Establishing Relational Responding in Accordance with Opposite as Generalized Operant Behavior in Young Children

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Running Head: Relational Frames and Opposition

ABSTRACT

The current study constituted the first attempt to generate repertoires of relational responding in accordance with opposite, as generalized operant behavior, when they are found to be absent in young children. Three children, aged between 4 and 6 years, participated in the study. A basic problem-solving task was adopted from previous research to test and train patterns of relational responding in accordance with opposite. This task involved presenting a child with various numbers of identically-sized paper coins and providing the following instructions, for example: "This coin buys many (or few) sweets, and is opposite to this coin, which would you take to buy as many sweets as possible"? All three participants failed to pass baseline tests for specific patterns of relational responding in accordance with opposite. Various interventions, including training and testing across different stimulus sets and across different numbers of sets, were then successfully used with all participants to establish these relational responses as well as increasingly complex patterns of opposite responding. Generalization tests also demonstrated that the relational responding generalized to novel stimuli and experimenters. In addition, the use of a non-contingent reinforcement condition for one participant, during which no improvement was made, together with contingency reversals for all three participants, indicated that the trained and tested opposite responding may be considered a form of generalized operant behavior. These findings support previous research and lend positive support to Relational Frame Theory's approach to derived relational responding, and to the functional analysis of human language and cognition. Alternative interpretations of the data are also considered.

Relational Frame Theory (RFT) has to date generated a substantive body of demonstration research with both adults and children that includes evidence of the derivation of novel stimulus relations in the experimental context (for a book-length review, see Hayes, Barnes-Holmes, & Roche, 2001). While some of this work has involved attempts to *facilitate* patterns of relational responding that emerge from preexisting behavioral repertoires (Barnes-Holmes, Barnes-Holmes, Roche, & Smeets, 2001a; Barnes-Holmes, Barnes-Holmes, Roche, & Smeets, 2001b; Healy, Barnes-Holmes, & Smeets, 2000), other studies have provided evidence of the *establishment* of relational repertoires that did not appear to exist prior to the experimental manipulations (Barnes-Holmes, Barnes-Holmes, Smeets, Strand, & Friman, this volume; Lipkens, Hayes, & Hayes, 1993).

In the study by Barnes-Holmes, et al (this volume), the researchers presented three young children, aged between four and six years old, with a problem-solving task that involved two or three identically-sized paper coins in an attempt to test and train patterns of relational responding in accordance with the arbitrary relations of more-than and less-than. On each trial, the experimenter described how the coins compared to one another in terms of their value (e.g., A buys more than B and B buys more than C), and the child was asked to pick the coin that would "buy as many sweets as possible". Within the context of the problem-solving task, numerous sets of coins were used to establish and test relational performances in accordance with more-than and less-than.

The results of the initial baseline tests of the arbitrary more-than and less-than relations conducted by Barnes-Holmes, et al. indicated that that target comparative performances did not appear to exist in the behavioral repertoires of the three young children. Interventions suggested by RFT, including training and testing across stimulus sets, were then successfully used to establish increasingly complex patterns

of relational responding in all three children. Generalization tests demonstrated that the relational responding successfully generalized to novel stimuli and to a novel experimenter. In addition, the use of a non-contingent reinforcement condition for one participant, during which no improvement was made, together with contingency reversals for all children, indicated that the trained and tested relational responding may be considered a form of generalized operant behavior.

One potential criticism of the Barnes-Holmes, et al. study alluded to by the authors was the possibility that because the children were trained and tested on the same four trial-types, the resulting relational responses, though novel, were not genuinely derived (i.e., the children were exposed to novel stimuli, but not novel trial-types, during the tests). Although this possibility seems unlikely because novel stimuli were employed in the generalization tests, the current study attempted to address this issue specifically by the inclusion of novel *numbers* of stimuli in the context of establishing relational responding in accordance with opposite.

To test and train responding in accordance with opposite, a similar problem-solving task was designed that involved presenting a child with various numbers of identically-sized paper coins. On each trial, the experimenter specified that one of the coins (either the first or the last in the sequence) was worth the value of many or few sweets and thereafter described how the coins compared to one another. As in the previous study, the child was then asked to pick the coin or coins that would buy as many sweets as possible. For example, in the simplest opposite task participants were presented with two coins and instructed: "If this coin buys many sweets, and is opposite to this coin (i.e., A=MANY: A opp. B) which would you take to buy as many sweets as possible?" Numerous sets of coins and objects were used to test and train the relational performances in order to establish specific patterns of opposite responding. One of the key features of this study was that for all trial-types involving

four or more coins, a correct response required choosing at least two coins and during the presentation of a novel number of coins (e.g., presenting five instead of four), the number of correct coins varied. This feature of the opposite task was critical in that it permitted an examination of the generalization of opposite responding to a number of elements that had not been trained using a previous stimulus set.

METHOD

Participants

Three children (Participants 1, 2, and 3) were involved in the current study. At the beginning of the experiment Participant 1 (P1), male, was 4 years and 8 months old; Participant 2 (P2), female, was 6 years and 2 months old; and Participant 3 (P3), male, was 4 years old. At the end of the experiment P1 was 5 years and 2 months old; P2 was 6 years and 5 months old; and P3 was 4 years and 5 months old. The first two children were enrolled in a crèche in Cork, and the third child was enrolled in a crèche in Dublin. These individuals were chosen on the basis of parental consent, and that neither their parents nor their crèche supervisor had identified them as presenting a learning difficulty.

