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A TRANSFER OF SELF-DISCRIMINATION RESPONSE FUNCTIONS THROUGH EQUIVALENCE RELATIONS

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The present study tested the idea that human self-discrimination response functions may transfer through equivalence relations. Four subjects were trained in six symbolic matching-to-sample tasks (if see A1, choose B1; A1-C1, A2-B2, A2-C2, A3-B3, A3-C3) and were then tested for the formation of three equivalence relations (B1-C1, B2-C2, B3-C3). Two of the B stimuli (B1 and B2) were then used to train two different self-discrimination responses using either detailed instructions (Subjects 1 to 3) or minimal instructions (Subject 4) on two complex schedules of reinforcement (i.e., subjects were trained to pick the B1 stimulus if they had not emitted a response, and to pick the B2 stimulus if they had emitted one or more responses on the previous schedule). All 4 subjects showed the predicted transfer of self-discrimination response functions through equivalence relations (i.e., no response on the schedule, pick C1; one or more responses on the schedule, pick C2). Subjects also demonstrated this transfer when they were required to discriminate their schedule performance *before* exposure to the schedule (i.e., "what I intend to do"). Four control subjects were also used in the study. Two of these (Subjects 5 and 6) were not exposed to any form of matching-to-sample training and testing (nonequivalence controls). The 2 remaining subjects (7 and 8) were exposed to matching-to-sample training and testing that incorporated stimuli not used during the transfer test; C1 and C2 were replaced by N1 and N2 during the matching-to-sample training and testing, but C1 and C2 were used for the transfer tests (equivalence controls). All 4 subjects failed to produce the self-discrimination transfer performances observed with the experimental subjects.

Key words: self-discrimination response function, stimulus equivalence, transfer, derived transfer, knowing, instructions, humans

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Language-able humans often respond discriminatively to such questions as "What have you done?" and "What are you going to do?" The reinforcement contingencies that establish this form of "self-discrimination" appear to differ from the contingencies that establish the discriminated behavior itself. In the words of Skinner (1974, p. 30), "There is a difference between behaving and reporting that one is behaving, or reporting the causes of one's behavior. In arranging conditions under which a person describes the public or private world in which he lives, a community generates that very special form of behavior called knowing." In other words, the verbal community is largely responsible for establishing a behavioral repertoire that allows us to respond discriminatively to our own behavior (see Hineline & Wanchisen, 1989).

This view of "knowing" or "self-awareness" has been empirically examined using nonhuman subjects. For example, Lattal (1975) employed pigeons to assess the self-discriminative properties generated by two complex reinforcement contingencies. Responding according to either differential-reinforcement-of-low-rate (DRL) or differential-reinforcement-of-other-behavior (DRO) schedules produced a "choice" component in which the correct choice was defined by the reinforcement contingency that preceded it (i.e., the birds learned to peck a red key if they had previously pecked for reinforcement and to peck a green key if they had not pecked for reinforcement). Other studies with pigeons have also provided evidence for self-discrimination using duration of interresponse times (IRTs) (Reynolds, 1966), different fixed-ratio (FR) values (Pliskoff & Goldiamond, 1966), temporal intervals (Reynolds & Catania, 1962), and lengths of response runs (Shimp, 1982) as discriminative stimuli.

Although these studies with nonhumans have demonstrated that subjects' own behavior may function as discriminative stimuli, recent stim-

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ulus equivalence research has shown that certain properties of human discrimination, in general, are not readily predicted using the traditional concepts of discriminative control (see Barnes, 1994; Hayes, 1991; Sidman, 1990). In one study, for example, Barnes and Keenan (Experiment 1, 1993b) demonstrated a transfer of high- and low-rate schedule responding through derived equivalence relations. They first trained subjects on a series of related conditional discriminations in a symbolic matching-to-sample format (i.e., A1-B1, A1-C1, A2-B2, A2-C2), and then explicitly trained high-rate and low-rate performances on a schedule task in the presence of the two B stimuli (i.e., B1, low rate; B2, high rate). Subsequently, the researchers demonstrated a transfer of discriminative control over the two types of schedule performance through derived equivalence relations (i.e., C1, low rate; C2, high rate), without any further training. Because the C1 and C2 stimuli did not have a direct history of reinforcement for high- and low-rate performances in their presence, and were not related to the B or A stimuli along any consistent physical dimension, this derived transfer of discriminative functions is difficult to predict using the traditional concepts of discriminative stimulus control, conditional discriminative stimulus control, or stimulus generalization (Barnes, 1994).

Other studies have also demonstrated a derived transfer of stimulus control through equivalence relations using both discriminative functions (deRose, McIlvane, Dube, Galpin, & Stoddard, 1988; deRose, McIlvane, Dube, & Stoddard, 1988; Gatch & Osborne, 1989; Hayes, Devany, Kohlenberg, Brownstein, & Shelby, 1987; Kohlenberg, Hayes, & Hayes, 1991; Wulfert & Hayes, 1988) and consequential functions (Hayes et al., 1987; Hayes, Kohlenberg, & Hayes, 1991). As yet, however, no published study has attempted to show a transfer of self-discrimination response functions through derived equivalence relations.

The derived transfer of self-discrimination response functions may have important implications for the experimental and conceptual analysis of human verbal self-reports and self-awareness. For example, a better understanding of how *derived* self-reporting develops in the behavior of young children may help to provide a behavior-analytic interpretation of certain emotional problems in adulthood. Consider, for instance, children who are constantly criticized and told by their parents that they are "bad," "nothing but trouble," and "stupid." When such children interact with the verbal community, these constant critical remarks may come to participate in equivalence relations, and more general negative self-discriminations will emerge. For example, during their verbal development, such children may respond to "bad" as equivalent to "I'm a worthless person," "stupid" as equivalent to "I'm a failure," and "nothing but trouble" as equivalent to "No one loves me." This form of equivalence responding may cause the young adult to conclude that, "I am a worthless failure, and no one loves me," without being explicitly taught to make this form of self-discrimination (Hayes, 1987, 1992). Clearly, the experimental demonstration of a transfer of self-discrimination response functions through equivalence relations would represent an important step in developing a behavior-analytic understanding of certain clinical disorders and perhaps human self-awareness in general (the reader is referred to Hayes & Wilson, 1993, for a detailed conceptual analysis of this issue).

The present study sought to determine whether human adult self-discrimination response functions could transfer through equivalence relations.[1] Subjects were first exposed to conditional discrimination training on six matching-to-sample tasks (i.e., if see A1, choose B1; A1-C1, A2-B2, A2-C2, A3-B3, A3-C3) and were then tested for the formation of three equivalence relations (i.e., B1-C1, B2-C2, B3-C3). Following a successful equivalence test, subjects were trained in two self-discrimination performances on a time-based schedule task; if subjects did not respond on this task, choosing B1 was reinforced, and if they did respond, choosing B2 was reinforced. Finally, they were tested for a transfer of these self-discrimination response functions through derived equivalence relations (i.e., no response, choose C1; response, choose C2).

[1] The reader should be aware that the term *equivalence relation,* as used here, refers to the behavioral process of arbitrarily applicable relational responding, rather than to the "standard" matching-to-sample equivalence procedure. We will address some of the conceptual issues raised by our use of this process-based terminology at greater length in the Discussion.

