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A transformation of discriminative functions in accordance with equivalence relations

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In two experiments each consisting of six phases, two adults and six 5- to 6-year-old children were taught A-B and A-C conditional discriminations and were tested for the derivation of two combinatorially entailed equivalence relations (B1-C1 and B2-C2). Next, the behavioural function of clapping hands was reinforced in the presence of B1 and waving was reinforced in the presence of B2. Finally, subjects were tested for a transformation of functions where they were required to first clap or wave and were then presented with the C stimuli. It was predicted that subjects would select C1 having clapped, and C2 having waved on the preceding task (i.e., if clap, then pick C1/if wave, pick C2). All subjects demonstrated the predicted performance. Present findings are discussed from a relational frame perspective with an emphasis on the nature of derived transformation effects.

Key words: transformation of functions, equivalence relations, conditional discrimination, self-discrimination, relational frame theory, children, adults.

Behaviour analysis continues to witness burgeoning interest in the study of derived stimulus relations. Typically studied using a matching-to-sample (MTS) procedure, the basic finding is as follows. Suppose, for instance, reinforcement is delivered for selection of comparison B in the presence of the sample A, and for selection of comparison C in the presence of sample B, respectively. Most verbally able humans will now readily reverse these explicitly reinforced conditional discriminations in the absence of further training. That is, they will now select A given B and B given C in accordance with derived symmetrical or mutually entailed stimulus relations. Furthermore, subjects will now also select C given A and A given C in accordance with derived transitive and equivalence or combinatorially entailed stimulus relations, without further training. Following such a derived performance, the stimuli are said to participate in an equivalence class (Sidman, 1994) or relational frame of equivalence (Hayes, Barnes-Holmes, & Roche, 2001). Perhaps what is most interesting about derived stimulus relations such as equivalence are that the test outcomes are not readily predicted by the traditional concept of conditional discrimination since neither A nor C has a direct history of differential reinforcement with regard to the other, and therefore neither stimulus should control selection of the other. The implications of a behaviour-analytic approach to an understanding of derived or novel behaviour for which a direct history of reinforcement is remote has not gone unnoticed (Hayes et al., 2001; Hayes & Hayes, 1992).

Another key feature of derived stimulus relations is the transfer or transformation of stimulus functions. The transformation of stimulus functions is said to refer to the altering or transform-

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ing of the stimulus functions of relata based on contextual cues for a relevant function (C_{func}) and the derived stimulus relation (C_{rel}) in which the events participate (for a review, see Dymond and Rehfeldt, 2000). For instance, if the C stimulus mentioned above is paired explicitly with an eliciting stimulus, such as brief electric shock (C_{func}), then A will also likely acquire eliciting functions based on its derived equivalence relation (C_{rel}) with C. To date, an increasing number of stimulus-function transformations have been studied in several laboratories with a wide range of operant and respondent behavior (e.g., Barnes & Keenan, 1993; Dougher, Augustson, Markham, Greenway, & Wulfert, 1994; Dougher, Perkins, Greenway, Koons, & Chiasson, 2002; Dymond & Barnes, 1994, 1995; Hayes, Kohlenberg, & Hayes, 1991; Rehfeldt & Hayes, 1998; Roche & Barnes, 1997; Smeets & Barnes-Holmes, 2003; Whelan & Barnes-Holmes, 2004).

For instance, in the study by Dymond and Barnes (1994) subjects were first trained in six matching-to-sample tasks (i.e., if Al select B1, A1-C1, A2-B2, A2-C2, A3-B3, A3-C3) and were then tested for the formation of three equivalence relations (i.e., A1-B1-C1, A2-B2-C2, A3-B3-C3). Following a successful equivalence test, subjects were trained to emit two self-discrimination responses (discriminations based on one's own behaviour) on two time-based schedules of reinforcement: if subjects did not emit an operant response (pressing the computer space-bar), choosing one stimulus (B1) was reinforced, and if they did emit one or more responses, choosing another stimulus (B2) was reinforced. Finally, subjects were tested for a transformation of these self-discrimination response functions through derived equivalence relations (i.e., no response - choose C1, and one or more responses - choose C2; Test 1). All four experimental subjects demonstrated the predicted formation of three equivalence relations and the transfer of self-discrimination response functions through two of these relations. Subjects also demonstrated this performance when they were required to discriminate their schedule performance before exposure to the actual schedule (i.e., "what I intend to do"; Test 2).

