# A transfer of functions and a conditional transfer of functions through equivalence relations in three- to six-year-old children.

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When a verbally able human is trained to make a number of related conditional discriminations, the stimuli that enter into these discriminations often become related to each other in ways that were not explicitly trained. Suppose, for example, a person is taught to select the arbitrary comparison stimulus B in the presence of the sample stimulus A, and is then trained, in a similar manner, to select another arbitrary stimulus C in the presence of A. Following this explicit training, it is likely that the subject will, without further training, respond in accordance with (a) the symmetry relations, given B select A, and given C select A, and (b) the combined symmetry and transitivity relations, given B select C, and given C select B. Responding in accordance with symmetry and transitivity, in a matching-to-sample context, is normally accepted as evidence that the three stimuli (A, B, C) participate in an equivalence relation (see Barnes & Holmes, 1991; Fields, Adams, Verhave, & Newman, 1990; Sidman, 1992).

Researchers have also shown that when a simple discriminative function is explicitly trained to one stimulus that participates in an equivalence relation, that same function may then transfer to the other stimuli participating in the relation without further training (e.g., Barnes & Keenan, 1993; Bush, Sidman, & de Rose, 1989; de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; de Rose, McIlvane, Dube, & Stoddard, 1988; Hayes, Devany, Kohlenberg, Brownstein, & Shelby, 1987; Wulfert & Hayes, 1988). In the study conducted by Hayes et al. (1987), for example, adult subjects were trained in the following conditional discrimination tasks: If sample A1, select comparison B1 and not B2; if A2, select B2 and not B1; if A1, select C1 and not C2; if A2, select C2 and not C1. All of these subjects subsequently responded in accordance with two equivalence relations (i.e., if B1, select C1 and not C2; if B2, select C2 and not C1). A stimulus from each equivalence relation was then given a distinct, simple discriminative function; in the presence of B1 clapping was reinforced, and in the presence of B2 waving was reinforced. During testing, the discriminative functions assigned to the B1 and B2 stimuli were seen to transfer through equivalence (e.g., B1[right arrow]A1[right arrow]C1) to the C1 and C2 stimuli, in the absence of differential consequences for either clapping or waving (i.e., B1[right arrow]clap transferred to C1[right arrow]clap, and B2[right arrow]wave transferred to C2[right arrow]wave).

A number of researchers have argued that this derived transfer of function effect may have important implications for a behavior-analytic understanding of some of the properties of human language, including symbolic control (e.g., Barnes, 1994; Barnes & Holmes, 1991; Barnes, McCullagh, & Keenan, 1990; Catania, Horne, & Lowe, 1989; Hayes, 1991; Hayes & Hayes, 1989; Sidman, 1992). Suppose, for example, that the spoken words "Dog," "Mutt," and "Hound" participate in the same equivalence relation. After a child is taught to orient towards the family dog upon hearing the word "Dog," he or she is likely to respond in the same way to "Mutt" and "Hound" without explicit training. In effect, the transferring of discriminative functions through equivalence relations may be functionally similar to the behavior of a young child who responds appropriately to a word or symbol without having been explicitly taught to do so (see Barnes & Holmes, 1991; Hayes et al., 1987; Sidman, Wynne, Maguire, & Barnes, 1989, p. 273).

If the derived transfer of functions through equivalence relations is to help provide a functional analysis of symbolic control, then it should be possible to demonstrate a transfer of discriminative functions through equivalence with young verbally able children (see Catania et al., 1989; Hayes et al., 1987) and with verbally able, mentally retarded adults. If, however, a transfer of functions through equivalence requires relatively advanced verbal skills (e.g., logical/mathematical problem solving) that are acquired during an advanced second and third level education, then young children and severely retarded adults should be unable to show the transfer effect (see Wulfert & Hayes, 1988, p. 140). Although there is evidence that mentally retarded subjects can show a derived transfer through equivalence (e.g., de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; de Rose, McIlvane, Dube, & Stoddard, 1988; but see Barnes & Keenan, 1993, p. 63), as yet there are no published data that show this effect in young verbally able children. A transfer of functions through symmetry has been demonstrated with a 5-year, 5-month-old child (Catania et al., 1989). Unfortunately, however, these researchers were unable to test for a transfer of functions through equivalence (i.e., combined symmetry and transitivity), because the school term ended (and the subject became unavailable) before the appropriate training and testing could be conducted. The first part of the current study aimed to extend the Catania et al. research by demonstrating a transfer of functions through equivalence using six normally developing, verbally able children.

An important feature of words or symbols is the extent to which their behavioral functions or "meaning" may change as a function of context (see Reese, 1991, pp. 114-115). For example, compare the two "meanings" of the word bat when a parent says to their child "Look at the bat" while (a) watching a baseball game, or (b) watching a wildlife film. In the context of a baseball game, the child will probably respond to the word bat as "meaning" 'a piece of wood for hitting a ball,' but in the context of the wildlife film, the child will respond to the word as "meaning" 'a small, black, flying animal.'