METHOD

Subjects

Eight subjects, 4 male and 4 female, participated in the study. Their ages ranged from 18 to 30 years (M = 22.5). All subjects were recruited through personal contacts, both on and off campus. Two subjects were personal acquaintances of the second author and were educated and employed in areas outside of psychology. Five subjects were first-year psychology undergraduates, and 1 was a psychology postgraduate; all attended University College Cork. None of the subjects had any knowledge of stimulus equivalence or related phenomena. Subjects were randomly assigned to the experimental or control conditions (outlined below) and were paid an hourly rate (IR£2.00 or about $3.00) for participation. They could also earn money while performing the experimental tasks.

Apparatus and Materials

Subjects were seated at a table in a small experimental room with an Acorn Computer Ltd., British Broadcasting Corporation (BBC) Master Series 128 microcomputer with a Pace floppy disk drive and a computer monitor that displayed white characters on a black background. White circular paper dots (1 cm in diameter) were glued to the "Z," "V," and "M" keys on the computer keyboard to designate them as response keys. Stimulus presentation and the recording of responses were controlled by the computer, which was programmed in BBC BASIC.

General Experimental Sequence

There were three experimental phases. During Phase 1, the 4 experimental subjects were trained in a series of conditional discriminations (i.e., A1-B1, A2-B2, A3-B3, A1-C1, A2-C2, A3-C3) and were then exposed to a matching-to-sample equivalence test (i.e., B1-C1, B2-C2, B3-C3). If subjects "failed" the equivalence test they were retrained and retested until they "passed." In Phase 2, subjects were exposed to a three-stage self-discrimination training procedure, during which two of the stimuli that participated in the equivalence relations were used to train two different self-discrimination responses on two complex schedules of reinforcement. That is, choosing B1 was reinforced if a subject had not emitted a response, and choosing B2 was reinforced if one or more responses had been emitted during the immediately prior exposure to one of the two schedules. Phase 3 involved testing for the transfer of self-discrimination response functions through equivalence relations to the C1 and C2 stimuli in the absence of explicit reinforcement (i.e., no response, choose C1; one or more responses, choose C2). Phase 4 involved a modification of Phase 3 in which subjects were required to "discriminate" their schedule performance before exposure to one of the two schedules (i.e., choose C1, do not respond; choose C2, emit one or more responses). Two of the 4 control subjects were exposed to the same general experimental sequence, except that the C1 and C2 stimuli used during conditional discrimination training and equivalence testing were replaced by two additional stimuli, N1 and N2 (note that the C1 and C2 stimuli, which were novel stimuli for the control subjects, were used during the self-discrimination transfer tests). The 2 remaining control subjects were exposed to the self-discrimination training and transfer tests, but were not given any prior exposure to conditional discrimination training or matching-to-sample equivalence testing.

Matching to sample. Conditional discriminations were examined using a symbolic matching-to-sample procedure. Stimuli were three-letter nonsense syllables (e.g., JOM, ZID) that were selected randomly from a pool of 12 syllables for each subject. The sample and the two (or three) comparison stimuli always differed in at least two letters. For matching-to-sample trials, the sample appeared centered in the top half of the monitor screen, followed 1.5 s later by the comparison stimuli, which were positioned to the left and right of the sample, 2 in. from the bottom of the screen (i.e., no observing response to the sample was required). On those trials in which three comparison stimuli were presented, the third comparison was positioned 2 in. from the bottom of the screen, directly below the sample. On each matching-to-sample trial the position of the comparison stimuli was varied randomly (i.e., when two comparisons were presented, the correct nonsense syllable could appear on either the left or right with equal probability, and when three comparisons were presented, the correct nonsense syllable could appear on the left, middle, or right with equal probability). Subjects selected a comparison stimulus by pressing one of two (or three) keyboard keys (marked by white paper dots) that corresponded positionally to the stimuli on the screen (i.e., one key was on the left, another on the right, and where appropriate, the third was in the middle).

Schedule performance. During schedule performance trials, the words "SPACE-BAR TASK" appeared in the center of the monitor screen. Subjects were required to press the space bar on the computer keyboard (the auto-repeat function was disabled for the entire study). On each trial, the computer quasi-randomly (see next paragraph) generated one of two reinforcement schedules: (a) a recycling conjunctive fixed-time (FT) 5-s fixed-ratio (FR) 1 schedule, or (b) a recycling conjunctive DRO FT 5-s schedule. The recycling conjunctive FT 5-s FR 1 schedule required that the subject respond at least once (i.e., press the space bar) during the programmed 5-s interval. If this requirement was met, the subject's performance was defined as correct. If the subject did not respond during the programmed 5-s interval, the performance was defined as incorrect. The recycling conjunctive DRO FT 5-s schedule required that the subject not respond at all (i.e., not press the space bar) during the entire 5-s programmed interval. If this requirement was met, the subject's performance was defined as correct. If the subject responded during the programmed 5-s interval, the performance was defined as incorrect.

For the first trial, and for every trial that followed a correct schedule performance, the computer generated one of the two schedules with equal probability (i.e., a .5 probability for each schedule). However, on those trials that followed an incorrect schedule performance, the computer simply presented the previously generated schedule. Thus, subjects could not obtain reinforcers across 50% (on average) of the trials by consistently emitting the same performance.

Programmed consequences. The correct completion of a schedule control or matching-to-sample training trial removed the stimulus display and produced "CORRECT" in the center of the screen, accompanied by a high-pitched beep for 1.5 s. The incorrect completion of a schedule-control or matching-to-sample trial removed the stimulus display and produced "WRONG" in the center of the screen (again for 1.5 s, without auditory feedback). A message on the lower right side of the screen appeared simultaneously with both types of feedback indicating the total number of points earned *within a given session* (i.e., "POINTS EARNED = 4"); 1 point was added for each correctly completed trial, and 1 point was deducted for each incorrectly completed trial (each point was worth 1 Irish penny or about 1.5 cents). A 1-s intertrial interval (i.e., the screen cleared and remained blank) followed all programmed consequences. On all test trials, the computer omitted all feedback messages and proceeded directly to the intertrial interval.

The computer controlled for typing errors on all tasks (i.e., hitting one of the nonfunctioning keys on the keyboard) by displaying the message "YOU HAVE MADE A MISTAKE—TRY AGAIN" on the screen for 2 s; immediately after this message, the subject was presented with the same sample and comparisons. The appropriate feedback followed this correction procedure.

Procedure

All subjects were trained and tested individually in one or more sessions lasting approximately 45 to 120 min each. The number of sessions required to complete the experiment varied between one and three across subjects. An interval of no more than 1 day between sessions was generally allowed. All money earned was paid 2 weeks after completion of the entire study (the average payment, including the hourly rate of two Irish pounds for participation, was IR£6.50 or about $9.75).