If research on equivalence and derived transformation are to have implications for the behavior analysis of language and cognition then it should be possible to demonstrate a contextually controlled transformation of functions in accordance with equivalence relations in verbally able children and developmentally disabled adults (see Dougher et al., 2002). Evidence in this regard is promising. Derived symmetrical relations have been observed in a 16 month old infant (Lipkens, Hayes, & Hayes, 1993) and evidence exists that adults with developmental disabilities can show derived transfer (e.g., de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988). Also, Barnes et al., (1995) demonstrated a transfer and a conditional transfer of discriminative functions through equivalence relations in children aged between 3 and 6 years of age. Similarly, Smeets et al. (1997) examined emergent stimulus-stimulus and stimulus-response relations in preschool children, and Dymond and Barnes (1997a) have replicated their 1994 study with children, the youngest of whom was aged 8. It remains to be seen, therefore, whether children younger than 8 years of age are capable of the derived performances seen in these and other transfer studies. The present study was an attempt to answer this question.

Recent relational frame research has expanded the analysis of derived behaviour to include tests for the transformation of stimulus functions in accordance with relations other than equivalence such as same, opposite, and more-than/less-than. Specifically, research has shown that any stimulus function can be transformed in accordance with the particular relation employed (e.g., Dymond & Barnes, 1995; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeady, 2000; Whelan & Barnes-Holmes, 2004). For example, suppose a child has learned to clap her hands twice in the presence of an arbitrary stimulus, X. Now, if X participates in a derived relation of more-than with another stimulus, Y, and in a derived relation of less-than with Z, it is likely that the child will, without further training, clap hands more-than twice in the presence of Y and less-than twice in the presence of Z. The term transformation of functions is used to describe effects such as this instead of transfer, because the explicitly trained 'clap twice' function of X does not transfer to Y and Z (i.e., Y and Z do not acquire 'clap twice' functions), but rather the 'clap twice' function of X transforms the functions of Y and Z in accordance with more-than and less-than relations (Dymond & Rehfeldt, 2000).

In the majority of studies attempting to study transformation, the tested stimulus functions usually remain topographically unchanged from the trained stimulus functions (i.e., train and test a discriminative function). As Dougher et al., (2002) point out, "stimulus equivalence studies concerned with the transfer of function generally report the transfer of identical functions, but it remains to be seen whether this is necessarily or even generally the case. It is possible, for example, that partial or even novel functions can be created for equivalent stimuli through transfer of function" (p. 64). A complete description of such an outcome necessitates use of the term transformation rather than transfer since all derived relational responding involves a transformation of functions to some extent, and without contextual control "all stimuli would eventually acquire the functions of all other stimuli" (Dougher et al., 2002, p. 64).

Similarly, in most of the research of this kind, testing sessions are often conducted within the same context and subject to the same constraints (i.e., experimenter-provided instructions and task presentation) as the training context. The present study sought to address the possibility of whether a transformation of functions would be demonstrated in accordance with equivalence relations when the training and testing contexts are different (i.e., train a discriminative function and test for a self-discriminative function). According to relational frame theory research, the transformation of stimulus functions is always under contextual control, and hence derived functions may emerge in accordance with both equivalence relations and multiple stimulus relations (Dymond & Rehfeldt, 2000).

As outlined above, subjects in the Dymond and Barnes (1994, 1997a) studies were exposed to the second transformation test, Test 2 (i.e., choose C1 - no response, and choose C2 - one or more responses) immediately following exposure to Test 1 (i.e., no response - choose C1, and one or more responses - choose C2). It is possible that experiencing the tests in this order may have provided subtle cues to the subjects to "do what I have just done [on Test 1] but in reverse order [on Test 2]." That is, it was highly likely that subjects would, when presented with Test 2, choose C1 and emit one or more responses, and choose C2 and emit no response, having successfully completed transfer Test 1. In fact, all subjects who showed transfer on Test 1 did so on Test 2 also.

Clearly, Test 2 was a different testing context from that of Test 1, but the emergent behavior (schedule performance and stimulus selection) were the same in both tests. The present study examined the possibility of training one function such as a discriminative function (e.g., see B1 - clap/see B2 - wave), and testing for emergence of a self-discrimination function (e.g., clap - C1/wave - C2) as in the Dymond and Barnes (1994, 1997a) studies. It would be inaccurate to describe this as a 'transfer' of functions, since the trained and tested functions differ. Rather, it is more appropriate to describe this pattern as a 'transformation' of functions, as the discriminative functions of B1 and B2 are 'transformed' in accordance with equivalence relations when C1 and C2 are tested as self-discrimination functions. The present study sought to demonstrate this transformation effect in accordance with equivalence relations in young children (Experiment 1) and adults (Experiment 2). In Phases 1-3, A-B and A-C conditional discriminations were trained, and Phase 4 tested for the derivation of B-C equivalence relations. In Phase 5, two discriminative functions, clapping and waving hands, were trained to the B1 and B2 stimuli (B1-clap/B2-wave), and in the crucial test phase, Phase 6, a transformation of functions was tested (i.e., if clap, then pick C1/if wave, pick C2).