This important aspect of "meaning" has implications for the current behavioral interpretation of symbolic control (see Hayes & Hayes, 1989, pp. 170-171). Specifically, if similar behavioral processes underlie both derived transfer (through equivalence) and "meaning," then the discriminative functions of stimuli participating in an equivalence relation should, like the "meaning" of a word or symbol, be manipulable by context. Although this form of contextual or conditional control over the behavioral functions of stimuli in an equivalence relation has been demonstrated with normal human adults (e.g., Wulfert & Hayes, 1988), it remains to be seen whether language-able children or retarded adults are capable of demonstrating a conditional transfer of control through equivalence. For example, imagine that a child has formed an equivalence relation (A1-B1-C1), and is then trained to clap when one of the equivalent stimuli (B1) is presented in a YELLOW context, and is trained to wave when the same stimulus (B1) is presented in a BLUE context. If this conditional discriminative control transfers through equivalence, then in the absence of further explicit training, stimulus C1 in a YELLOW context will control clapping and C1 in a BLUE context will control waving. The second part of the present study attempts to show this effect with the same children who were used in the first stage of the experiment.

The current study also addressed a number of additional issues. First, because the training and testing materials were not presented to the children on a computer, a double-blind procedure was employed during all test phases. In this way, a correct performance could not occur through subtle cueing from the experimenter (cf. Barnes et al., 1990; Devany, Hayes, & Nelson, 1986; Lipkens, Hayes, & Hayes, 1993). Second, three control subjects were used to check for a number of procedural artifacts that may give rise to a false positive equivalence performance when subjects are exposed to repeated training and testing (e.g., Barnes & Keenan, 1993; Harrison & Green, 1990; Hayes, Kohlenberg, & Hayes, 1991). Finally, the present research examined whether contextual control over a derived transfer of functions would itself transfer from an auditory to a visual stimulus modality (see Lynch & Green, 1991).

## Method

### Subjects

Nine language-able children, 5 males and 4 females, served as subjects. The children attended the University College Cork creche. The only criterion used in choosing the subjects for the study, apart from age, was regular attendance at the creche (i.e., at least 3 days every week). Subjects were allocated to the experimental and control groups on a random basis. All children possessed verbal skills that were generally consistent with their chronological ages. Although no formal assessment of the children's "verbal ages" was conducted, the researchers did not observe any verbal abnormalities (i.e., unusually retarded or advanced abilities) during their interactions with the children, and neither parents nor caretakers had ever reported any such abnormalities. Furthermore, four of the children showed some difficulty in correctly naming the colors 'blue' and 'yellow' (see "Pretraining and testing for color naming"), thereby indicating that at least these subjects did not possess highly advanced verbal abilities. Six children served as experimental subjects and three served as controls. Their names (these have been changed in the interests of confidentiality) and their ages, to the nearest month at the end of each subject's participation in the study, were as follows. Experimental: Ann - 2 years and 11 months (for convenience, this child will be referred to as a three-year-old), Beth - 3 years 0 months, Cara - 3 years and 5 months, David - 4 years and 1 month, Eamon - 4 years and 3 months, Fred - 6 years 0 months. Control: Gina - 3 years and 1 month, Harry - 4 years and 2 months, Ian - 6 years and 2 months.

Stimuli and Materials

Each experimental subject was trained and tested on one of three different stimulus sets. Each set consisted of six visual forms, designated A1, B1, C1, A2, B2, and C2. The three stimulus sets used for the experimental subjects were also used with the control subjects (one set for each subject), except that an additional two stimuli were included in each set (i.e., N1 and N2 stimuli, which replaced the C1 and C2 stimuli during conditional discrimination training and equivalence testing). All visual forms measured approximately 36 [cm.sup.2] ([ILLUSTRATION FOR FIGURE 1 OMITTED] for an example of the abstract visual forms used in the current study). Each set for the experimental subjects was constructed by randomly selecting the six figures from a pool of twelve (two additional figures, N1 and N2, for the controls were selected randomly from the remaining six figures for each subject).

The stimuli were presented in thick black outline on either plain white, yellow, or blue paper (33 cm by 22 cm). For matching-to-sample tasks, the long side of the sheet was placed horizontally so that the sample stimulus always appeared in the center, upper half of the sheet, with the two comparison stimuli appearing in the lower left- and right-hand corners. For those tasks where only one stimulus was presented to the subject, the short side of the sheet was placed horizontally, and the stimulus appeared in the center of the sheet.

Pretraining and Testing for Color Naming

The second part of the study was designed to examine a transfer of conditional control from an auditory to a visual modality (i.e., the experimenter said "blue" and "yellow" during conditional transfer training but provided 'blue' and 'yellow' backgrounds during conditional transfer testing). Therefore, before the study commenced, each child was exposed to an exercise designed to train and/or test correct naming of the colors 'yellow' and 'blue.' This exercise was conducted by the second author in the experimental room in the creche. Each individual subject was presented with two toy bears (they were placed in random positions on a small table in front of the subject). One bear was colored yellow and the other blue (they were identical in all other respects). The experimenter asked the child to "Please give me the blue (or yellow) bear." If the child complied, he or she was told: "Yes! Well done, thank you for giving me the blue (or yellow) bear." If the subject picked up the wrong bear (e.g., the yellow bear when asked for the blue bear) he or she was told: "No! That is the yellow (or blue) bear, please give me the blue (or yellow) bear." This procedure was repeated until the subject picked both bears correctly across six consecutive trials (i.e., the experimenter asked for both bears in a quasi-random order, with each bear being requested three times in each block of six trials). All subjects picked the correct bears across the first six trials except for Ann and Gina who both picked the wrong bear (blue when asked for yellow) on the first trial (their next six trials were correct). In the next stage of the color naming exercise, each subject was handed one bear, and was asked: "What color is this bear?" A correct answer was followed by praise (e.g., "Well done, that's right, it is the blue bear."). A wrong answer was corrected (e.g., "No! This bear is blue"). This procedure was repeated until the subject "tacted" (see Skinner, 1957) both bears correctly across six consecutive trials (i.e., both bears were handed to the subject in a quasi-random order, with each bear being presented three times in each block of six trials). All subjects responded correctly across the first six trials except for Ann, Cara, David, and Gina, all of whom gave the wrong name on the first trial (their next six trials were correct). All subjects were then exposed to exactly the same procedure except that (a) two toy cars, one yellow and one blue, were used (the cars were identical except in color), and (b) no feedback was presented after each trial (i.e., after the child's response the experimenter remained silent and simply proceeded to the next trial). None of the subjects made any errors during this second exposure to the color naming tasks. The same "no feedback" procedure was then conducted for a second time, except that two sheets of A4 sized paper, one blue and the other yellow, were used instead of toy cars. Again, none of the subjects made any errors during this final exposure to the color naming exercise.