Matching-to-sample equivalence training and testing (experimental subjects). The 4 experimental subjects were trained in six matching-to-sample tasks (see Figure 1) using stimuli selected randomly (for each subject) from a pool of nine nonsense syllables (A1, A2, A3; B1, B2, B3; C1, C2, C3). The subject was seated in front of the computer monitor and keyboard, and was read aloud the following instructions while the experimenter pointed at the relevant keys:

> In a moment the computer will present four nonsense syllables on the screen. You should look at the nonsense syllable at the top and then choose one of the three nonsense syllables at

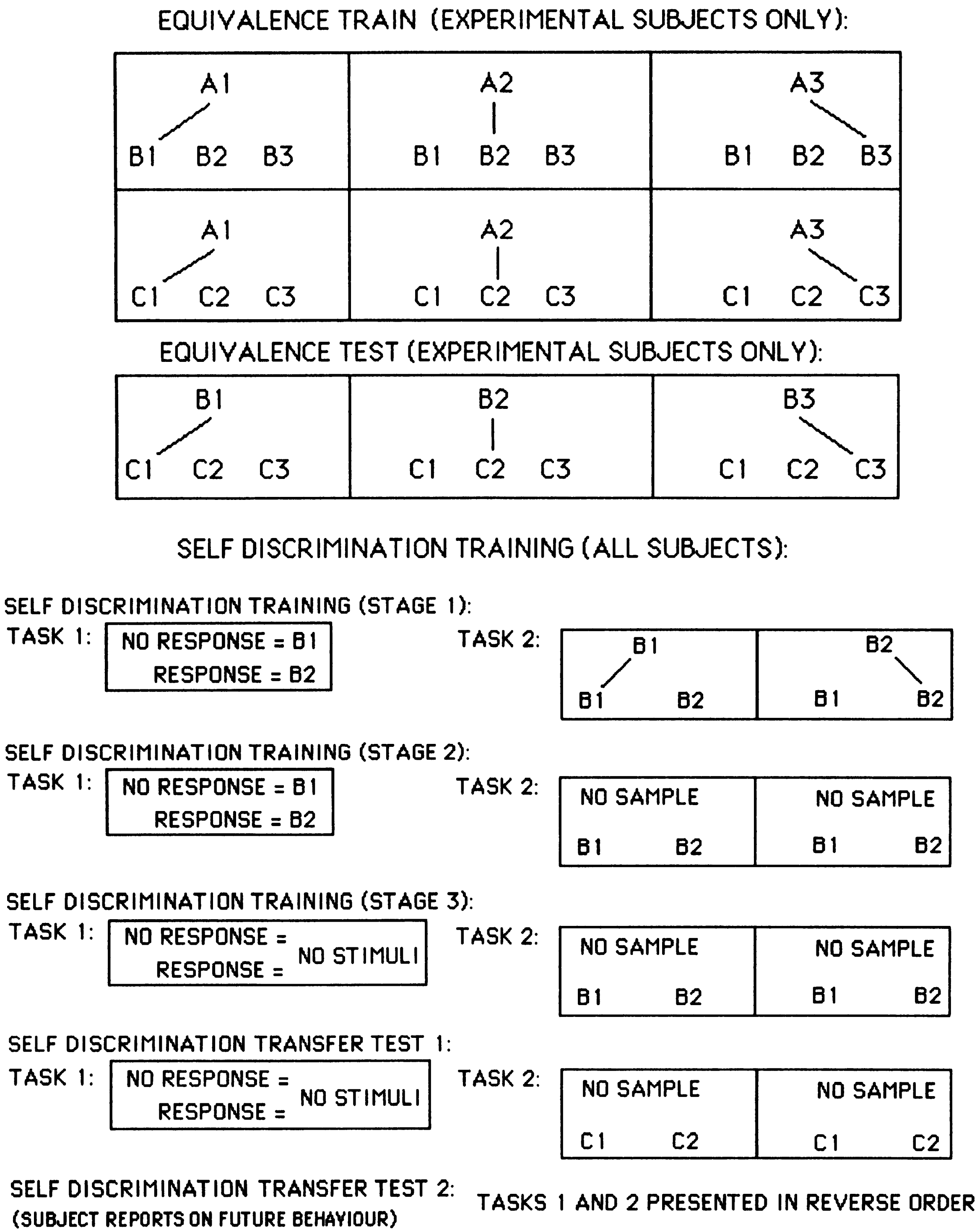

Fig. 1. Upper panel: Schematic representation of equivalence training and testing tasks. Trained and predicted relations are indicated by lines from samples to comparisons. Lower panels: Schematic representation of self-discrimination training Stages 1, 2, and 3 and self-discrimination Transfer Tests 1 and 2.

> the bottom by pressing one of the marked keys on the keyboard.
> To choose the syllable on the left, press the marked key on the left.
> To choose the syllable in the middle, press the marked key in the middle.
> To choose the syllable on the right, press the marked key on the right.
> If you have any questions then ask them now, because the experimenter is not allowed to discuss the experiment with you until you have completed the entire study.

A copy of these instructions was left on the table beside the computer.

On each matching-to-sample trial, the sample (A1, A2, or A3) was presented, followed 1.5 s later by three comparison stimuli (i.e., B1, B2, B3 or C1, C2, C3). Subjects were first trained on the three A-B matching-to-sample tasks. Each of these was presented in a quasi-random order (i.e., each task presented twice in each block of six trials) until the subject produced six consecutive correct responses across one block of six trials. The same procedure was then used to train the three A-C relations. Finally, all six A-B and A-C matching-to-sample tasks were quasi-randomly mixed (i.e., each of the six trial types was presented once every six trials). Subjects were required to produce a total of six consecutive correct responses across one block of six trials before training was terminated. When A1 was the sample, B1 and C1 were correct. When A2 was the sample, B2 and C2 were correct. When A3 was the sample, B3 and C3 were correct. As indicated in Figure 1, B and C comparisons could not appear on the same trial. The minimum possible number of trials to complete the training phase was 18. If a subject did not complete training after 60 min, training was terminated for that session (training was normally resumed later that day).

Following completion of the equivalence training phases, subjects were exposed to a matching-to-sample equivalence test (i.e., combined symmetry and transitivity). The test consisted of three matching-to-sample tasks involving the B stimuli as samples and the C stimuli as comparisons (Figure 1). These tasks were presented in a quasi-random order, with each of the three tasks occurring 10 times for a total of 30 trials. The mastery criterion was 90% correct responding (i.e., 9 of 10 responses on each task correct). Because this was a test, no feedback occurred on any trial. Subjects were exposed to the equivalence test, and retraining (if necessary), until the mastery criterion was reached.

Self-discrimination training instructions. All subjects were seated in front of the computer, and 7 of the 8 subjects were presented with the following "detailed" instructions, which were read aloud by the experimenter while pointing to the relevant keys:

> The computer will present the words "SPACE-BAR TASK" on the computer screen. Whenever you see these words, you must either keep pressing the space bar [a false instruction used to initiate a high response rate], or not press at all. After each task the computer will tell you whether you did the right thing. *There is no way you can get all the space-bar tasks correct, but the best strategy is to keep pressing on some tasks, and on other tasks not to press at all.*
> After each space-bar pressing task, the computer will present two nonsense syllables at the bottom of the screen. You must learn to select the correct nonsense syllable *after* each space-bar pressing task. The computer will tell you when your choice is correct and when it is wrong. *Unlike the space-bar task, you can learn how to always choose the correct nonsense syllable.*
> You select the nonsense syllable on the left by pressing the marked key on the left and the syllable on the right by pressing the marked key on the right.
> Remember your objective is to earn as many points as possible by always trying to make the correct response on both the space-bar pressing tasks and the nonsense syllable choice tasks.
> If you have any questions ask them now, as the experimenter is not allowed to discuss the experiment with you after you have started.