Setting and Apparatus

Each session was conducted in a quiet room free from distraction within each child's respective crèche facility and the children participated individually. The experimenter and child sat side-by-side at a small wooden table during most of the sessions. During generalization tests (described later) a novel experimenter and the child sat together on the floor. One hundred and seventy identically-sized colored paper circles were employed. These were described to the children as "coins", and this label is used throughout the current paper. There were 57 blue coins, 57 red coins and 56 green coins and each coin was marked with a different pattern (i.e., no two

coins were identical). These coins were used to construct 17 sets of coins with ten coins in each set. In each set of coins, there were three blue coins, three red coins and three green coins, and another coin of one of the three colors. Sets of coins were constructed anew for each participant. The coins contained in each set were designated as A, B, C etc., depending on the number of coins in use (participants never saw these labels). Across sets, the letters designated to the coins were randomized and thus control by either the dimension of color or pattern was eliminated. Only one set of coins was used at any one time. Only one participant was exposed to all seventeen sets, and the full ten coins from any set were never actually used with any of the children. Each set of coins was placed on a background of white A3 paper (referred to as the stimulus sheet), in either a horizontal or random presentation. A number of additional sets of stimuli was employed throughout the study to test for generalization. These included: books, audio cassette boxes, cups, pencils, beads, spoons, and pasta shapes. All of the generalization objects in each category (e.g., books) were identical in size. Other materials were employed as reinforcers including colored beads, commercially available children's stickers and sweets. The reinforcers and an upright glass jar were placed on a wooden tray. The tray was placed to the left, and slightly in front of the experimenter throughout each session.

Programmed Consequences

A correct response consisted of the child pointing to the correct coin or coins (depending on the trial-type and the number of coins in use) and was followed by the words: "Yes, you are correct. Good girl/boy. Take a bead." At this point, the child was allowed to select a colored bead from the tray, located on the table. An incorrect response was defined as making an incorrect choice or emitting no response within 10 seconds of the instruction. After collecting eight beads in the glass jar, the child was

allowed to select a sticker/sweet from the wooden tray. Punishment during training trials consisted of the experimenter saying: "No, this is not correct. You lose a bead." The experimenter then removed a bead from the jar and placed it back in the tray, and the next training trial began. No programmed consequences followed any test trial.

General Procedure

Testing and training each involved blocks of eight trials. Participants were first exposed to a baseline test to determine whether they could respond in accordance with opposite relations in the context of the experimental task. On each test or training trial the child was required to point to a particular coin or coins, depending on the particular trial-type. When there was more than one correct coin, participants were not required to point to the coins in any particular sequence. For a trial to be recorded as correct, the child was required to point only to the correct coin or coins. The children were never instructed as to the correct *number* of coins to choose on any given trial. Pointing to any incorrect coin, even if a correct coin was also chosen, was recorded as an incorrect response. If a child made any comment during a trial, the experimenter simply replied: "We can talk after we have finished our work."

In general, sessions lasted no more than 20 minutes per day, and the children were exposed to a maximum of four sessions per week. When sessions lasted more than 10 minutes, a break of 5 minutes was provided mid-way through the session. At the beginning of each block of training or testing trials, the experimenter always asked the child: "Do you want to do some more work?" If the child indicated that s/he did want to do more, the experimenter continued as planned. If, however, the child responded negatively (or indicated during a training or test block that s/he wished to stop), the experiment was terminated for that day. If the child had reached a training criterion or passed a test during the previous block, in the next session the experimenter continued with the next planned stage of the experiment. If, however,

the child had failed to reach a training criterion or pass a test during the previous block (or asked to stop at any point during a block) the next planned stage was not presented. Instead, the next training or test block normally involved some form of reduction in the complexity of the previously presented stage (e.g., presenting three coins rather than four coins). Procedural details specific to each participant are described in a combined Procedure and Results section.

Testing opposite relations among four coins. Participants were first exposed to a 'baseline' test of opposite relations among four coins. This test consisted of a single block of eight test trials using four coins (A, B, C, and D) from Set 1, positioned horizontally left-to-right from A to D (i.e., A then B, then C, then D). On the first trial of each session, the experimenter placed the bead container on the table and positioned the coins according to the appropriate trial-type. Each child was first instructed that s/he was going to play a 'birthday game'. The following instructions were then given.

> "I want you to imagine that it is your birthday today and you have to go to the shops to get sweets for your birthday party. If I tell you that this coin (e.g., experimenter pointed to coin A) buys many (or few) sweets, and this coin (experimenter still pointing to coin A) is opposite to this coin (experimenter pointed to coin B), and this coin (experimenter still pointing to coin B) is opposite to this coin (experimenter pointed to coin C), and this coin (experimenter still pointing to coin C) is opposite to this coin (experimenter pointed to coin D), which would you take to buy as many sweets as possible?"

On subsequent trials, shorter instructions were provided (i.e., only the second sentence of the instructions was presented). There were four trial-types in each block of eight test trials, with each trial-type presented twice in a random order without replacement. These trial-types are depicted in Table 1.