EXPERIMENT 1

Method

Subjects

Six children, two male and four female, participated. Five of the children were recruited from a local after-school play scheme (CJ, GG, KF, PR, & TP) and one from personal contacts (HH). The ages of the children, in years and months, at completion of the study were as follows: CJ (5.7),

GG (6.2), HH (4.11), KF (4.8), PR (5.11), and TP (5.1), (M = 5.3).

Apparatus, Stimuli, Instructions, and Reinforcement Procedure

A paper-based, tabletop presentation procedure was employed (see Dymond & Barnes, 1997a; Dymond, Rehfeldt, & Schenk, in press). The stimuli were 6 cm x 6 cm Greek symbols black in color (see Figure 1) displayed on 29.5 cm x 21 cm sheets of laminated white paper. Each sheet was presented individually on a bookstand placed before the subject. Additional materials were a clear-plastic container and a tray of multicolored beads. Filling the container required 30 beads.

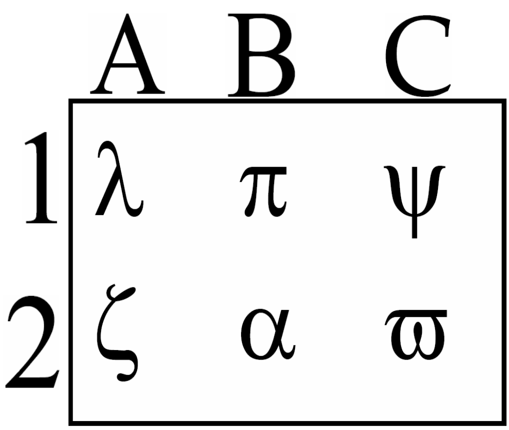


Figure 1. Stimuli used in the study (A1-B1-C1, A2-B2-C2).

During the first few conditional discrimination training trials, children were instructed to "Look at the shape at the top [of the page] and pick one of the shapes at the bottom". Pointing to the designated S+, or 'correct', stimulus was followed by the experimenter saying "Good, that's right. Take a bead" and "No, that's wrong. No bead" following incorrect responses. During the AB and AC conditional discrimination training trials, all of the subjects' correct responses produced reinforcers. However, from the Mix onwards, and with the exception of Discriminative Function training, reinforcement was only delivered after, on average, every second correct response (i.e., intermittent reinforcement). This was signaled to the subjects by the experimenter saying they "would not always be told whether [they] are right or wrong" and was employed to prepare subjects for subsequent testing phases. Instructions given at all other stages of the experiment will be outlined later.

Procedure

Sessions were conducted three to five times a week in either a small experimental room within the play scheme building or in a quiet room of the subjects' home. Each session lasted between twenty and forty minutes and consisted of a minimum of sixteen trials.

Interpolated tasks were employed from the Mix onwards. That is, from the outset different trial-types, both training and testing, were presented in a given block of sixteen trials. Interpolated tasks help ensure the stability of trained relations during crucial test phases and may thus avoid any potential methodological difficulties involved in demonstrating derived behaviors (Dymond & Barnes, 1997a). There were six Phases in the present study (see Table 1). Subjects received, first AB and then AC conditional discrimination training, the Mix (AB and AC discriminations), BC probes for equivalence relations, discriminative function training, and the self-discrimination transformation test.

Phase 1: A-B Conditional Discrimination Training

At the beginning of the first session, the experimenter asked the child if they wanted to "play a game with some shapes" and were shown a 'magic box' containing various small toys and stickers. Having selected a prize, the child was told that a bead would be given for every correct response and that when the container was full of beads he or she had won the pre-selected prize.

An adapted version of the revised blocked-trial procedure (Smeets & Striefel, 1994) was employed to teach the baseline conditional discriminations with four subjects (CJ, GG, PR, and HH). Each phase of the conditional discrimination training involved three steps, each a prerequisite for the next.

Step 1: In this step, subjects were trained to point to the comparison stimuli B1 in the presence of A1 and B2 in the presence of A2. The B1 and B2 comparisons were presented at invariant left (B1)-right (B2) locations. The A1 and A2

Table 1. Phases, Tasks, Trials, and Criterion

PHASE	TASKS	TRIALS	CRITERION
1-3	Conditional Discrimination Training		
	A-B: (A1-B1/B2, A2-B1/B2)	16	15/16
	A-C: (A1-C1/C2, A2-C1/C2)	16	15/16
	Mix: (A-B/A-C)	16	15/16, 15/16*
4	Equivalence Test		
	B-C: (B1-C1/C2, B2-C1/C2)	4	4/4
	Mix: (A-B/A-C)	12	11/12
5	Discriminative Function Training		
	B1 -> Clap	6	
	B2 -> Wave	6	12/12
6	Transformation Test		
	Clap -? C1	4	
	Wave -? C2	4	7/8
	B1 -> Clap	4	
	B2 -> Wave	4	4/4
	B-C: (B1-C1/C2, B2-C1/C2)	4	4/4

Note: Alphanumerics (A1, B1, etc.) indicate the stimuli presented in each phase (subjects never saw these labels). Correct comparisons in A-B and A-C conditional discrimination training and B-C combined symmetry and transitivity testing appear underlined. * Intermittent reinforcement.

samples were presented quasi-randomly, with the only constraint being that a sample could not appear more than twice consecutively across a block of sixteen trials. On reaching criterion of 15/16 correct responses, subjects progressed to the next step.