A copy of these instructions was left on the table beside the computer.

The instructions were modified for Subject 4 so as to provide only the minimum amount of information necessary to initiate the subject's contact with the experimental contingencies. This modification allowed us to examine the possibility that extensive and detailed instructions are necessary to generate self-discrimination and derived transfer-test performances using the current procedures (see Saunders, Saunders, Williams, & Spradlin, 1993; Sigurdardottir, Green, & Saunders, 1990). These "minimal" instructions were as follows:

> The computer will present the words "SPACE-BAR TASK" on the computer screen. Whenever you see these words, you must learn how to press the space bar.
>
> After each space-bar pressing task, the computer will present two nonsense syllables at the bottom of the screen. You must learn to select the correct nonsense syllable.
>
> You select the nonsense syllable on the left by pressing the marked key on the left and the syllable on the right by pressing the marked key on the right.
>
> If you have any questions please read the instructions again, and then just "have a go," and see how you get on. The experimenter is not allowed to discuss the experiment with you until after you have completed the entire study.

The appropriate instructions were repeated if a subject requested, and any questions were answered by referring the subject to the instructions. Once the session had started, there was no further contact between subject and experimenter until the session was over.

Self-discrimination training. Three training stages, each consisting of 20 trial blocks, were used to establish the subjects' self-discrimination responding. Each trial involved two tasks, one presented after the other: (a) a schedule-control task and (b) a matching-to-sample task. The purpose of the three training stages was to obtain stimulus control by the on-screen stimuli, and then remove the on-screen stimuli (in two steps), so that the control transferred to the subjects' own behavior (this three-stage training sequence emerged after considerable pilot work).

During the first task of Stage 1, the nonsense syllable designated B1 was always presented on the screen (below the words "SPACE-BAR TASK"), and subjects were required either to respond (i.e., press the space bar) or not to respond (see Figure 1). If the subject did not emit a response, the B1 stimulus remained on-screen for the duration of the schedule (i.e., 5 s). Alternatively, if the subject made a response, B1 was immediately replaced by the nonsense syllable designated B2, and each response thereafter caused B2 to flash (i.e., disappear for 0.25 s and then reappear). When subjects had completed Task 1, they were exposed to a matching-to-sample task (Task 2). In Task 2, the sample was the same stimulus that had been on the screen at the end of the schedule performance task (i.e., B1 or B2). The two comparison stimuli were B1 and B2. When B1 was the sample, B1 was the correct comparison. When B2 was the sample, B2 was the correct comparison. In effect, subjects could produce a correct matching-to-sample response at this stage, by means of identity matching, without necessarily discriminating their own schedule performance. These two tasks were presented in blocks of 20 trials (i.e., Task 1 followed by Task 2, each repeated 20 times), and they represented the first stage in establishing self-discrimination functions for both B1 and B2.

Stage 2 was identical to Stage 1, except that in Task 2 the matching-to-sample format was modified; no sample was presented above the two comparisons (Figure 1). By not presenting a sample during Task 2, subjects were thus required to "remember" the sample that had been present at the end of the schedule-control trial (i.e., a delayed identity-matching procedure). As in Stage 1, subjects could produce a correct matching-to-sample performance on Task 2 without discriminating their own schedule performance.

Stage 3 was identical to Stage 2, except that the stimuli involved in Task 1 were removed. That is, a subject's performance on this task was not accompanied by the appropriate on-screen nonsense syllable. This final modification thus required that the subject discriminate his or her "no response/response(s)" performance on the previous schedule in order to produce the correct response (i.e., choose the correct nonsense syllable) on Task 2 (see Figure 1). This is the first point at which subjects had to discriminate their preceding schedule performance.

It is important to recall that the use of recycling conjunctive schedules for self-discrimination training arranged that each schedule trial terminated after 5 s, and the appropriate feedback was presented. Thus, when choosing comparison stimuli, subjects were simply required to discriminate the absence or presence of responding on the schedule rather than the reinforcement contingency (see Hineline & Wanchisen, 1989). For instance, even if a subject did not emit a response on the recycling conjunctive FT 5-s FR 1 schedule, and thus "WRONG" appeared after the 5-s interval, he or she could still successfully discriminate an "incorrect schedule performance" (i.e., pick B1).

Mastery criterion. During training Stages 1 and 2, there was no specific mastery criterion, although in general, subjects progressed from one stage to the next only when they achieved 18 of 20 correct matching-to-sample responses (Task 2) in a given block of 20 trials. During training on Stage 2, if they barely failed to reach this criterion (e.g., 16 of 20) they were normally reexposed to the same stage, but if their performance fell well below criterion (e.g., 12 of 20) they were returned to Stage 1.

A strict mastery criterion of 18 of 20 correct matching-to-sample responses within a given block of 20 trials was employed for self-discrimination training Stage 3. If subjects failed to meet this criterion, they were either reexposed to Stage 3 or returned to an earlier stage. No specific criteria were used to decide whether a subject should be retrained on Stage 3 or returned to an earlier stage, although decisions were usually based on how poorly or well a subject had performed on his or her last exposure (e.g., if performance approached the 18 of 20 stability criterion, subjects were reexposed to Stage 3, but if it did not, they were returned to an earlier stage). No explanation or other form of verbal contact between subject and experimenter was allowed during or between these blocks of training trials.

Self-discrimination transfer tests: Test 1. Having completed self-discrimination training with the B1 and B2 stimuli, subjects were exposed to the first transfer-of-function test (Figure 1). Test 1 was identical to the final self-discrimination training stage, except for one important difference; the stimuli in Task 2 were the nonsense syllables designated C1 and C2. This tested for a derived transfer of self-discrimination response functions (i.e., no response, B1; response, B2), through equivalence relations, to the C1 and C2 stimuli (i.e., no response, C1; response, C2). No feedback occurred on Task 2 across any of the 20 test trials ("correct" and "wrong" feedback occurred on Task 1 trials, but the "points earned" feedback was omitted during all transfer tests).

Test 2. Test 2 involved a reversal in the order of presentation of Task 1 and Task 2 (Figure 1). Subjects were first presented with the C1 and C2 stimuli, and were required to select the stimulus that corresponded to what they "intended to do" on the following schedule task. Before exposure to Test 2, subjects were simply told, "This time you have to pick a nonsense syllable before you press the space bar." That is, if a subject chose C1 and did not respond on the schedule task, the previous selection of C1 was defined as correct. Similarly, if a subject selected C2 and subsequently responded on the schedule task, the previous selection of C2 was defined as the correct self-discrimination response. Again, no feedback occurred on Task 2 for any trial.

Control Procedures

Nonequivalence control subjects. Two subjects (5 and 6) were trained in all three self-discrimination training stages but did not receive matching-to-sample equivalence training or testing. Subjects were then exposed to Test 1 and Test 2. The nonequivalence subjects were employed to control for the possibility that the transfer of self-discrimination response functions may occur without any prior form of matching-to-sample equivalence training or testing (i.e., as a result of an unexpected procedural artifact).