INSERT TABLE 1 ABOUT HERE

Each of these trial-types may be described as follows: A buys many: and A is opposite to B, which is opposite to C, which is opposite to D (A-Many: A opp B opp C opp D); D buys many: and D is opposite to C, which is opposite to B, which is opposite to A (D-Many: D opp C opp B opp A); A buys few: and A is opposite to B, which is opposite to C, which is opposite to D (A-Few: A opp B opp C opp D); and D buys few: and D is opposite to C, which is opposite to B, which is opposite to A (D-Few: D opp C opp B opp A). When the experimenter specified that a particular coin bought many or few sweets, that coin was always identified first. For example, for the trial-type 'A-Many: A opp. B opp. C opp. D', the experimenter pointed to the A coin first, whereas for the trial-type 'D-Few: D opp. C opp. B opp. A', the experimenter pointed to the D coin first.

With trials involving relations between four coins, each trial-type consisted of two correct choices (A and C, or B and D). For example, given the relation 'D-Many: D opp. C opp. B opp. A', coins D and B were the correct choices. However, given the relation 'A-Many: A opp. B opp. C opp. D', coins A and C were the correct choices (see Table 1). Failing to select *both* correct coins was defined as an incorrect response. To pass a block of test trials, participants were required to produce at least 7 out of 8 correct responses.

Horizontal/random stimulus presentations. All of the trial-types used in the baseline test involved coins presented horizontally from A to D (i.e., A beside B beside C beside D). After participants had successfully completed this test, they were exposed to the same coins presented in random positions (to eliminate stimulus control by location alone). During random presentations, coins could be placed in any location on the stimulus sheet. This horizontal-first, random-second sequence was adopted throughout the experiment. That is, once the children had passed a test

involving any given number of coins presented horizontally, they were then exposed to the same coins presented in random positions.

Training opposite relations among four coins. If participants failed the baseline test, they were exposed to training of the same relations using the same four coins, again in horizontal positions. In effect, they were exposed to the *same* procedure as used in testing, except that programmed consequences were provided during training. Training trials were also presented in blocks of eight trials. The number of training trials depended on the participants' performance, and they were required to achieve a mastery criterion of eight consecutively correct responses. Successful training with four coins was always followed by a test involving four coins from a new set, again presented horizontally. If participants failed this test again, they were reexposed to training with the same relations using the same set of coins presented horizontally. If they passed this test, the same coins were then presented randomly. If the children passed the baseline test at this point with both horizontal and random positions, they were introduced to a test of opposite relations among five coins, using the same set (see below). If they failed the test, they were trained on the same set and tested on a new set. This pattern of recursive training and testing continued until each child passed the test using a *novel* set of coins (in both horizontal and random positions).

Testing and training opposite relations among five coins. The trial-types involved in five-coin presentations were identical to those used with four coins, except that a fifth coin was added. Coins A and E now "bought many and few sweets", instead of coins A and D (as in four-coin presentations), and either A or E was pointed to first, depending on the relation specified. These trial-types are depicted in Table 2. With presentations involving five coins, a correct response was defined as selecting two or three coins, depending on whether the coin specified

bought many or few sweets. For example, when coins A or E "bought many" a correct response was defined as selecting three coins (A, C, and E). However, when coins A or E "bought few" a correct response was defined as selecting two coins (B and D). If participants passed the five-coin test in both horizontal and random positions, they were introduced to a test of the same relations involving six coins, using the same set (see below). If they failed the five-coin test, they commenced with the same pattern of recursive training and testing employed with four coins.

INSERT TABLE 2 ABOUT HERE

Testing and training opposite relations among six coins. The trial-types involved in six-coin presentations were identical to those used with five coins, except that a sixth coin was added. Coins A and F now "bought many/few sweets", instead of coins A and E, and either A or F was pointed to first, depending on the relation specified. These trial-types are depicted in Table 3. With presentations involving six coins, a correct response was always defined as selecting three coins, depending on which coin was specified, and whether this bought many or few sweets. For example, when coin A "bought many" or coin F "bought few" a correct response was defined as selecting coins A, C, and E. However, when coin A "bought few" or coin F "bought many" a correct response was defined as selecting coins B, D, and F. If participants passed the six-coin test in both horizontal and random positions, they were introduced to a test involving would and would-not trial-types, using the same set (see below). If they failed the six-coin test, they commenced with the same pattern of recursive training and testing employed with four and five coins.

INSERT TABLE 3 ABOUT HERE

Responding in accordance with 'would' and 'would-not'. When participants had passed horizontal and random tests with six coins, they were exposed to 'would' and 'would-not' trial-types. During these trials, the children were instructed as follows:

> "This time, I will sometimes ask which coin *would* you take to buy as many sweets as possible, and other times I will ask which coin would you *not* take to buy as many sweets as possible?"

During these trials, participants were required across blocks of training and/or testing to indicate which coin/s they *would* and *would not* select (referred to as 'would/would-not' training and testing) in order to buy as many sweets as possible. From an RFT perspective, the word "opposite" functioned as a Crel, whereas "would" and "would-not" functioned as Cfuncs. This test consisted of one block of eight test trials randomly presented. These eight trials consisted of the same four trial-types as in the six-coin presentation, except that each trial-type was presented once for 'would' responding and once for 'would-not' responding (i.e., each trial-type was presented with a 'would' and a 'would-not' question). Training and testing with would and would-not responding were identical, except for the provision of programmed consequences. If participants failed the six-coin would/would-not test, they commenced with a similar pattern of recursive training and testing employed previously, except that the training and testing now incorporated would and would-not trial-types.