General Procedure

Each child was trained and tested individually. A session usually lasted for no more than 40 min (at least 20 min per session were devoted to nonexperimental, play activities which were designed to maintain the subjects' cooperation). The number of sessions required to complete the experiment ranged between 10 and 19. Subjects were never exposed to more than two sessions per day. Each experimental session was conducted by either the first or second author (hereafter referred to as the researcher) or by one of three final year undergraduate students who were blind to the general purpose of the study and had no knowledge of the stimulus equivalence research paradigm (hereafter referred to as the blind tester). Before commencing each session, the researcher and the blind tester often played informally with the child; first in the presence of one of the caretakers from the creche, and then alone in the experimental room. These interactions lasted up to 20 minutes, depending on when the researcher felt that the child was sufficiently relaxed to participate in the experiment. During the training phases of the experiment, the blind tester left the experimental room (i.e., she could neither see nor hear the experiment taking place) and the researcher conducted the training. During testing phases, the researcher left the room and the blind tester conducted the experiment.

Prior to the study, the researchers and blind testers had agreed on twelve different names for the twelve stimuli to be used in the experiment (e.g., "eye," "curtain," "hedgehog"). It was therefore possible to obtain a record of the subject's responses to the stimuli during the test phases, without the blind tester knowing whether the subjects' responses were in accordance with the trained relations. For example, a response on a matching-to-sample test trial could be recorded as "hedgehog - curtain," meaning that the subject had chosen the comparison stimulus named "curtain" in the presence of the sample stimulus named "hedgehog."

At the beginning of the first session, the researcher sat beside the child on a low chair facing an empty table, and said: "You and I are going to play some games together, but you are going to have to help me play because I am not very good at them - Okay?" Subsequent sessions were started by simply asking, "Do you want to play our game today?" At the end of a training phase and before the beginning of a test phase, the researcher would say to the child: "You know, I bet Liz (i.e., one of the blind testers) would like to play the game with you now. I'll go and get her." The blind tester then returned with the researcher and said: "I would like to play the game with you. Is that okay?" If the child appeared unwilling, the blind tester gently coaxed the child to agree to play the game. Before the test phase commenced, the researcher left the room saying: "I'm going now, but I'll see you in a little while." At the end of each test phase, the blind tester fetched the researcher, and they played informally with the child for approximately 5 min. At a convenient time during this informal play, the researcher examined the blind tester's data sheet before deciding whether to continue or terminate the session.

The same general procedural sequence was employed for all subjects. However, because the experiment for each child was conducted across multiple sessions, earlier phases were replicated whenever a key training or testing phase was preceded by a break of 1 day or more (the specific experimental sequence for each subject will appear in the context of the results). A diagrammatic outline of the general procedure is presented in Figure 2.

Experimental Subjects

Phase 1: Conditional discrimination training. During conditional discrimination training ([ILLUSTRATION FOR FIGURE 2 OMITTED], top panel) the subject was presented with four tasks: A1-B1, A2-B2, A1-C1, and A2-C2. Training commenced for the first time, when a stimulus sheet for one of these tasks (e.g., A1-B1) was placed on the table directly in front of the child. The researcher pointed to the sample figure and said: "Look at this shape." When the child looked at the sample, the researcher then said: "Now touch one of the shapes below" (after the first block of 10 trials these explicit instructions were omitted). If the child responded correctly, reinforcement was given immediately in the form of verbal praise (e.g., "That's right, you are clever!"). Brief, playful cuddling and tickling, and/or access to fruit juice, was also employed after approximately every fifth correct response. In addition, for the three-year-old children a hand puppet was used to reinforce correct responses (i.e., the researcher brought the puppet out from under the table, and it "praised" the subject's performance, and briefly played with the child).

During the first 10 training trials, four of the children (2 experimental and 2 control subjects) sometimes refused to respond, saying, "I don't know." When this happened, the researcher prompted the subject to make the correct choice. This involved physically guiding the child's hand to the appropriate comparison stimulus. Another feature of the early training procedure (i.e., the first block of 10 training trials) involved providing explicit feedback about an incorrect response. That is, each time the child responded incorrectly, the researcher shook his/her head and said, "No, that is not the right one; this one (pointing to the correct comparison stimulus) is the right one." After the first block of 10 training trials, however, only reinforcement was delivered. That is, when the subject responded incorrectly, the researcher made no comment and simply proceeded to the next trial.