Equivalence control subjects. Two subjects (7 and 8) were exposed to a modified version of the matching-to-sample equivalence training and testing. Specifically, these 2 subjects received the same general sequence of training and testing as the experimental subjects, except that during conditional discrimination training, the C1 and C2 stimuli were replaced by two additional stimuli, N1 and N2. In effect, the control subjects were trained on six tasks (A1-B1, A2-B2, A3-B3, A1-N1, A2-N2, A3-C3) and were tested for equivalence on three tasks (B1-N1, B2-N2, B3-C3). The equivalence controls were exposed to the same transfer tests as the experimental subjects using the C1 and C2 stimuli, which were novel stimuli for the control subjects. These 2 subjects were employed to test the possibility that correct transfer performance may emerge as a result of mere exposure to a matching-to-sample equivalence procedure (i.e., as a result of some unexpected procedural artifact).

RESULTS

The results are shown for each subject in Figures 2 to 5. The word "Train" followed by a number gives the number of training trials presented during a subject's first exposure to the matching-to-sample equivalence training

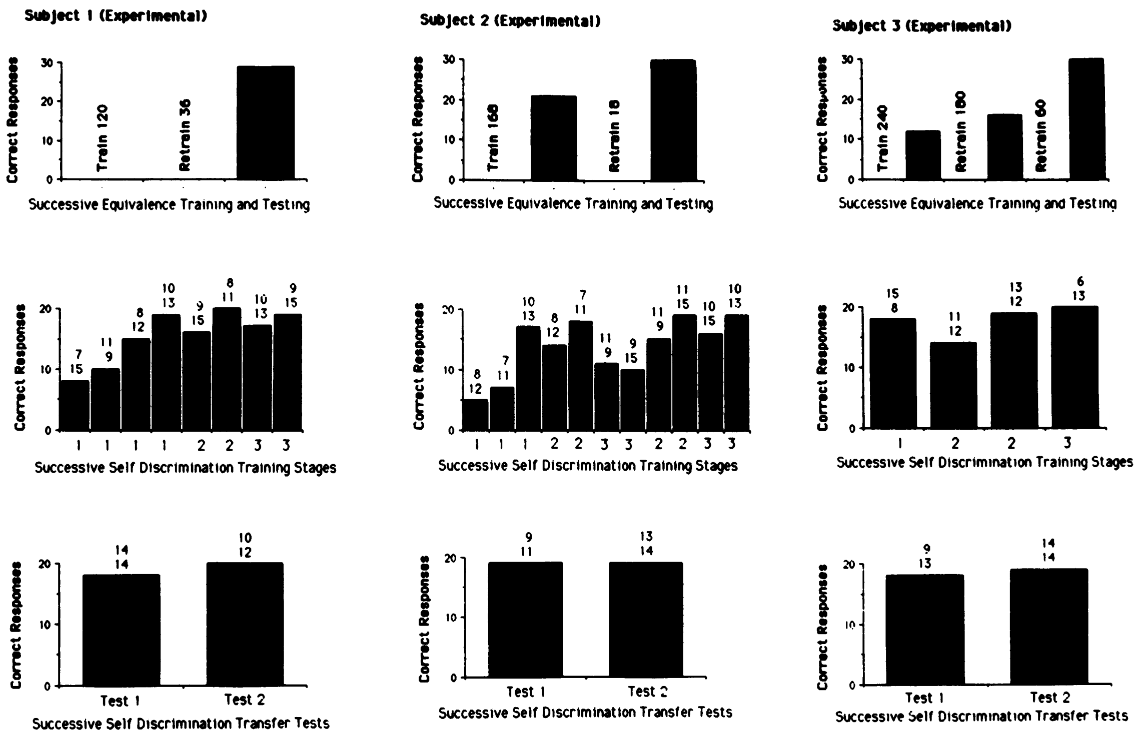

Fig. 2. Results of equivalence training and testing and self-discrimination training and testing for Subjects 1, 2, and 3, who were provided with detailed instructions (see text for details).

(upper graphs in all figures). "Retrain" followed by a number indicates the number of training trials presented during all subsequent exposures to these training phases (i.e., when a subject failed to achieve the mastery criterion during training or testing). The numbers above each column for the self-discrimination training stages and transfer tests (center and lower graphs in all figures) provide information regarding the subjects' performance across each block of 20 schedule-performance trials. The top number above each bar shows the number of trials on which the subject responded (i.e., pressed the space bar), and the lower number indicates the number of correct schedule tasks completed.

Equivalence Experimental (Detailed Instructions)

Subject 1 (Figure 2) required two exposures to the matching-to-sample training (a total of 156 trials) before successfully reaching the mastery criterion on his first exposure to the equivalence test (i.e., 29 correct responses out of 30). This subject then required four exposures to self-discrimination training Stage 1, two exposures to Stage 2, and two exposures to Stage 3. When Subject 1 was exposed to the self-discrimination transfer tests, he produced 18 correct responses on Test 1 and 20 correct responses on Test 2, thereby demonstrating the predicted transfer of self-discrimination response functions from the B to C stimuli through equivalence relations. Subject 2 (Figure 2) "failed" his first equivalence test after 168 training trials, but passed on his second exposure after a further 18 training trials. This subject then required 11 exposures to the three self-discrimination training stages, four of which were to the crucial Stage 3. During his subsequent exposures to Transfer Tests 1 and 2, the predicted performances emerged. Subject 3 (Figure 2) required three exposures to the matching-to-sample training and equivalence testing before reaching the equivalence mastery criterion (a total of 480 training trials and 90 test trials). She then passed Stage 3 of the self-discrimination training after one exposure to Stage 1 and two exposures to Stage 2. On the subsequent Transfer Tests 1 and 2,