Generalization test. When participants had completed all of the test and training procedures outlined above, they were exposed to a generalization test (with no feedback) with six identically-sized objects (instead of coins), randomly positioned around the floor of the experimental room. This generalization test

contained identical trial-types to the would/would-not test. Children were never trained on the stimulus sets used for generalization tests. Further generalization tests were conducted, each with novel objects, following two contingency reversals (see below). Novel experimenters who were unfamiliar with the general purpose of the study and who had no knowledge of behavioral psychology conducted all generalization tests. Each of the novel experimenters was provided with an appropriate script of the relevant question to be asked on each trial at the beginning of each session. Novel experimenters were not required to record responses (this was done by an independent observer). The novel experimenters were also explicitly instructed not to work out the correct answer to each trial because doing so might interfere with the experiment.

Follow-up test. Follow-up tests, where possible, were conducted one month after the completion of testing and training to determine if the relational performances remained intact across extended periods of time (see Rehfeldt & Hayes, 2000; Saunders, Wachter, & Spradlin, 1988). This test involved a novel set of six coins presented randomly with would and would-not trial-types. Additional training proved not to be necessary during the follow-up test for any child.

Contingency reversals. When participants had passed all of the tests outlined above, the reinforcement contingencies were reversed (i.e., Reversal 1) in order to determine the operant nature of the performances that had been demonstrated. In effect, the children were now required to respond *away* from the coin or coins the choice of which would have been reinforced previously. That is, given the relation 'A-Many: A opp B opp C opp D', for example, selecting coins B and D was reinforced, as opposed to selecting coins A and C. After participants had passed all of the tests contained in Reversal 1, including the generalization test, a second reversal (i.e., Reversal 2) was introduced in order to complete an A-B-A reversal

design for each child. In Reversal 2, the contingencies were reversed a second time, and the original reinforcement contingencies were reinstated. That is, given the relation 'A-Many: A opp B opp C opp D', for example, selecting coins A and C was reinforced as in the original training. At this point the experiment concluded with generalization tests. The details of these reversals for each child is presented in the Procedure and Results section.

Testing opposite relations among seven coins/objects. When participants had completed the two contingency reversal conditions, they were exposed to a test involving seven coins or seven generalization objects randomly positioned on the floor of the experimental room. This test was identical to a generalization test, except that on some occasions coins were used instead of generalization objects. The trial-types involving seven coins/objects were identical to those used with six coins in random positions, except that a seventh coin/object (G) was added. Coins/objects A and G now "bought many or few sweets", and either A or G was pointed to first, depending on the relation specified. These trial-types are depicted in Table 4. With presentations involving seven coins/objects, a correct response was defined as selecting three or four coins/objects, depending on whether the specified item 'bought many or few sweets'. For example, when coin A or G "bought many" a correct response was defined as selecting four coins (A, C, E, and G), and when coin A or G "bought few" a correct response was defined as selecting three coins (B, D, and F). This seven-item random presentation also involved would and would-not trial-types.

INSERT TABLE 4 ABOUT HERE

Testing opposite relations among eight, nine, and ten objects. When participants had been exposed to the test involving seven coins/objects, they were

subsequently exposed to tests involving eight, nine, and/or ten generalization objects (i.e., coins were not used) in random presentations. These tests were identical to the generalization test described above. The trial-types with eight objects were identical to those used with seven coins/objects, except that another object (H) was added, and this together with object A, was specified as buying many or few sweets (see Table 5). With presentations involving eight objects, a correct response was always defined as selecting four objects, depending on which object was specified, and whether this 'bought many or few sweets'. For example, when object A "bought many" or object H "bought few" a correct response was defined as selecting objects A, C, E, and G. However, when object A "bought few" or object H "bought many" a correct response was defined as selecting coins B, D, F and H.

INSERT TABLE 5 ABOUT HERE

The trial-types involving nine objects were identical to those employed with eight objects, except that in each case an extra object was added. Objects denoted as A and J were pointed to first and identified as those 'buying many or few sweets' (see Table 6). A correct response was defined as selecting four or five objects, depending on whether the specified object 'bought many or few sweets'. For example, when object A or J "bought many" a correct response was defined as selecting five objects (A, C, E, G, and J), and when objects A or J "bought few" a correct response was defined as selecting four objects (B, D, F, and H).

INSERT TABLE 6 ABOUT HERE

With trial-types involving ten objects, A and K were specified as 'buying many or few sweets' (see Table 7). A correct response was always defined as selecting five objects, depending on which object was specified, and whether this bought many or few sweets. For example, when object A "bought many" or object K "bought few" a correct response was defined as selecting A, C, E, G, and J. However, when object A "bought few" or object K "bought many" a correct response was defined as selecting B, D, F, H, and K.

INSERT TABLE 7 ABOUT HERE

Inter-observer reliability.

Approximately 25 percent of training and testing trials were observed by an independent observer (or two observers during the generalization tests), who had no knowledge of experimental psychology. The observer could not see the experimenter's data sheet during the experimental sessions. The observer and experimenter disagreed on a total of six training trials and three test trials.