Step 2: This step was identical to Step 1, except that the locations of the comparisons were reversed; B1 was now presented on the right and B2 on the left.

Step 3: In this step, the locations of the comparisons varied quasi-randomly across trials, with the constraint that the correct comparison did not appear at the same location for more than two consecutive trials.

Phase 2: A-C Conditional Discrimination Training

This phase was identical to that of Phase 1 except that B stimuli were replaced by C stimuli.

Two subjects (TP & KF) were taught A-B and A-C conditional discriminations using the traditional block trial method (e.g., Dymond & Barnes, 1997a; Saunders, Drake, & Spradlin, 1999). Subjects were trained in four tasks: A1-B1, A2-B2, A1-C1, and A2-C2. The two A-B tasks were presented first, each task appeared quasi-randomly 8 times in a block of 16 trials. Next, the A-C tasks were trained in the same manner. The mastery criterion was 15/16 correct responses per block.

Phase 3: A-B and A-C Mix Conditional Discrimination Training

In this Phase, each of the four trial types (A1-B1, A2-B2, A1-C1, & A2-C2) were presented four times in a quasi-random order to all six children. The left-right positions of the comparison stimuli varied quasi-randomly across trials. On reaching criterion, subjects were exposed to the Mix again, this time under conditions of intermittent reinforcement which resulted in, on average, every second correct response being reinforced. When criterion was once again achieved, subjects progressed to Phase 4.

Phase 4: Equivalence Test

Phase 4 consisted of the presentation of twelve baseline trials (A-B and A-C) randomly interspersed with four combined symmetry and transitivity (equivalence) probe trials (B1-C1 and

B2-C2, each twice). The left-right positions of the comparison stimuli varied quasi-randomly across trials. If a subject selected C1 in the presence of B1 and C2 in the presence of B2 on each of the four probe trials, it was assumed that responding in accordance with combined symmetry and transitivity (i.e., equivalence) had emerged. Subjects were retrained and retested only if they made either less than 11/12 correct responses on baseline trials or less than 4/4 correct responses on the equivalence probe trials. The sequences of trials were generated quasi-randomly with the only constraint that a particular trial type (training or testing) could not re-occur more than twice consecutively. Responses on B-C test trials did not result in feedback.

Phase 5: Discriminative Function Training

At the beginning of this phase, the experimenter said, "Now I am going to show you some shapes. When you see one shape you must clap your hands like this [experimenter demonstrates] and when you see the other shape you must wave like this [experimenter demonstrates]. I will tell you when you are right and when you are wrong." On each trial, the experimenter placed a stimulus sheet on the stand before the child and asked "Clap or wave?" (after the first five trials, this question was omitted). Clapping was reinforced in the presence of B1, and waving was reinforced in the presence of B2 (see Table 1). Each stimulus, B1 and B2, was presented six times quasi-randomly in each block of twelve trials, with the only constraint being that a stimulus could not appear on more than two consecutive trials. Criterion in this phase was 12/12 correct responses.

Phase 6: Transformation of Functions Test

During this Phase, eight transformation of functions test trials were interspersed with four discriminative function training trials (B1 & B2), and four equivalence test trials (B1-C1 & B2-C2). The transformation of function trials was indicated to the child by the experimenter saying, "Now this time I want you to clap or wave first, and then pick a shape. So what do you want to do? Clap or wave?" Following a response by the child, the experimenter placed a stimulus sheet on the stand and asked the child to "pick one of the shapes" (after the first five trials, these instructions were omitted). No feedback was given following either the clapping or waving response or selecting a shape. The discriminative function training trials resulted in feedback, while the equivalence test trials continued to be presented in extinction. The stimulus sheets containing the two stimuli, C1 and C2, were presented quasi-randomly. If a subject clapped and selected C1, and waved and selected C2, at least seven times across eight trials, it was assumed a transformation of functions through equivalence relations (Train - see B1, clap/see B2, wave; Test - if clap, pick C1/if wave, pick C2) had emerged (see Table 1).