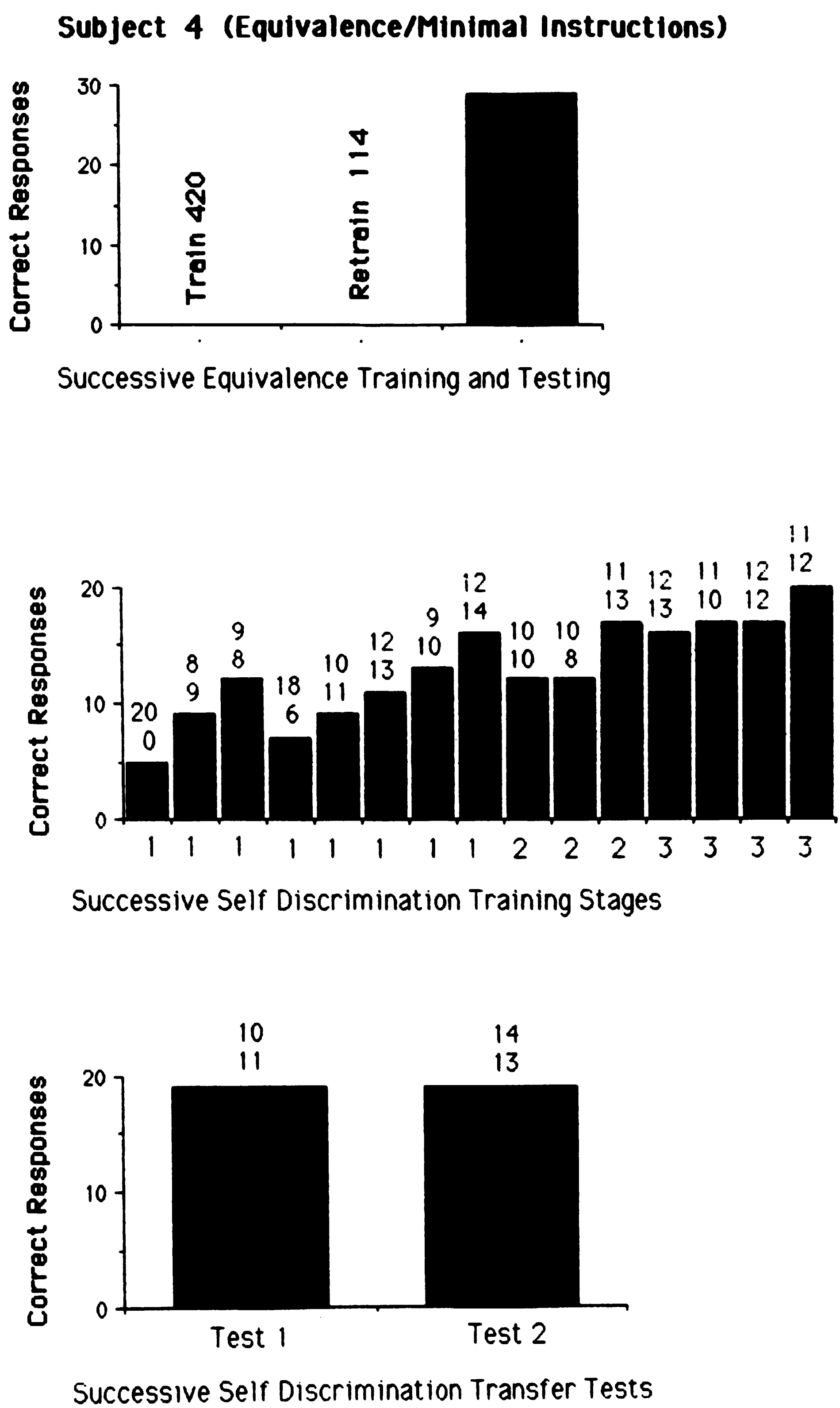

Fig. 3. Results of equivalence training and testing and self-discrimination training and testing for Subject 4 (minimal instructions).

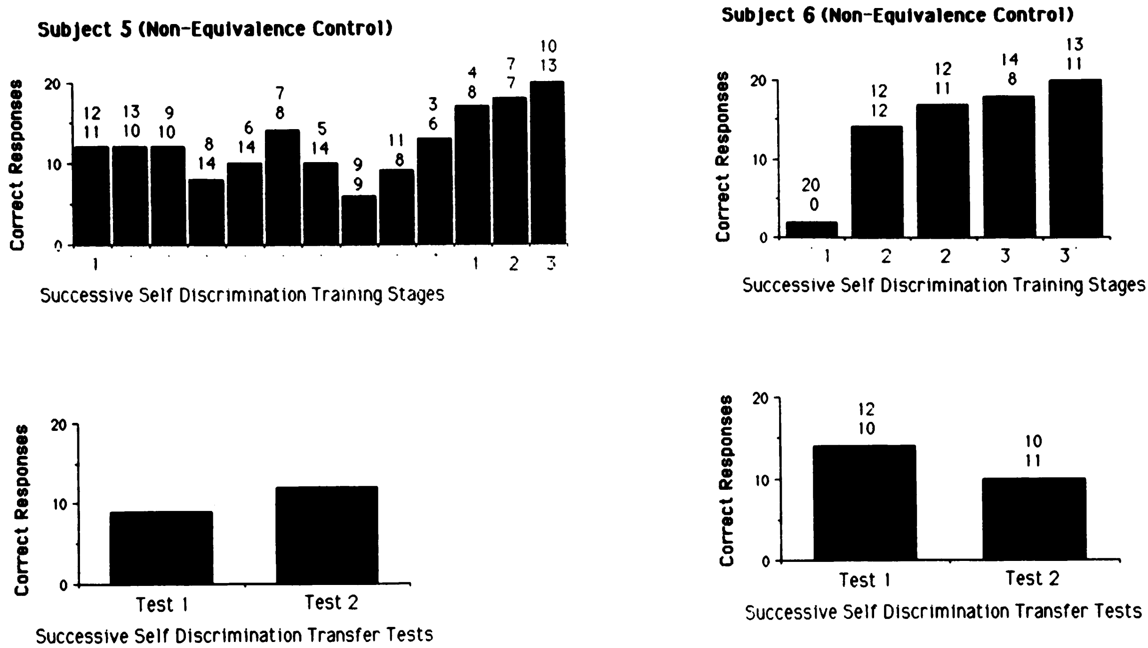

Fig. 4. Results of self-discrimination training and testing for nonequivalence control Subjects 5 and 6. No figures appear above the two bars for the transfer tests for Subject 5 because the within-trial data for this subject were lost due to a damaged floppy disk.

the subject showed the predicted derived transfer of self-discrimination response functions through equivalence relations.

Equivalence Experimental (Minimal Instructions)

Subject 4 (Figure 3) required two exposures to the matching-to-sample training (a total of 534 trials) before achieving the mastery criterion on his first exposure to the equivalence test (i.e., 29 correct responses out of 30). This subject then required 15 exposures to the self-discrimination training stages, four of which were Stage 3, before demonstrating the transfer of self-discrimination response functions through equivalence relations.

Nonequivalence Control

Subject 5 (Figure 4) required 13 exposures to the self-discrimination training stages, one of which was the crucial Stage 3. His performance on Transfer Test 1, however, failed to show the derived transfer demonstrated by the 4 experimental subjects. Subject 6 (Figure 4) required five exposures to the self-discrimination training stages, and her performance on Transfer Test 1 also failed to show any sign of transfer. These data support the conclusion that the transfer performances of the experimental subjects did not arise from an unpredicted artifact inherent in the self-discrimination training and testing procedures.

Equivalence Control

Subject 7 (Figure 5) passed her first equivalence test after a total of 192 training trials. This subject required 10 exposures to the self-discrimination training stages, three of which were the crucial Stage 3, but like the nonequivalence control subjects, she also failed to produce a derived transfer performance. Subject 8 (Figure 5) passed the equivalence test on his second exposure, after a total of 282 training trials. He then received five exposures to the self-discrimination training stages, one of which was to the crucial Stage 3. This subject was then given three consecutive exposures to Transfer Test 1 and one exposure to Test 2, but he still failed to show a derived transfer performance. These data clearly indicate that the transfer performances of the experimental subjects were not produced by an unpredicted artifact inherent in the matching-to-sample training and equivalence testing procedures.