PROCEDURE AND RESULTS

Given the nature of the study, the procedural details pertaining to each participant will be described in the context of the results. The complete procedure and results for P1 will be presented, but for P2 and P3 only those features of the experiment that differ from P1 will be described (i.e., the entire experimental sequence for P2 and P3 will not be described).

Participant 1

The training and test data for P1 are outlined in Table 8 and the child's performance during each test exposure is presented in Figure 1. During the baseline

test involving four coins from Set 1 presented horizontally, P1 failed to emit a correct response (i.e., he never chose the two correct coins on any trial). He was immediately exposed to blocks of training trials using four coins from Set 1 (corrective feedback was provided). Across 16 training trials, he produced only three correct responses, and he indicated that he wished to stop.

INSERT TABLE 8 AND FIGURE 1 ABOUT HERE

In Session 2, the training trials were simplified by using only two coins from Set 1. In *all* presentations involving only two coins, the coins were always presented in random positions. The child was exposed to two blocks of these training trials. The first block of trials involved coins A and B from Set 1, and the second block involved coins B and C from the same set. The number of training trials in each block to which the child was exposed depended on his performance during training. He was required to reach the mastery criterion of eight consecutively correct responses with the AB coins before training on the BC coins. There were four trial-types in this two-coin presentation for each pair of coins. The AB and BC trial-types are depicted in Tables 9 and 10. In one trial-type involving coins A and B, for example, the experimenter pointed to coin B first, and then said: "This coin buys many sweets, and is opposite to this coin (experimenter pointed to coin A). Which would you choose to buy as many sweets as possible?" A correct response consisted of selecting one coin depending on the relation specified. Each trial-type was presented twice in a quasi-random order in a block of eight trials. In Session 2, P1 reached the mastery criterion on the AB relations in 12 training trials, and produced 8 consecutively correct responses on the BC relations (making a total of 20 training trials). He was subsequently exposed to a test (i.e., no feedback) with two pairs of

novel coins (i.e., A and B, and B and C from Set 2). There were 16 test trials in total, one block of eight trials involved the AB relations and the other block involved the BC relations. He passed this test when he produced 15 correct responses (a minimum of 14 correct was required: see Table 8).

INSERT TABLES 9 AND 10 ABOUT HERE

Having passed the test with two coins presented horizontally, P1 was then (in Sessions 2 and 3) exposed to training involving three coins in horizontal positions. For this training the same coins used previously were now presented simultaneously (i.e., A, B, and C from Set 2). There were four trial-types in the three-coin presentation. These are shown in Table 11. Each trial-type was presented twice in a quasi-random order without replacement in a block of eight trials. In one trial-type, for example, the experimenter pointed to the C coin first, and then said: "This coin buys few sweets, and is the opposite to this coin (experimenter pointed to B), and this coin (still pointing to B) is the opposite to this coin (experimenter pointed to A). Which would you choose to buy as many sweets as possible?" Depending on whether the experimenter specified that a coin could buy many or few sweets, a correct response consisted of selecting one or two coins. If the specified coin (A or C) bought many sweets, a correct response was defined as choosing two coins (i.e., A and C). If the selected coin bought few sweets, a correct response was defined as choosing only one coin (i.e., coin B). Participant 1 failed to reach the mastery criterion after 40 training trials, and indicated that he wished to stop.

INSERT TABLE 11 ABOUT HERE

In the following session (Session 4), the child was reexposed to training trials involving only two coins, using the same set of coins (i.e., A, B, and C from Set 2). He reached the mastery criterion on the AB relations in 10 training trials, and produced 8 consecutively correct responses on the BC relations. He was immediately reexposed to a test involving two blocks of two-coin presentations, but with novel coins (i.e., A, B, and C from Set 3). The child passed this test when he produced 15 out of 16 correct responses (see Table 8), and was then reexposed to the same coins in a three-coin horizontal presentation for the second time. However, he once again failed to produce eight consecutively correct responses after 16 training trials, and indicated that he wished to stop. In summary, P1 had, on two occasions, successfully trained in accordance with the mutually entailed opposite relations between two coins, and had twice passed a test that examined the derivation of these relations with a novel set. However, the child had failed to respond in accordance with the combinatorially entailed opposite relations among three and four coins presented in horizontal positions.

At this point, the relational frame of 'sameness' was employed in an attempt to establish the combinatorially entailed relation of opposite (casual observation indicated that responding in accordance with the frame of 'sameness' was already established in the child's behavioral repertoire). In Session 5, the child was exposed once again to the same three coins in horizontal positions. When the participant emitted an incorrect response he was given a set of novel instructions that provided a contextual cue for responding in accordance with 'sameness'. For example, on the first trial the experimenter pointed to the A coin, and said: "This coin buys many sweets, and is opposite to this coin (B), and this coin (B) is opposite to this coin (C). Which would you choose to buy as many sweets as possible?" (coins A and C were the correct choices on this trial). At this point, the participant produced an incorrect

response and was immediately given the following instruction: “No, that’s not correct. If this coin (A) buys many sweets and is opposite to this coin (B), and this coin (B) is opposite to this coin (C), then these two coins (A and C) are the *same*.” The child was simply required to listen to the instruction and the next trial was presented immediately. During this training he emitted five incorrect responses, and each time he was presented with the ‘sameness’ instruction. With this intervention, he reached the mastery criterion on the opposite relations with three coins in horizontal positions in 17 training trials (see Table 8). He was then immediately (in Session 5) exposed to a test (i.e., no feedback or ‘sameness’ instructions) of these relations, using three novel coins (i.e., from Set 4). This test consisted of four trial-types identical to those used in training, each of which was presented twice in a quasi-random order. He passed this test when he produced 7 correct responses out of 8 (a minimum of 7 correct was required: see Table 8).