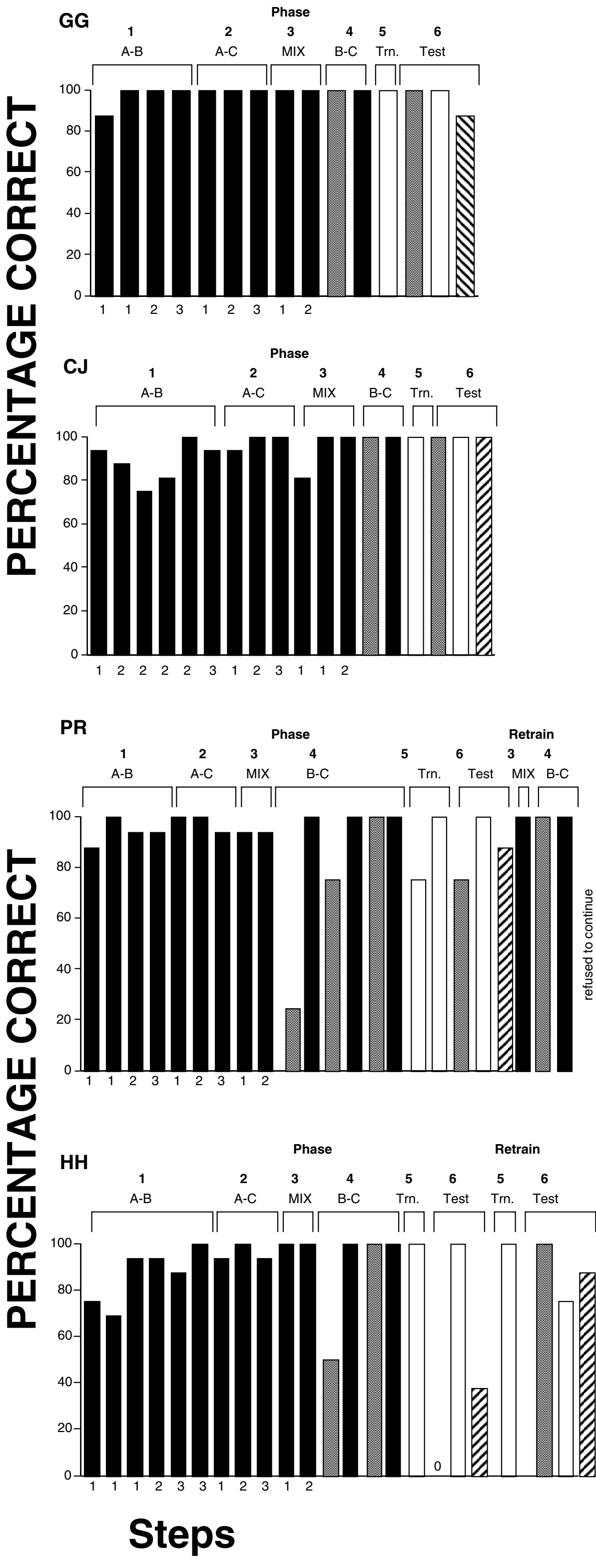
It is important to note that the procedures of the transformation test allowed for the emergence of non-predicted performances. That is, it was conceivable that a child could emit the same response, clapping or waving, across the eight transformation test trials. Despite this possibility, this was never observed. Appendix 1 gives the distribution of clapping and waving responses for those children whose data are available.

Results and Discussion

Interobserver agreement scores were calculated for a total of 512 (54%) training and testing trials, with agreement ranging from 98% to 100%.

Results for each subject are shown in Figures 2 and 3. Subject GG responded at 100% correct for all but one of her exposures to the conditional discrimination training phases (A-B and A-C), and showed errorless emergence of B-C equivalence relations in Phase 4. Following one successful exposure to the discriminative function training Phase 5, GG made 7/8 (87.5%) correct responses on the self-discrimination transformation test and maintained her performance on equivalence and discriminative function trials, thus demonstrating the predicted transformation of functions in accordance with equivalence relations.

Subject CJ required a total of twelve exposures to the blocks of A-B and A-C conditional discrimination trials before demonstrating the emergence of B-C equivalence relations in Phase 4. She reached criterion on her first exposure to Phase 5, and subsequently demonstrated perfect performance (8/8) on the transformation test tri-



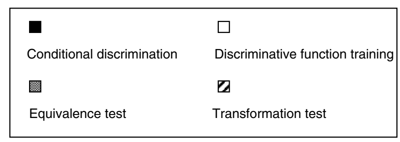


Figure 2. Showing the percentage of correct responses across all experimental phases for subjects GG, CJ, PR, and HH, and the number of revised blocked-trial training steps required to reach criterion. Following retraining in Phase 4, PR refused to continue. The symbol "0" underneath HH's results for Phase 6 indicates 0/4 correct responses on the B-C equivalence test trials (see text for details).