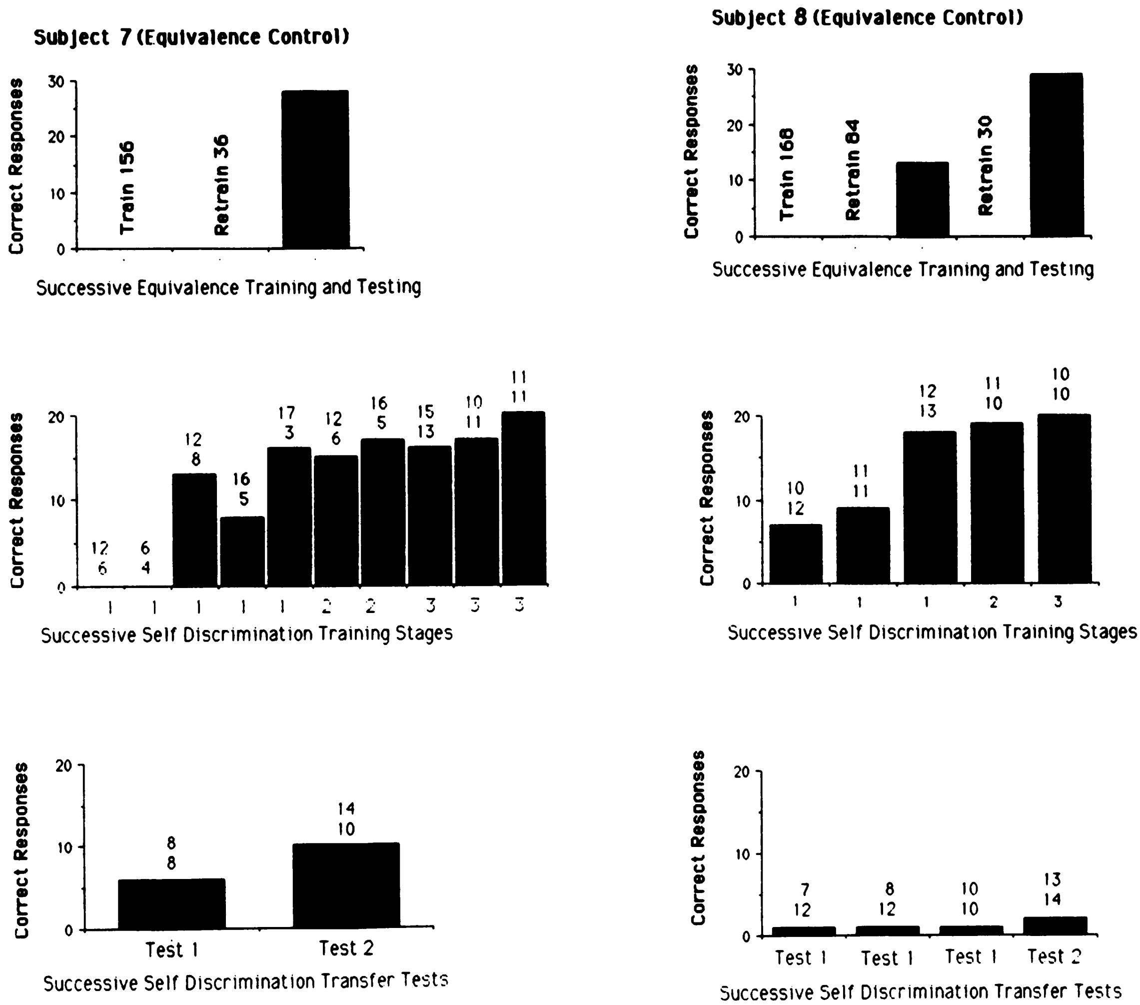

Fig. 5. Results of equivalence training and testing and self-discrimination training and testing for equivalence control Subjects 7 and 8.

DISCUSSION

All 4 experimental subjects demonstrated the predicted formation of three equivalence relations and the transfer of self-discrimination response functions through two of these relations, and 1 of the 4 subjects demonstrated this transfer when minimal instructions were used to initiate the self-discrimination training. None of the 4 control subjects, however, produced a "transfer-like" performance. It is important to note that all 4 experimental subjects showed a transfer of functions during their first exposure to the transfer tests. It is very likely, therefore, that the predicted performances were largely derived from the trained relations, and certainly were not produced by the additional feedback provided by the repeated training and testing that is often employed in transfer-of-function procedures (see Barnes & Keenan, 1993b, p. 63). The present findings extend previous transfer-of-function research (e.g., Barnes & Keenan, 1993b; de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; Hayes et al., 1991; Wulfert & Hayes, 1988), in that the derived transfer effect has been shown for the first time with self-discrimination response functions, both with regard to prior (Test 1) and subsequent (Test 2) schedule performance.

Although the detailed and extensive verbal instructions given to 3 of the experimental subjects at the beginning of the self-discrimination training may have played a role in generating the predicted transfer effects (see Baron & Galizio, 1983; Saunders et al., 1993; Sigurdardottir et al., 1990), the results obtained from Subject 4 suggest that the instructions were not, in fact, necessary to produce the transfer performances. Clearly, however, the use of only one "minimally instructed" subject does not allow us to determine the extent to which the presentation of detailed instructions facilitated (or perhaps suppressed) derived transfer. Indeed, the role of instructions in transfer studies remains unclear. For example, although intuitively we might expect detailed instructions to facilitate a transfer performance, recent evidence (Green, Sigurdardottir, & Saunders, 1991) suggests that when subjects are exposed to detailed and extensive instructions they may show a transfer of functions *less* readily than subjects who are provided with minimal instructions. Such a finding, combined with the absence of this effect in the present study, indicates that a systematic investigation of the role of verbal instructions in transfer studies is needed.

Another issue that requires further attention is the nature of the relationship between the derived responding seen on matching-to-sample equivalence tests and the derived responding observed on transfer tests. All of the experimental subjects in the current study showed the predicted transfer performance immediately following their derived responding on the matching-to-sample tasks. A number of other researchers, however, have reported that matching-to-sample equivalence responding may occur *without* a subsequent transfer performance in accordance with the matching-to-sample equivalence relations (e.g., de Rose, McIlvane, Dube, & Stoddard, 1988; Green et al., 1991). The relationship between derived behavior on matching-to-sample and transfer tasks is a complex and poorly understood area. For example, although matching-to-sample equivalence may occur without transfer, it is also the case that testing for equivalence using a matching-to-sample procedure can increase the likelihood that the predicted transfer performance (through equivalence relations) will emerge (e.g., Hayes et al., 1991; Wulfert & Hayes, 1988). Clearly, therefore, additional research is needed in this area, and thus it seems best simply to view the current findings as further evidence that a derived transfer is highly likely, but not certain, following derived responding on matching-to-sample tasks (see Barnes & Keenan, 1993b, pp. 79–80).

The Conceptual Status of Equivalence and Derived Transfer

Thus far, we have used the phrase "a transfer of self-discrimination response functions *through* equivalence relations" to describe the transfer test performances of the experimental subjects. However, it is also possible to view the self-discrimination response functions in this study as participating in the equivalence relations, rather than as something that "transfers through" the relations. Consider the following interpretation of the current data. In Stages 1 and 2 of the self-discrimination training, the B1 and B2 stimuli were paired with responses (or response-produced stimuli); B1 remained on the screen before a response was emitted on the schedule, but if a response occurred, B2 replaced B1, and B2 then flashed after every subsequent response on the schedule. During Stage 3 of the self-discrimination training, the subjects then demonstrated that the schedule performances (i.e., the response-produced stimuli) as samples controlled selection of B1 and B2 as comparisons. In effect, this was a conditional discrimination in which the subject's own behavior served as the sample in a delayed matching-to-sample task. Thus, we could conceptualize this as training D1-B1 and D2-B2 and testing for D1-C1 and D2-C2 (Transfer Test 1) and C1-D1 and C2-D2 (Transfer Test 2) to determine whether the D stimuli (the subjects' schedule performances) joined the previously established equivalence relations (D1-B1-A1-C1 and D2-B2-A2-C2).