Training on the first task (e.g., A1-B1), required the subject to select the correct comparison (i.e., B1) in the presence of the sample (i.e., A1), without prompting and without feedback about incorrect responses, 10 times across a block of 10 training trials (i.e., the mastery criterion). The left-right positions of the comparisons on all matching-to-sample tasks were counterbalanced across trials. When the subject achieved the mastery criterion on the first task, he or she was then trained on a second task. For example, if a subject had been trained on A1-B1, then A2-B2 training was introduced; that is, selecting B2 in the presence of A2 was reinforced. Once the mastery criterion was reached, Mix 1 was introduced, in which the two previously trained tasks (in this case, A1-B1 and A2-B2) were quasi-randomly mixed (each task occurring five times in each block of 10 trials) until the subject again met the mastery criterion.

Subjects were then trained to criterion on a third task (e.g., A1-C1), and subsequently on the fourth remaining task (in this case, A2-C2), before being exposed to Mix 2 where both tasks (in this case, A1-C1 and A2-C2) were presented five times in a quasi-random order in each block of 10 trials. When a child reached the mastery criterion on Mix 2, all four matching to-sample tasks were quasi-randomly presented (each task presented at least twice in every block of 10 trials). This was called the Final Mix, and again the mastery criterion required that the child emit 10 correct responses across a block of 10 training trials.

During the conditional discrimination training, all of the subjects' correct responses produced one or more reinforces. However, during the Final Mix, this continuous reinforcement schedule was reduced, so that reinforcement was only delivered after every second correct response. This was done in order to prepare the subjects for the absence of reinforcement in the testing phases of the experiment.

Once a subject had successfully completed the Final Mix, it was then used to review the baseline conditional discriminations at the beginning of a session, where a break of one day or more had occurred since the last session. During these reexposures to the Final Mix, subjects were given blocks of 10 trials until they produced 10 correct responses within a single block. These data will not be presented here because none of the subjects failed to produce less than 10 out of 10 correct responses in the second block of 10 trials when reexposed to the Final Mix.

Phase 2: Equivalence test. This phase began with the blind tester saying to the subject, "In the next part of the game, like before, I want you to look at the shape at the top and then point to the right shape at the bottom. I don't know which is the right shape, so I'll have to be really quiet until the game is over. When we've finished the game, you can have some juice and we'll play hide-and-go-seek" (or some other game the child enjoyed). The two tasks B1-C1 and B2-C2 ([ILLUSTRATION FOR FIGURE 2 OMITTED], second from top panel) were presented in a quasi-random order (each task presented five times across each block of 10 trials). During the equivalence test, no reinforcement or corrective feedback was given after any trial. If the subject selected C1 in the presence of B1 and C2 in the presence of B2 at least 9 times across a block of 10 trials, it was assumed that equivalence responding had emerged (e.g., B1 to A1 to C1 through combined symmetry and transitivity). The reader should note that because derived transfer, and not stimulus equivalence per se, was the main focus of this study: (a) only two equivalence tasks were used in this phase (e.g., we could also have tested for the C1-B1 and C2-B2 relations), and (b) 9 out of 10 correct responses, rather than 10 out of 10, was used as the mastery criterion for equivalence responding.

Phase 3: Transfer of function training. At the beginning of this phase, the researcher said, "Now we are going to play a new game. I am going to show you two shapes. I want you to clap like this (researcher demonstrated) when you see one shape and wave like this (researcher demonstrated) when you see the other shape. I will tell you whether you got it right or wrong." On each trial, the researcher placed a stimulus sheet on the table in front of the subject and asked, "What should you do?" (after the first five trials, this question was omitted). Clapping was reinforced in the presence of B1 and waving in the presence of B2 ([ILLUSTRATION FOR FIGURE 2 OMITTED], third from top panel). On the first three occasions where a subject made an incorrect response (e.g., waving in the presence of B1), the researcher said, "No," shook his/her head, and stated and demonstrated the correct response. Thereafter, incorrect responses were simply ignored by the researcher (i.e., no reinforcement was given, and the subject proceeded directly to the next trial). The two stimuli were presented five times each in a quasi-random order across each block of 10 trials. In order to complete this training phase, subjects were required to emit 10 correct responses across one block of 10 training trials.

Phase 4: Transfer of function testing. This phase commenced when the blind tester instructed the subject as follows: "Now I am going to show you two shapes, and like before you have to clap for one shape and wave for the other shape. Because I don't know whether you should clap or wave, I have to be very quiet until the game is over." The two stimuli, C1 and C2, were presented in a quasi-random order (each stimulus presented five times across each block of 10 trials). During the transfer of function test, no reinforcement or corrective feedback was given after any trial. If the subject clapped in the presence of C1 and waved in the presence of C2, 10 times across a block of 10 trials, it was assumed that a transfer of functions through equivalence relations had emerged ([ILLUSTRATION FOR FIGURE 2 OMITTED], fourth from top panel).