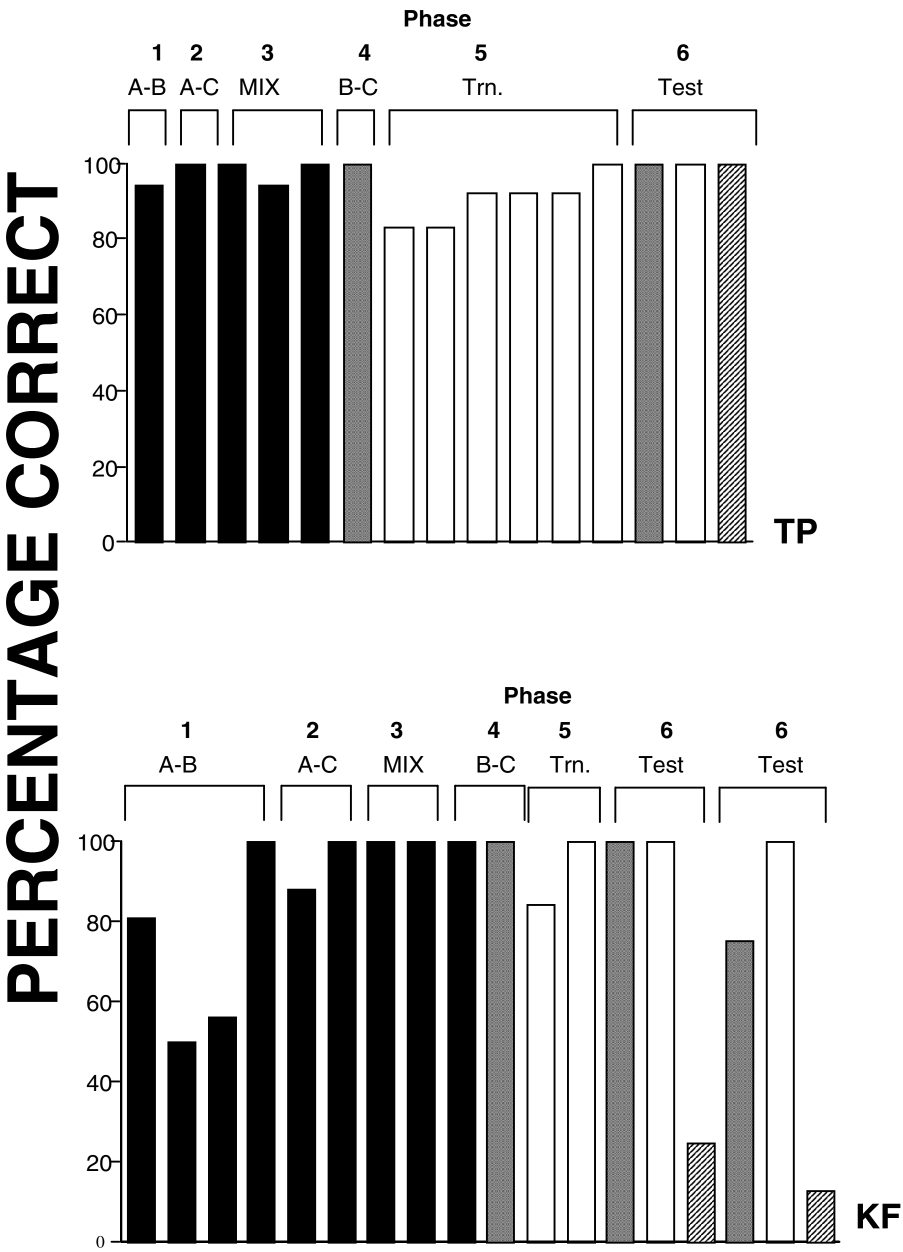


Figure 3. Showing the percentage of correct responses across all experimental phases for subjects TP and KF.

als thus demonstrating the predicted transformation of functions in accordance with equivalence relations.

Subject PR required nine exposures to the blocks of A-B and A-C conditional discrimination training trials, and three exposures to Phase 4 before he showed the emergence of B-C equivalence relations. Following two exposures to Phase 5, PR made 7/8 (87.5%) correct responses on the transformation test in Phase 6. However, his performance on the B-C equivalence trials (3/4 correct) was below criterion. Inspection of the data indicated that PR made an incorrect response on the first B-C equivalence test trial and the correct response on the remaining three trials. He was subsequently retrained (Phase 3) and retested (Phase 4), but refused to continue with the experiment before he could be re-exposed to the transformation test.

Subject HH required eleven exposures in total to the blocks of A-B and A-C conditional discrimination training trials, and two exposures to Phase 4 before she demonstrated the emergence of B-C equivalence relations. Following one exposure to Phase 5, HH made 3/8 (37.5%) correct responses on the transformation test trials, thus failing to meet criterion. She also failed to demonstrate B-C equivalence, and was subsequently retrained on Phase 5, rather than Phase 4, due to experimenter error. On her second exposure to Phase 6, HH demonstrated successful B-C equivalence and a transformation of functions, thus showing the predicted transformation of functions in accordance with equivalence relations.