In the following session (6), the participant was exposed to another test involving the same coins used previously, but this time they were presented in random positions (i.e., on each trial the coins were placed on the stimulus sheet in a completely random manner). He failed to pass this test when he produced only 5 out of 8 correct responses, and he was subsequently exposed to explicit training trials with the coins presented in random positions. He reached the mastery criterion in a total of 25 trials. In Session 7, the child was exposed to a test using a novel set of three coins (Set 5) positioned randomly on each trial. He passed this test without error. Following this successful test performance with a three-coin random presentation, he was immediately reexposed to the baseline test involving four coins positioned horizontally. He failed this test, producing only 3 out of 8 correct responses.

In earlier sessions with this child, attempts to train the combinatorially entailed relations of opposite among four coins (Session 1) had failed, but the relational frame of 'sameness' had been successfully used to establish these relations with three coins. In the next session (8), therefore, the frame of 'sameness' was employed once again to establish these relations with four coins. In this session the participant emitted two incorrect responses, and each time he was presented with the 'sameness' instruction, as outlined above. With this intervention, he reached the mastery criterion on the opposite relations with four coins in 13 training trials (see Table 8). He was then immediately exposed to a test of these relations using four coins from a novel set (Set 6) positioned horizontally. He passed this test without error. In the subsequent session (Session 9) the child was tested on the same set of coins presented randomly. Again he passed this test without error.

Having now passed tests involving two, three, and four coins presented in horizontal and random positions, the child was introduced to a test involving the opposite relations among five coins positioned horizontally (see Table 2). On one trial-type, for example, the experimenter pointed to the A coin, and said: "This coin buys many sweets, and is opposite to this coin (B), and this coin (B) is opposite to this coin (C), and this coin (C) is opposite to this coin (D), and this coin (D) is opposite to this coin (E). Which would you choose to buy as many sweets as possible?" (coins A, C, and E were the correct choices on this trial). Each trial-type was presented twice in a quasi-random order in a block of eight trials. The participant failed this five-coin test when he produced only 4 correct responses (a minimum of 7 correct was required: see Table 8). Following this failure, he was exposed (in Session 10) to explicit training involving the same five coins presented horizontally. Feedback was provided on all trials, but no 'sameness' instructions were employed. This training consisted of four trial-types identical to those used in

the previous test, each of which was presented twice in a quasi-random order in a block of eight trials. He reached the mastery criterion of eight consecutively correct responses in only 9 trials. The participant was then immediately exposed to another test involving five coins from a novel set (7). He passed this test without error. This was immediately followed by another test with the same coins presented in random positions, and again he passed without error.

In Session 11, P1 was introduced for the first time to the test involving six coins presented horizontally (see Table 3). On one trial-type, for example, the experimenter pointed to coin F first and said: "This coin buys few sweets, and is opposite to this coin (E), and this coin (E) is opposite to this coin (D), and this coin (D) is opposite to this coin (C), and this coin (C) is opposite to this coin (B), and this coin (B) is opposite to this coin (A). Which would you choose to buy as many sweets as possible?" (coins A, C, and E were the correct choices on this trial). Each trial-type was presented twice in a quasi-random order, in a block of eight test trials. Participant 1 passed this test without error, and immediately thereafter he passed a test in which the same set of coins was presented in random positions (see Table 8).

At this point (in Session 12), the would/would-not test was introduced, in which the participant was required on half of the eight trials to select the coin that would *not* buy as many sweets as possible. This test involved one 'would' and one 'would-not' choice for each of the trial-types in a six-coin presentation. An example of one of the 'would-not' trial-types was as follows. "This coin (F) buys few sweets, and is opposite to this coin (E), and this coin (E) is opposite to this coin (D), and this coin (D) is opposite to this coin (C), and this coin (C) is opposite to this coin (B), and this coin (B) is opposite to this coin (A). Which would you *not* choose in order to buy as

many sweets as possible?" A correct response on this trial consisted of selecting the three coins B, D, and F. The participant passed this test without error.

Following this successful test performance, a novel experimenter (Session 12) conducted a generalization test using six identically-sized cups randomly positioned around the table in the experimental room. This generalization test involved would and would-not trial-types identical to those used in the previous test. The participant immediately passed the generalization test without error. One-month later, (Session 13) P1 passed without error a follow-up test involving six novel coins presented randomly, and including would and would-not trial-types.

At this point, reversed reinforcement contingencies were introduced in order to establish the generalized operant nature of the opposite responding. The participant was now required to respond away from the coins, the choice of which had been reinforced previously (see Figure 1). During Reversal 1, the procedures employed in the original reinforcement contingency were replicated, commencing with training on four coins presented horizontally, and involving would-only trial-types. Participant 1 was immediately trained on this four-coin horizontal presentation and required only 9 trials to reach the mastery criterion (i.e., he made an error on the first trial only and then responded consistently to the new contingency arrangement). He was then tested on four novel coins in horizontal positions (Set 9), and passed without error. He subsequently produced perfect responding on the following tests, respectively; four coins in random positions; five coins in horizontal then random positions; six coins in horizontal then random positions; six coins in random positions involving would and would-not trial-types, and a generalization test involving six identically-sized books in random positions including would and would-not trial-types conducted by a novel experimenter. At this point, P1 had clearly demonstrated

that the original pattern of responding, observed before the introduction of the contingency reversal, had been modified.

