. Thus, accurate test performances preceded any possibility of significant accidental reinforcement of correct responses. Note also that the common consequences could reinforce incorrect responses in the first trials of a test, thus preventing improvement on later trials. However, one subject in Experiment 1 and the 3 subjects in Experiment 3 scored above 91% correct in a test after failing the previous one, and LJS, in Experiment 1, responded correctly to the PQX test after repeated unsuccessful testing.

For the PQX relations to be formed, the two stimuli in the sample (e.g., P1 and Q1) must be discriminated from one another. For example, if A1B1 in the ABX discriminations and P1Q1 in the PQX discriminations functioned as an integrated compound (Bush et al., 1989; Lynch & Green, 1991), it seems impossible to explain the formation of the PQX relations. The argument may be clearer when these putative compounds are labeled as follows. If A1 forms a compound with B1, A1 and B1 control behavior as a single element (Bush et al., 1989; Lynch & Green, 1991) and the compound can be labeled Sample H1; the A1B2 compound can be labeled Sample H2, and so forth. Thus, the trained relations would be H1X1, H2X2, H3X2, H4X2, H5X1, H6X2, H7X2, H8X2, and H9X1 (see Figure 1b, left to right and top to bottom). Those relations can be labeled the HX relations. Similarly, P1Q1 can be labeled G1, P1Q2 can be labeled G2, and so on, and the tested relations would be G1X1, G2X2, G3X2, G4X2, G5X1, G6X2, G7X2, G8X2, and G9X1 (see Figure 2b, left to right and top to bottom). These can be called the GX relations. Then, after the training of HX, the emergence of GX would not be expected, according to the literature (e.g., R. Saunders et al., 1988).

Moreover, two sample elements are not sufficient for the PQX performance. If X1 is trained to be selected in the presence of a compound sample with two elements, there is no reason for X1 to be selected in the presence of a novel compound sample composed of two stimuli (for the same reason as above). The common elements between the ABX and PQX instances are the relations that are shared among A1B1, A2B2, and A3B3, and P1Q1, P2Q2, and P3Q3, on the one hand; and A1B2, A1B3, and so on, and P1Q2, P1Q3, and so on, on the other. These relations are the same because the reinforcing consequences of selecting B1, B2, and B3 in the presence of A1, A2, and A3 (in the relations between A and B) and the reinforcing consequences of selecting Q1, Q2, and Q3 in the presence of P1, P2, and P3 (in the relations between P and Q) in the previous AB and PQ training were the same in both cases. The same applies for the remaining relations A1B2, A1B3, and so on, and the punitive consequences.

The PQX relations cannot be explained by stimulus–reinforcer mediation, because all the P and Q stimuli had been followed equally often by both the positive and negative consequences. Thereafter, the only common element between ABX and PQX was the relation among the stimuli in the sample.

Why, then, do the two stimuli A and B or P and Q work as two different sample elements instead of as a single compound? An analysis of the conditions for a conditional discrimination (K. Saunders & Spradlin, 1989, 1990) shows that three prerequisites are necessary for a conditional discrimination: a successive discrimination among the samples, a simultaneous discrimination among the comparisons, and a relation between each sample and its corresponding comparison. Those three features were, in the present research, a result of the AB training. Thus, when the subjects were trained with the ABX relations, the discriminations among the different AB sample elements may have occurred because of previous AB training. In other words, the AB training may have caused A and B to function as separate stimuli when presented in the ABX training. Similarly, the PQ training may have caused P and Q to function as separate stimuli in the PQX test.

In Experiment 3, novel stimuli E1, E2, or E3, and F1, F2, or F3 appeared in different combinations, forming a two-element sample while X1 or X2 were comparisons. Further selections of F1 in the presence of E1, F2 in the presence of E2, and F3 in the presence of E3 were made in the EF test. That test showed that the EFX training brought about a relation between the stimuli associated with X1. An analogous analysis may be performed concerning the role of the E and F stimuli that formed the sample when the selection of X2 was reinforced in the EFX training (e.g., E1 and F2); in that case, selections of one stimulus in the presence of the other, in the EF test, did not occur, but selections of an alternative comparison did. Thus, after a sample consisting of two related stimuli controlled selections of X1 or X2, relations between some of those sample stimuli were shown when tested in a simple conditional discrimination format. This outcome suggests a form of relating the stimuli other than through direct exposure to conditional discrimination training, as it occurs in common matching-to-sample training and tests for equivalence.

In EFX training, X1 had the function of establishing some kind of class relation between a Stimulus E and a Stimulus F, whereas X2 had the function of establishing some kind of nonclass relation between the E and F stimuli. It seems that the only reason for X1 and X2 to show those particular functions was the previous ABX training and PQX testing, because in ABX and PQX, Comparison X1 was selected in the presence of two stimuli having that class relation, and X2 was selected in the presence of two stimuli not having that relation.

There is a feature of X1 and X2 that distinguishes these stimuli from the other stimuli used in the present experiments: Although some stimuli may form classes (e.g., AB), X1 and X2 do not belong to a class of particular stimuli. The argument is parallel to that used in analyzing contextual control (Sidman, 1986): Following the training of A1B1X1 and A2B2X1, if X1 belongs to the same class as A1 and B1 and A2 and B2, then all the stimuli would merge into one class. Of course, this would make consistent responding impossible, and it does not happen. The same applies for X2.

Concerning the functional role of X2, there are two possibilities: (a) Responses to X2 may occur because this stimulus is associated with any sample–incorrect comparison relation. (b) Responses to X2 may occur because this stimulus is associated with any stimulus pair that does not have a stimulus–correct comparison relation. In this case, responses may be similar to responses by exclusion (McIlvane et al., 1987; Stromer & Osborne, 1982).

Conditional discriminations and stimulus relations may be useful to explain verbal behavior. The present experiments can be analyzed in Skinner's (1957) terms. Thus, in conditional discriminations, comparison selections may be supposed to tact the sample. Referring to the PQX relations, selections of X1 are somehow equivalent to "yes" responses, and selections of X2 are somehow equivalent to "no" responses; both responses are controlled by the relation among other events. These operants are defined by Skinner as descriptive autoclitics. Experiments 1 and 2 may help to understand acquisition of generalized yes/no responding under different sources of control. Experiment 3 may help to understand, for example, how a child may associate Picasso with painting after being told "Picasso was a painter." Further research using young children and substituting comparison selection by uttered words may enhance our understanding of verbal behavior.

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