Phase 5: Conditional transfer of function training. The researcher began this phase by stating, "We are going to play a slightly harder game now, so it's important that you listen very carefully, and try really hard, okay. In a minute, I'm going to show you two of the shapes you've seen before, but each time I show you a shape I will say either 'yellow' or 'blue.' You must listen very carefully to the color I say, and look at the shape. When you've done this, you must either clap or wave. I will tell you whether you've done the right thing." The researcher then placed either a B1 or B2 stimulus card on the table, and said in a clear and loud voice either "Yellow" or "Blue." Clapping was reinforced given "Yellow"/B1 or "Blue"/B2 and waving given "Blue"/B1 and "Yellow"/B2 ([ILLUSTRATION FOR FIGURE 2 OMITTED], fifth from top panel). If the child made an incorrect response, the researcher said, "No, that is wrong. When I say "Yellow" (or "Blue") and I show you this shape, you should clap (or wave)." This correction procedure was employed for the first three incorrect responses. Thereafter, incorrect responses were simply ignored by the experimenter (i.e., the child proceeded directly to the next trial without reinforcement). The researcher presented the four tasks (i.e., "Yellow"/B1, "Blue"/B1, "Yellow"/B2, and "Blue"/B2) in a quasi-random order, with each task presented five times in each block of 20 trials. To complete this phase, a subject was required to emit 20 correct responses across a block of 20 trials. Throughout this training phase all of the subjects, except Fred and Ian, sometimes repeated the color stated by the experimenter. This "echoic" response (Skinner, 1957) was always ignored by the experimenter.

Phase 6: Conditional transfer of function testing. At the start of this phase, the blind tester instructed the subjects as follows: "I am going to show you some shapes on colored paper, and you have to show me whether you should clap or wave. Because I don't know what you should do, I have to be very quiet until the game is over." Four different stimulus sheets were presented during this test phase; C1 on yellow paper, C1 on blue paper, C2 on yellow paper, and C2 on blue paper (note that this was the first time since the pretraining that colored paper had been used). These four sheets were presented in a quasi-random order (each stimulus sheet presented five times across each block of 20 trials). The four "correct" responses were clapping in the presence of C1 on yellow paper and C2 on blue paper, and waving in the presence of C1 on blue paper and C2 on yellow paper ([ILLUSTRATION FOR FIGURE 2 OMITTED], bottom panel). No reinforcement or corrective feedback was given after any trial. If a subject produced 20 "correct" responses across a block of 20 trials, it was assumed that a conditional transfer of functions through equivalence relations had emerged. All of the children sometimes overtly tacted the color of the cards during this phase (i.e., stated out loud the color of the stimulus card when it was presented). This tacting response was always ignored by the blind tester.

Control Subjects.

All three control subjects were exposed to the same general sequence of training and testing as the experimental subjects, except that during conditional discrimination training and equivalence testing two additional stimuli, N1 and N2, were substituted for C1 and C2 respectively. In effect, the control subjects were trained on the following four tasks: A1-B1, A2-B2, A1-N1, and A2-N2, and tested for equivalence on the following two tasks; B1-N1 and B2-N2. The controls were then exposed to the same transfer training and testing as the experimental subjects; training with the B1 and B2 stimuli, and testing with the novel (for the controls) C1 and C2 stimuli. All control subjects were exposed to the same amount (if not more) of recursive training and testing as the experimental subjects. Experimental and control subjects were studied in random order, and sometimes "concurrently" (e.g., one in the morning and one in the afternoon), so that the blind testers' exposure to the performance of the experimental subjects would be unlikely to affect their interaction with the controls, or vice versa.

Recording. During conditional discrimination training and equivalence testing, a response was recorded if the subject physically touched (a) one of the comparison stimuli with his or her hand (this response could be either correct or incorrect), (b) an inappropriate part of the stimulus card (e.g., the sample), or (c) the table on which the stimulus card was placed ("b" and "c" responses were always incorrect). For transfer training and testing, a response was recorded if the subject (a) clapped his or her two hands together, (b) waved one hand in the air, or (c) produced hand movements that could not be clearly categorized as either clapping or waving ("a" and "b" responses could be either correct or incorrect and "c" responses were always incorrect).

Reliability. Agreement data were collected for approximately 40% of the test phases for each subject throughout the experiment. These data were collected by an independent observer (i.e., she was neither a researcher nor a blind tester, and like the latter she was unaware of the general purpose of the study and had no knowledge of the stimulus equivalence research paradigm). Before the first observation session, the observer was trained to label all of the visual forms using the 12 names employed by the researchers and blind testers (e.g., "eye," "curtain," "hedgehog"). During observation sessions, the independent observer sat behind the subject in a position that enabled her to obtain a clear view of the stimulus materials without being able to see the blind tester's data sheet (i.e., neither the blind tester nor the observer had any knowledge of the other's scoring during the session). Agreement was calculated using the formula: Agreement/(Agreement + Disagreement). An agreement was recorded when the blind tester and the observer both recorded the same data for the same trial (e.g., Phase 2/Trial 1: hedgehog - curtain or Phase 6/Trial 1: Yellow - curtain - wave). A disagreement was recorded when the blind tester and the observer failed to record exactly the same data for the same trial. Interobserver agreement ranged from 95% during one test phase to 100% for all other (observed) test phases.

Results

Figures 3 to 7 show the data for each subject in terms of percentage of responses correct within each successive block of 10 trials across Phases 1 to 4 (i.e., conditional discrimination training, equivalence testing, and transfer training and testing) and within each successive block of 20 trials across Phases 5 and 6 (i.e., conditional transfer training and testing).