In the following session (14), P1 was exposed to Reversal 2, which involved a return to the original reinforcement contingency (see Figure 1). Because the child had proceeded so rapidly through Reversal 1, the second reversal was introduced with training on a six-coin random presentation with would and would-not trial-types. He reached the mastery criterion in the minimum number of training trials, although the reinforcement contingency was reversed. Without testing on six coins, he proceeded immediately to a test involving seven coins in random positions (see Table 4). Participant 1 passed this test without error. Finally, he was exposed to a generalization test involving eight identically-sized pencils (see Figure 2) randomly positioned around the floor of the experimental room, conducted by a novel experimenter. He also passed this test without error.

Participant 2

The training and test data for P2 are outlined in Table 12 and this child's performance during each test exposure is presented in Figure 2. The testing and training procedures employed with P2 were similar to those employed with the previous child. However, there were two key differences between these participants. Unlike P1, P2 quickly reached the mastery criterion on the baseline relations involving four coins presented horizontally, requiring a total of only 51 training trials. However, once P1 had passed the baseline test he immediately passed the subsequent test involving four coins in random positions. This was not the case with P2, who required a very similar series of extended interventions to pass the first test involving the random presentation of coins as P1 had required to pass the baseline test.

INSERT TABLE 12 AND FIGURE 2 ABOUT HERE

After failing the first test involving four coins in random positions, P2 was exposed to 16 training trials, but failed to reach the mastery criterion. The relation of 'sameness' was then used to facilitate opposite training as had been done with the previous child (although this intervention was employed at a much earlier point in P2's experimental history than was the case for P1). Once again, when the child made an incorrect response she was simply required to listen to the 'sameness' instruction before the next trial was presented. On this occasion, the intervention was not successful and she failed to reach the mastery criterion. The training was then simplified to three coins in random positions but she also failed to reach criterion during this training. The procedure was then simplified further by presenting only two coins from the same set, as had been done with the previous child. She reached the mastery criterion in the minimum number of trials and passed a subsequent test involving a novel set of coins. She subsequently failed to reach the mastery criterion on a three-coin random presentation for the second time.

At this point (Sessions 11-13) the relation of 'sameness' was employed once again, this time with a three-coin random presentation. During this training, the 'sameness' intervention proved more successful with three coins in random positions, and the child reached the mastery criterion after 115 training trials. She was immediately exposed to a test involving three novel coins presented randomly (Set 7), but failed once again. In the following Session (14) she was trained again on the three-coin random presentation using the same coins, *without* the 'sameness' instruction (because the child had produced 5 out of 8 correct responses during the previous test). She reached the mastery criterion during this training in the minimum number of trials, and passed a subsequent test with three novel coins without error. Given that she had now passed a test involving three coins randomly presented, she

was reexposed to a test involving four coins. At this point in the experiment, it did not seem necessary to retest the four-coin horizontal presentation, because she had demonstrated little difficulty with the horizontal format. She failed a test of four coins in random positions without any correct responses. In Sessions 14 and 15, she was explicitly trained on this four-coin random presentation, and reached the mastery criterion after 40 training trials. She passed a subsequent test with four novel coins presented randomly without error.

The performances of P2 during the rest of the experiment were very similar to those recorded for the previous child, with a number of very minor differences. After passing the test involving five coins in random positions, this child subsequently required explicit training with six coins in horizontal positions, and thereafter passed all subsequent tests (prior to the reversal conditions) without training. During Reversal 1, P2 required a second exposure to training on the reversed relations among four coins in horizontal positions and also required limited training with five coins in horizontal positions, neither of which had been required by the previous participant. Some minor alterations to the procedure were also employed during Reversal 2. Specifically, after receiving training on would and would-not trial-types with six coins in random positions and passing a subsequent test of these relations, P2 was exposed to the following tests; seven coins, and eight, nine, and ten generalization objects (all of which involved would and would-not trial-types and the random presentation of the stimuli). Participant 2 passed all of these tests without error (see Figure 2).

Participant 3

The training and test data for P3 are outlined in Table 13 and this child's performance during each test exposure is presented in Figure 3. Participant 3 was first

exposed to a total of six baseline tests, with two exposures to each of three sets of coins (i.e., Sets 1-3), involving would-only responding.

INSERT TABLE 13 AND FIGURE 3 ABOUT HERE

After failing all six baseline tests without a single correct response, P3 was introduced immediately to extended non-contingent reinforcement training. The number of non-contingent reinforcement training trials was set at greater than the maximum number of training trials required by both of the previous children to pass a test of the baseline relations, in order to provide a strong test of whether mere exposure to the experimental tasks would generate the performance. Participant 2 had required the greater number of 165 training trials, and so to exceed this figure and to present the training trials in blocks of eight as had been done previously, P3 was exposed to 224 non-contingent reinforcement trials (i.e., 28 blocks of 8). These trials involved four-coin horizontal presentations identical to the baseline test, except for the provision of non-contingent reinforcement. To make this form of training closely resemble the explicit training given to previous participants, similar quantities of reinforcement, trial repetitions, and bead withdrawals to those used previously were employed. For example, in each block of eight trials reinforcement was provided on four trials, two trials were repeated, and a bead was withdrawn after one trial (the sequence of these manipulations was randomized across blocks). The feedback that was provided was *entirely* random, and may or may not have been correct in terms of the specified relations.