Subject TP required one exposure to each block of A-B and A-C conditional discriminations and three exposures to the Mix before reaching criterion. He demonstrated equivalence on his first test exposure and then required six blocks of discriminative function training trials before achieving criterion. In the final phase, Phase 6, TP produced an errorless performance thus showing the predicted transformation of functions in accordance with equivalence relations.

Subject KF required a total of eight exposures to the A-B, A-C and Mix conditional discriminations before demonstrating the emergence of B-C equivalence relations in Phase 4. She reached criterion on her second exposure to Phase 5, and following two exposures to the transformation test phase, failed to achieve criterion.

In summary, five out of six children showed the predicted transformation of functions in accordance with equivalence relations. Four subjects, including PR, demonstrated the transformation of functions on their first exposure to the test, while HH required a second exposure, and KF failed to produce the predicted performance.

EXPERIMENT 2

This experiment was a replication of Experiment 1 but with normal adults. Two female undergraduates aged 24 and 20 years old respectively, were recruited through personal contacts. Neither subject was familiar with stimulus equivalence or related phenomena. The procedures were identical to Experiment 1 (including the use of the revised-blocked trial procedure to train the baseline discriminations) except that in training trials, correct and incorrect responses were followed by verbal feedback only ("Correct", "Incorrect"). Both subjects performed in a near errorless fashion and completed the experiment in one session. Together, they made 2 errors on 328 training trials and zero errors on 32 test trials.

GENERAL DISCUSSION

The present study shows that children and adults, having derived two, three-member equivalence relations (A1-B1-C1/A2-B2-C2), will subsequently transform a trained discriminative function (B1-clap/B2-wave) in accordance with equivalence when tested as a self-discrimination function (clap -? C1/wave -? C2). This extends the findings of previous transfer research (Barnes et al., 1995; Dougher et al., 2002; Dymond & Barnes, 1994, 1997a) in at least two ways. First, children younger than 8 years of age are readily capable of the derived performances seen in other transfer studies (e.g., Dymond & Barnes, 1997a) and this extends the analysis of derived effects to children of preschool age. Second, the present study clearly demonstrated a transformation of functions in accordance with equivalence relations when the training and testing contexts differed (i.e., train discriminative functions and test for self-discriminative functions).

Prior to subjects being tested for a transformation of functions, they needed to have first acquired the baseline conditional discriminations. In general, three procedures exist for establishing arbitrary conditional discriminations. The first of these, called trial-and-error training, involves presenting tasks in which the sample-comparison relations change over trials with the assumption being that "differential reinforcement is a sufficient condition for establishing relational responding (i.e., if A1, select B1; if A2, select B2)" (Smeets & Striefel, 1994, p. 242). This, however, is not always the case (Zygmont, Lazar, Dube, &

McIlvane, 1992) and the trial-and-error training method is frequently ineffective precisely because it assumes that extraneous sources of stimulus control such as stimulus or positional preferences will be phased out through differential reinforcement. The second method, called the blocked-trial procedure, has a long history in behaviour analysis but is not without limitations. Typically, three steps are involved in which the same sample-comparison arrays are presented (i.e., A1-B1) with the locations (left-right) of the comparisons randomly changing over trials. As each discrimination is learned, new sample-comparison arrays (i.e., A2-B2) are introduced. The difficulty with the blocked-trial procedure is that conditional discrimination is not required until the third and final step. That is, simple discrimination of the sample (S+) is sufficient to achieve criterion (Barnes et al., 1995, p. 426; Devany, Hayes, & Nelson, 1986; Dymond & Barnes, 1997a, p. 22), and this change from simple to conditional discrimination often results in total failure by children to learn the tasks involved (Auguston & Dougher, 1992).

Recently, a third training method, the revised blocked-trial procedure (Smeets & Striefel, 1994) has been developed. The revised blocked-trial procedure was used in the present study to teach the baseline conditional discriminations, with minimal errors, in six subjects (4 children and 2 adults) and in so doing, some of the limitations of the trial-and-error and blocked trial methods outlined above were avoided; additional training was not necessary to master 'true' conditional discriminations and the range of steps required to achieve criterion was not large across subjects. Of course, it could be argued that the revised-blocked trial procedure permits subjects to point to the left when presented with sample stimulus A1 and to point to the right when given A2, and effectively ignore the comparison stimuli. However, if it were the case that subjects merely learned a positional discrimination in Step 1 (see A1-point left/see A2-point right), they should have encountered difficulties in Step 2 when the positions of the comparisons were reversed. The findings of the present study show that this was clearly not the case, as only one subject (CJ) required more than one exposure to Step 2 in Phase 1, suggesting that simple discrimination of the sample stimuli was not sufficient to achieve criterion.