Experimental Subjects

Ann ([ILLUSTRATION FOR FIGURE 3 OMITTED], upper section). Ann required 30 trials on the A1-B1 task before reaching the mastery criterion (i.e., 10 consecutive correct responses across a block of 10 trials). Ann also needed 30 trials on the A2-B2 task, and a further 40 during exposure to Mix 1 (i.e., the quasi-random presentation of the A1-B1 and A2-B2 tasks). Subsequent training on A1-C1, A2-C2, and Mix 2 was completed in a further 70 trials. During the Final Mix (i.e., the quasi-random presentation of all four matching-to-sample tasks) Ann failed to reach the mastery criterion (or show any improvement) across 30 trials, and thus she was retrained on Mix 1 and Mix 2 (10 trials each), before being reexposed to the Final Mix, which she passed in 20 trials. Ann was then tested for equivalence (B1-C1 and B2-C2 tasks), but she failed to produce the required minimum of 9 out of 10 correct responses. Ann was then reexposed to the Final Mix, which she passed in a single block of 10 trials. She was then tested again for equivalence, and she produced 10 out of 10 consecutive correct responses across her third block of 10 trials, thus demonstrating the formation of the two predicted equivalence relations. Ann was immediately exposed to the transfer of function training (B1[right arrow]clap and B2[right arrow]wave), and met the mastery criterion in 20 trials, before producing 20 successively correct responses on the transfer of function test (C1[right arrow]clap and C2[right arrow]wave), thus showing the predicted transfer of functions through the two equivalence relations. During the latter stages of the experiment, Ann had shown increased signs of boredom, and during the transfer training and testing she became somewhat uncooperative. When the researcher and blind tester approached Ann the day after the transfer training and testing (and on a number of subsequent days), she showed signs of distress and shouted "I don't want to play!" It was decided therefore to terminate her participation in the study.

Beth ([ILLUSTRATION FOR FIGURE 3 OMITTED], lower section). Beth passed through each stage of the conditional discrimination training (i.e., A1-C1, A2-C2, Mix 1, A1-B1, A2-B2, Mix 2, Final Mix) in a total of 140 trials. She then produced 10 out of 10 consecutive correct responses on her first exposure to the equivalence test. Subsequently, Beth achieved the transfer training (B1[right arrow]clap and B2[right arrow]wave) mastery criterion on her second block of 10 trials, before emitting 20 consecutive correct responses during her first exposure to the transfer test (C1[right arrow]clap and C2[right arrow]wave). Beth was then exposed to conditional transfer training ("Yellow"/B1[right arrow]clap, "Blue"/B1[right arrow]wave, "Yellow"/B2[right arrow]wave, and "Blue"/B2[right arrow]clap), but she failed to show any improvement across 40 training trials. During her next session, she was successfully retested for equivalence, and then successfully retrained and retested on the transfer tasks (i.e., to ensure that the derived behavioral relations were still intact). Beth was then reexposed to the conditional transfer training and reached the mastery criterion on her third block of 20 trials, but she failed to show a conditional transfer of functions across two blocks of 20 test trials (YELLOW/C1[right arrow]clap, BLUE/C1[right arrow]wave, YELLOW/C2[right arrow]wave, and BLUE/C2 [right arrow]clap). The day's session was terminated at this stage, but when Beth was approached on subsequent days, she shouted "I don't want to play games with you," and thus her participation in the study was terminated.

Cara ([ILLUSTRATION FOR FIGURE 4 OMITTED], upper section). Cara completed the conditional discrimination training after 160 trials, passed the equivalence test on her first exposure, completed transfer training in 20 trials, and then passed the transfer test. During her next session Cara was successfully retested for equivalence, and was exposed to conditional transfer training, but she failed to achieve the mastery criterion after two blocks of 20 trials. Subsequently, Cara was successfully retested for both equivalence and a transfer of functions, but immediately after her successful transfer performance, Cara asked if she could "go and play outside now?" and the session was terminated. When Cara was approached by the researcher and blind tester on subsequent days, she shouted "No, No, No!" and therefore her participation in the study was terminated.

David ([ILLUSTRATION FOR FIGURE 4 OMITTED], lower section). David completed conditional discrimination training after 140 trials, demonstrated equivalence, and was then successfully exposed to the transfer training and test phases. He then passed the conditional transfer training in two blocks of 20 trials, but failed the conditional transfer test (across two blocks of 20 trials). David was successfully retested for equivalence and successfully retrained and retested on the transfer tasks. He then passed the conditional transfer training for a second time (after two blocks of 20 trials), but again failed the conditional transfer test (across one block of 20 trials). David was then retrained on the conditional transfer tasks, successfully reexposed to the equivalence test, but failed the conditional transfer test for a third time. Following another successful equivalence test, David was exposed to a novel test procedure in which the conditional transfer training and testing tasks were presented on alternate trials, with each of the eight training and testing tasks occurring at least twice across each block of 20 trials (although tentative, there is evidence which suggests that interpolating training and testing may facilitate derived transfer [see Barnes & Keenan, 1993]). Reinforcement only followed training tasks, never testing tasks, and the order of conditional transfer training and testing trials was unsystematic in that a clapping or waving test trial could follow either a clapping or waving training trial (e.g., "BLUE"/B1[right arrow]wave?, YELLOW/C1[right arrow]clap?, "BLUE"/B2 [right arrow]clap?, BLUE/C2[right arrow]clap?, and so forth). A new blind tester, who had not been involved with the study, was trained to conduct this interpolated training and testing. Because this new blind tester had never conducted the equivalence test, it was highly unlikely that she could deduce the derived relations and thus provide subtle cues to the subject. For example, an original blind tester may have deduced the following: "During the matching (equivalence) test David picked curtain given hedgehog; now 'Blue'/hedgehog means clap so Blue/curtain must mean clap." (Parenthetically, informal discussions with all of the blind testers at the end of the study indicated that none of them correctly guessed what the experiment was designed to demonstrate). When David was exposed to the interpolated, conditional transfer training and testing, he produced 40 consecutive correct responses. He was then exposed to the original conditional transfer testing phase (i.e., with no interpolated training trials), and he produced a further 40 consecutive correct responses, thus showing the predicted conditional transfer of functions through equivalence relations.