This would appear to be a more parsimonious description of the current findings insofar as it removes the need for the transfer-of-function terminology. However, it is important to remember that the term *stimulus equivalence* is merely a label for an experimental procedure and a particular experimental outcome and does not enjoy the status of a basic or fundamental behavioral principle, such as *reinforcement* or *discrimination* (see Barnes, 1994; Barnes & Holmes, 1991; Hayes, 1991; Hayes & Hayes, 1989; Pilgrim, 1993; Sidman, 1992; Stromer, McIlvane, & Serna, 1993). In effect, the behavioral phenomenon of stimulus equivalence remains unexplained, and thus a description of the current procedures and data in terms of equivalence alone is more parsimonious, but not more explanatory, than a description in terms of equivalence and transfer.

Of course, in recognizing equivalence as nonexplanatory, the same criticism may be leveled at the transfer-of-function terminology because it appears to use equivalence as an explanatory concept (i.e., transfer *through* equivalence implies that equivalence explains the transfer). However, it is important to understand that we have used the transfer-of-function terminology as defined by the relational-frame account, which views "standard" matching-to-sample equivalence responding and derived transfer of function performances through equivalence as products of the single behavioral process of arbitrarily applicable relational responding (Barnes, 1994; Barnes & Holmes, 1991; Barnes & Keenan, 1993b, p. 80; Hayes, 1991; Hayes & Hayes, 1989; Steele & Hayes, 1991). According to this account, the "standard" matching-to-sample performances described as symmetry and equivalence are a transfer of sample and comparison functions in accordance with the mutually (symmetry) and combinatorially (symmetry and transitivity) entailed relations of equivalence; "in an equivalence class the function of the sample transfers to a comparison or there would be no 'equivalence class'" (Hayes, 1992, p. 111; see also Barnes, 1994, for a detailed examination of this issue). Thus we should view the distinction between stimulus equivalence and a transfer of functions in the current paper as referring to the two defining but inseparable properties of the same behavioral process: (a) a transfer of matching-to-sample *and* self-discrimination response functions in accordance with (b) the mutually and combinatorially entailed relations of equivalence.

Parenthetically, relational-frame theory makes a distinction between entailment relations (i.e., mutual and combinatorial entailment) and a transfer of functions because functions may transfer in a large variety of patterns, and it is scientifically useful to discriminate these patterns from each other in a relatively consistent manner. These various patterns of transfer of function are normally categorized as instances of the mutually and combinatorially entailed relations of coordination, opposition, comparison, and so on (see Hayes & Hayes, 1989, for a detailed description of these and other entailed relations and see a forthcoming paper in this journal in which we report a transfer of self-discrimination response functions in accordance with the three entailed relations listed above). In effect, *the observed pattern of a transfer of functions defines the entailed relations*, and thus the entailed relations (e.g., symmetry and equivalence) do not exist as a behavioral event until a specific transfer of functions has occurred (e.g., a transfer of matching-to-sample functions on a standard equivalence test) (cf. McIlvane & Dube, 1990).

In summary, therefore, it is possible at the present time to describe the current findings using either the descriptive procedural terms of stimulus equivalence or the process-based, potentially explanatory transfer-of-function terminology of the relational-frame account. Of course, the language of relational-frame theory is explanatory only insofar as it helps the behavioral scientist to predict and control the history of behavioral interactions necessary to produce derived behavior such as matching-to-sample equivalence. Evidence in this regard, though limited, is growing (see Barnes, 1994; Barnes & Hampson, 1993; Cullinan, Barnes, Hampson, & Lyddy, in press; Dymond & Barnes, in press; Lipkens, Hayes, & Hayes, 1993; Schusterman & Kastak, 1993[2]; Steele & Hayes, 1991). Nevertheless, the decision to adopt the language of relational frame theory in the current paper remains a tentative one.

Implications for Self-Verbalized Rule Control

The present study shows that equivalence-generating procedures may be used in the experimental analysis of self-discrimination response functions with verbally competent human adults. There are a number of conceptual implications of this research for behavior analysis. We referred to a clinical issue in the Introduction, but the current findings may also

[2] Schusterman and Kastak (1993) have shown that a sea lion can show derived matching-to-sample equivalence (across 18 sets of stimuli) *after a history of explicit reinforcement* for responding in accordance with symmetry and transitivity (across 12 sets of stimuli). Although Schusterman and Kastak are not relational-frame theorists, their data clearly support the relational-frame explanation for equivalence (i.e., a behavioral effect that requires a specific history of arbitrarily applicable relational responding).

have a bearing on the area of self-verbalized rule control on schedules of reinforcement (see Chase & Danforth, 1991; Lowe, 1979). Specifically, it was shown that a derived transfer of self-discrimination response functions may occur in which schedule performance is discriminative for choosing a particular stimulus (Transfer Test 1) and in which that stimulus is also discriminative for the schedule performance (Transfer Test 2). This finding suggests that quite complex, nonlinear interactions between schedule performances and verbal descriptions may occur when verbally able humans are exposed to schedules of reinforcement. This effect may help to explain, at least in part, why some human subjects often produce "insensitive" patterns on reinforcement schedules (e.g., Catania, Matthews, & Shimoff, 1982; Lowe, 1979; Weiner, 1964). For example, an experimentally naive subject exposed to a fixed-interval (FI) schedule may produce a high-rate pattern on the first trial that will be discriminative for the "descriptive" response: "Pressing earns points." Given an appropriate context, the discriminative function of the schedule performance may transfer through the mutually entailed relation of symmetry to the verbal description of that performance, and thus the description may become discriminative for subsequent schedule performances (i.e., the subject will maintain a high-rate performance, and the behavior will appear to be insensitive to the FI contingency).

Of course, the interaction between schedule performance and a verbal description of that performance represents a behavior–behavior relation, and thus a complete account will involve the identification and manipulation of the historical and current contexts that produce and control the interaction itself (see Barnes, 1989; Barnes & Keenan, 1989, 1993a, 1994; Hayes & Brownstein, 1986). The current study provides another possible avenue for exploring this issue by developing procedures in which the relationship between the schedule performance and the "description" was explicitly trained (i.e., selection of B1 or B2 after a schedule performance) and tested (i.e., selection of C1 or C2 before or after a schedule performance). Furthermore, insofar as these procedures provided direct experimental (i.e., environmental) control over a behavior–behavior relation on a schedule of reinforcement (e.g., the discriminative functions of one behavior for the other were shown to be reversible across Transfer Tests 1 and 2), it would appear unwise to attribute *causal* properties to one class of behavior (e.g., verbal) over another class, as has been suggested by other researchers (e.g., Lowe, 1979; Wearden, 1988).

Conclusion

Clearly, there are a number of important conceptual issues that need to be considered in light of these data. However, many empirical questions remain. For example, could these types of performance be generated with less well educated adults, young children, verbally disabled humans, or nonhuman species? And perhaps more importantly, if one or more of these subject populations failed to demonstrate a derived transfer of self-discrimination response functions, what types of behavioral histories might we arrange to produce this form of derived transfer? Finding answers to these empirical questions should also help to clarify some of the wider conceptual issues raised by the present study.

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