In Phase 4, all but two of the subjects (PR and HH) showed the formation of equivalence relations on their first test exposure. PR and HH required three and two additional blocks of test trials before the predicted performance emerged. Such delayed emergence of equivalence relations is not uncommon and "any failure of a reinforcement contingency to generate an equivalence relation tells us that although such contingencies may be necessary for equivalence, they are not sufficient. Other factors must also help to determine whether the components of the analytic unit can be shown to be members of an equivalence class" (Sidman, 1994, p. 407). One such factor might be the procedure employed to train the baseline discriminations. In the present study, both of the children who were trained using the traditional blocked-trial method demonstrated immediate emergence of equivalence, whereas only two out of four children trained using the revised blocked-trial procedure did so. It may be that the traditional method in some way facilitates the immediate formation of two, three-member equivalence relations although further research is needed to compare the respective training procedure (Saunders et al., 1999; Smeets & Striefel, 1994). Another factor that may influence the immediate demonstration of equivalence relations concerns the training and testing of each component of equivalence separately (i.e., train A-B, test B-A symmetry, etc.). This 'simple-to-complex' protocol has been shown to facilitate the predicted derivation of stimulus relations on their first test exposure and thus avoids any potential interpretative difficulties that may arise if repeated training and testing is employed.

The present study showed a derived transformation effect that, as outlined in the Introduction, does not lend itself easily to an interpretation based on 'transfer'. Specifically, it was shown that when a discriminative function was trained to B1 and B2, this function could be transformed in accordance with equivalence relations. A self-discrimination function emerged for C1 and C2 when subjects were asked to clap or wave before selecting a stimulus. Prior to the transformation test, the subjects' experimental history with regard to their clapping and waving responses had been under direct discriminative control (i.e., if see B1, then clap; if see B2, then wave). By requiring subjects to clap or wave first, and then select a shape, subjects were required to discriminate their own behaviour on the preceding task (clapping or waving) and select C1 or C2 that were indirectly related to B1 and B2 via derived equivalence relations. In this way, the subject's discrimination changed, or was transformed, from direct environmental control to a derived discrimination based on one's own behaviour (i.e., self-discrimination). This ability emerged immediately for four subjects. Of course, it is likely that subjects would have also shown a derived transfer if C1 and C2 were tested as discriminative functions, not as self-discriminative functions. Indeed, a repertoire based on discriminative functions may be necessary before a transfer based on self-discriminative functions emerges.

The current findings may have implications for understanding self-verbalized rule control on operant tasks such as schedules of reinforcement. Specifically, it was shown that a transformation of discriminative functions might occur in which a stimulus is discriminative for emitting a particular response (clapping or waving) and in which the response is discriminative for selecting a particular stimulus. This finding, combined with those of Dymond and Barnes (1994) suggest that quite complex, non-linear interactions between operant responses and verbal descriptions may occur when verbally able humans are exposed to the present procedures. Furthermore, because the discriminative functions of one behavior for the other was shown to be reversible, it would appear unwise to attribute causal, mediational properties to one behavior (e.g., verbal) over another behavior, as has been suggested by other researchers (e.g., Lowe, 1979).

In conclusion, the findings of the present study show that adults and five- to six-year old children and are capable of complex derived performances such as a transformation of functions in accordance with equivalence relations when different training and testing contexts are employed. It remains to be seen whether younger children are capable of the derived performances seen in the present study, and if necessary, what reinforcement history (i.e., multiple exemplar training; see Nuzzolo-Gomez & Greer, 2004) is sufficient to facilitate the performance.

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Appendix 1. Distribution of Clapping and Waving Responses in Experiment 1, Phase 6 *

Subject	Test Exposure	Response	Correct?	Subject	Test Exposure	Response	Correct
KF	1	Clap	No	HH	1	Clap	Yes
		Wave	No			Wave	Yes
		Clap	No			Clap	Yes
		Wave	No			Wave	No
		Clap	No			Clap	No
		Wave	Yes			Wave	No
		Wave	Yes			Clap	No
		Wave	No			Wave	No
	2	Clap	No		2	Clap	Yes
		Wave	No			Wave	Yes
		Clap	No			Clap	Yes
		Wave	No			Wave	No
		Wave	No			Wave	Yes
		Clap	Yes			Clap	Yes
		Wave	No			Wave	Yes
		Clap	No			Clap	Yes
PR	1	Wave	Yes				
		Clap	No				
		Wave	Yes				
		Clap	Yes				
		Clap	Yes				
		Clap	Yes				
		Wave	Yes				
		Clap	Yes				

* Similar data were unavailable for the remaining subjects.