Eamon ([ILLUSTRATION FOR FIGURE 5 OMITTED], upper section). Eamon was successfully exposed to the conditional discrimination training (a total of 140 trials), the equivalence test, and to the transfer training. However, this subject had considerable difficulty in passing the transfer of function test (i.e., all of Eamon's incorrect responses on the transfer tasks consisted of clapping his hands together once and then immediately waving). Eamon failed five separate exposures to this test (a total of 70 trials) despite four successful exposures to the equivalence test, and five successful exposures to the transfer of function training. After Eamon's fifth failure on the transfer test, a novel test procedure was introduced, in which the equivalence testing tasks and the transfer testing tasks were presented on alternate trials, with each of the four tasks presented in a quasi-random order, with each occurring at least twice across each block of 10 trials (e.g., B1 - C1?, C1[right arrow]clap?, B1 - C1?, C2[right arrow]wave?, and so forth). During Eamon's first exposure to this modified test procedure, he again failed the transfer test (i.e., clapping and waving to each stimulus) but on his second exposure he produced 10 consecutively correct transfer responses. He was then successfully exposed to the conditional transfer of function training and testing phases of the experiment.

Fred ([ILLUSTRATION FOR FIGURE 5 OMITTED], lower section). Fred successfully completed the conditional discrimination training (a total of 130 trials), equivalence testing, and transfer training. Although he failed his first transfer test, he passed during his second exposure, following a second successful equivalence test and reexposure to the transfer training. This subject then completed the conditional transfer training (in 60 trials), but failed the conditional transfer of function test. Fred was then successfully reexposed to the equivalence test, transfer training and testing, and conditional transfer training. He then produced 18 correct responses on the conditional transfer test (i.e., 90% correct) which was below our 100% correct mastery criterion. During the next session, Fred was reexposed to the equivalence test and the conditional transfer training, before successfully passing the conditional transfer test (i.e., 40 consecutive correct responses).

Control Subjects

Gina, Harry [ILLUSTRATION FOR FIGURE 6 OMITTED], and Ian [ILLUSTRATION FOR FIGURE 7 OMITTED]. All three control subjects successfully completed the conditional discrimination training, equivalence testing, and transfer of function training, but repeatedly failed the transfer of function test. Although Harry and Ian consistently failed the transfer test, it was decided to proceed to the final stages of the experiment with these two subjects. This allowed us to determine whether it was possible for the control subjects to produce a performance similar to the conditional transfer of functions shown by the experimental subjects, without first showing the supposedly more basic transfer of functions. Harry and Ian successfully completed the conditional transfer of function training, but failed to pass the conditional transfer of function test.

In general, during the transfer test phases of the experiment, Gina tended to alternate between clapping and waving across trials (i.e., clapping on one trial and waving on the next, irrespective of the stimulus), whereas Ian systematically waved and clapped in the presence of both stimuli an equal number of times (e.g., for every clap in the presence of C1 he also waved in the presence of C1). Harry tended to either (a) emit the incorrect response on almost every trial, or (b) alternate, in the same way as Gina, between clapping and waving.

Discussion

All six experimental subjects demonstrated equivalence responding and the predicted transfer of discriminative control through equivalence relations. However, only the two four-year-old and the six-year-old experimental subjects showed a conditional transfer of control through equivalence, and only after repeated training and testing. All three control subjects demonstrated equivalence responding, but failed to show the predicted transfer or conditional transfer performances similar to those produced by the experimental subjects. This is the first experimental study to demonstrate a transfer and conditional transfer of functions through equivalence relations with young children. Furthermore, the fact that the three control subjects failed to show the transfer effects, combined with the use of a double blind procedure, makes it unlikely that the transfer was based on some form of procedural artifact rather than the derived equivalence relations.

Although the three younger children failed to show the conditional transfer effect, it would be unwise to assume, at this stage, that children younger than 4 years are incapable of demonstrating a conditional transfer. Two of the 3-year-olds (Ann and Cara) refused to continue with the study before we could expose them to a conditional transfer test, and the remaining 3-year-old (Beth) was given only one exposure to this test. Perhaps alternative experimental procedures that incorporated more powerful reinforcers for 3-year-olds (e.g., access to cartoons, musical toys, etc.) would prove successful in maintaining their interest for longer periods of time than was possible in the present study.

The current research also demonstrated a transfer of conditional control, from an auditory to visual modality, over derived transfer. Previous research with adults has shown cross modality conditional control over the formation of equivalence relations (Lynch & Green, 1991), but not cross modality conditional control over a transfer of functions through equivalence. It is interesting, however, that in passing the cross modality tests, three of the six subjects in the Lynch and Green study demonstrated similar difficulties to those seen in the current experiment (i.e., their subjects also required extensive retraining and retesting before they produced cross modality conditional control). More importantly, perhaps, is that after examining their subjects verbalizations, Lynch and Green (1991, p. 153) suggested that a likely reason for the observed difficulty was that the contextual functions of the auditory stimuli did not transfer immediately to their visual counterparts (i.e., the subjects' initially "ignored" the contextual stimuli during the tests). It is possible, therefore, that the children in the current study initially failed to respond to the color of the paper during the conditional transfer of function tests, but after repeated training and testing the auditory control established for the spoken words "Yellow" and "Blue" transferred, in some undefined way, to their respective visual forms. Although we did not systematically record subjects' verbalizations during or after the experiment, and thus this explanation remains highly speculative, it should prove a useful avenue for further study.

One criticism of the current research might be that the training and testing design employed was not the most likely procedure to produce derived transfer in young children. Specifically, the initial stages of the conditional discrimination training did not necessarily require conditional control by the sample stimuli; with just one sample and its designated comparison presented in each block of trials (e.g., A1 and B1, then A2 and B2) a simple discrimination of the S+ was sufficient to achieve the mastery criterion. Conditional discrimination was not required until the trial types (e.g., A1-B1 and A2-B2) were mixed (i.e., Mix 1, Mix 2, Final Mix). The fact that only one of the experimental subjects produced a perfect performance across the first block of trials during the first exposure to one of the three mixes suggests that additional training was required to obtain "true" conditional discrimination. This extra training could account for the subsequent failures because of uncooperativeness (i.e., the younger subjects might have shown conditional transfer if they had required less training and therefore completed a greater portion of the experiment before becoming bored). It is possible, therefore, that the failure to obtain conditional transfer with the three younger subjects might have been caused, at least in part, by the shift from simple to conditional discrimination training during Phase 1 of the experiment.

The present research raises two additional issues that will require further empirical attention. First, although we attempted to keep the verbal instructions to a minimum, avoiding those terms or phrases that are often considered to facilitate equivalence responding (e.g., "goes with," "matches the one at the top") and derived transfer (e.g., "all tasks are interrelated") (see Barnes & Keenan, 1993; Wulfert & Hayes, 1988), it remains unclear exactly what effects our instructions had on the derived performances. It is possible, for example, that the instructions played a significant role in establishing the baseline conditional discriminations and perhaps provided important contextual cues for equivalence and derived transfer (see Barnes, 1994). Nevertheless, it is important to remember that although the control subjects were also given extensive instructions they failed to show derived transfer, and thus the current data clearly demonstrated that the instructions used here were not sufficient to produce transfer (although they may be necessary). Thus we now know (a) that at least some of the transfer effects obtained with extensively instructed adults (e.g., Barnes & Keenan, 1993; Gatch & Osborne, 1989; Hayes et al., 1991; Wulfert & Hayes, 1988) do not necessarily require an extended preexperimental verbal history (e.g., a high school education), (b) that to show derived transfer, children do not need instructions that specify a relationship between the matching-to-sample and transfer tasks, and (c) that to show equivalence and transfer, children do not need an instruction that specifies an equivalence relation between the sample and the comparison.

The second issue that will require further empirical study relates to the effects of presenting specific testing tasks in either discreet blocks of trials, or interpolating them with either training and/or different test tasks within a single block. Two of the experimental subjects in the current study produced a correct derived performance, following repeated failures, when they were exposed to an interpolated conditional transfer training and testing procedure (i.e., David) or to an interpolated equivalence and transfer test (i.e., Eamon). This finding is consistent with the idea that interpolated testing procedures may sometimes facilitate derived behavior (see Barnes & Keenan, 1993, p. 78). Given that other studies have not always obtained reliable results with young children using procedures similar to those employed here (e.g., Auguston & Dougher, 1991), future researchers might consider examining the effects of various types of training and testing procedures on childrens' derived behaviors.

The fact that the three control subjects in the current study failed to show derived transfer indicates that the formation of the relevant equivalence relations, rather than just equivalence responding per se, is required before derived transfer may occur. However, it is important to note that (a) two of the experimental subjects (Eamon and Fred) initially failed to show the transfer performance, although they previously passed the equivalence test, and (b) three of the experimental subjects (David, Eamon, and Fred) all failed to show a conditional transfer of functions without repeated training and testing. The formation of the relevant equivalence relations thus does not ensure a derived transfer (or conditional derived transfer) of functions through those relations. Interestingly, other researchers have also reported this discrepancy between equivalence, transfer, and conditional transfer performances with adult subjects (e.g., de Rose, McIlvane, Dube, & Stoddard, 1988; Green, Sigurdardottir, & Saunders, 1991; Wulfert & Hayes, 1988), but as yet the exact nature of the relationship between equivalence and derived transfer remains a poorly understood area (but see Barnes, 1994, for a detailed discussion of this issue).

During the introduction it was suggested that the behavioral relations involved in derived transfer effects are functionally similar to the behavioral relations that can produce an appropriate response to a word or symbol without explicit teaching (see Barnes et al., 1990; Barnes & Holmes, 1991; Hayes, 1991; Sidman, 1992). The current demonstration of derived transfer in young, verbally able children is consistent with this idea, but of course this evidence is tentative. For example, the current study did not examine whether preverbal children, or nonverbal animals, would fail to show the transfer performances when exposed to similar experimental procedures, and if they did fail what history of reinforcement might establish derived transfer (see Barnes & Hampson, 1993; Cullinan, Barnes, Hampson, & Lyddy, 1994; Shusterman & Kastak, 1993). Clearly, considerable research is needed with verbally impaired humans and nonhuman subjects if we are to understand better the relationship (or lack of) between derived transfer and human language. Nevertheless, the current findings represent an important step in developing our understanding of this relationship, because they clearly show that derived transfer does not require the advanced verbal skills that are commonly acquired during an advanced educational training.

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