In Sessions 3-7, P3 was exposed to 224 non-contingent reinforcement training trials presented in the manner described above. At no point during this training did he produce eight consecutively correct responses on these relations. In fact,

throughout the non-contingent reinforcement condition, he continuously selected only one coin instead of two, and visual inspection of the raw data (not shown) also indicated that the coin that he selected was never correct on eight consecutive trials.

On the completion of the non-contingent reinforcement condition, P3 was reexposed to eight baseline tests, and once again failed all eight tests, without a single correct response. He was subsequently exposed to explicit training of the baseline relations using the same four coins presented horizontally. The performances of P3 were more similar to those recorded for P2 than for P1, in that he showed little difficulty in passing the baseline relations (i.e., he required a total of only 68 training trials) but showed great difficulty in passing the test of four coins in random positions. During training with four coins in random positions it was necessary on two occasions to revert to presenting only two coins. Furthermore, the 'sameness' intervention was used when attempting to train three coins in random positions. Neither of these interventions was sufficient to establish correct responding. At this point, training with three coins in horizontal positions was introduced. In Session 33, the child failed a test involving three coins in horizontal positions, although he had previously passed the baseline test involving four coins in horizontal positions. After further training, he passed two subsequent tests involving three coins in horizontal positions but repeatedly failed to reach the mastery criterion on three coins in random positions.

At this point, trials involving horizontal presentations were used to facilitate training with trials involving random presentations. In Sessions 36-39, each block of eight training trials with coins in random positions was preceded with a block of three training trials with coins in horizontal positions. In other words, in each 11-trial block, there were three training trials with coins in horizontal positions, to which the child always responded correctly (these data are not shown), followed by eight

training trials with coins in random positions. After 76 training trials with random presentations, where each block of eight was preceded by three correct horizontal trials, he finally reached the mastery criterion. On a subsequent test (Session 40) involving three novel coins in random positions, he passed without error. He passed all subsequent tests (prior to the reversal conditions) without further training. During Reversals 1 and 2, he required minimal training to pass the initial relations, and did not require extra training at any other point during either reversal condition (see Figure 3). At the end of Reversal 2, the child received a sequence of testing similar to that employed with P1. After training and testing on six coins in random positions with would and would-not trial-types, the participant was exposed to two generalization tests involving seven and eight objects in random positions. He passed both of these tests without error.

Response Sequences

As indicated previously, when the correct response involved two or more coins/objects participants were not required to choose the correct items in any particular sequence. The response sequences were, however, monitored throughout the experiment, and very consistent patterns emerged (these data are not shown). First, on all correct training trials, the children always chose the correct coins/objects in the same sequence in which they were specified in the experimenter's instruction (e.g., given "if C buys many, and C is the opposite to B and B is opposite to A. . ." all participants consistently chose C and then A). During the test trials, however, an interesting pattern emerged for all three participants, but only after the introduction of the first generalization test. Across approximately 20 percent of the post-generalization test trials, the participants spontaneously reversed the response sequences that were consistently observed during training and early testing (given the example presented above, they would sometimes choose A and then C). The

emergence of this pattern was not accompanied by any increase in errors, and casual observation indicated that all three children considered these reversed response sequences to be correct (although these reversals were never reinforced at any point in the experiment).

GENERAL DISCUSSION

The current data clearly demonstrate that specific patterns of relational responding in accordance with opposite can be established in the behavioral repertoires of 4, 5 and 6-year old normally-developing children. Furthermore, there is evidence to suggest that using the relational frame of 'sameness' may facilitate the establishment of these relations for some children, when these relations cannot easily be trained explicitly. Performance on the generalization tests provided additional evidence for the frame-like, or generalized operant qualities of these response patterns, in that these participants responded relationally to stimuli that differed along many physical dimensions from the coins used throughout most of the experiment.

The present study provides evidence that responding in accordance with the relational frame of opposite is a form of generalized operant behavior. All three children failed initially to pass baseline tests for responding in accordance with the relation of opposite. One participant (P3) was also provided with an extended baseline of non-contingent reinforcement, but still failed to demonstrate the appropriate relational responding before operant contingencies were introduced. These consistent failures indicated that the target relational performances were not present in the child's behavioral repertoire. Furthermore, the extensive training required by each of the three children to establish the patterns of relational responding provided even further evidence to support the conclusion that the target relational repertoires were absent prior to the commencement of the study.

Operant contingencies were applied across multiple sets of stimuli and these contingencies successfully established the target relational responses for all three participants. Increasingly complex patterns of these relational responses were also established by the operant contingencies (e.g., contextual control by would/would-not), thereby demonstrating that specific patterns of relational responding had been established for each child. Data from the generalization tests, the non-contingent reinforcement phase, and the two contingency reversals also indicated that these relational responses were a class of generalized operant behaviors. The current findings support and extend the previous similar study by Barnes-Holmes, et al. (this volume).

In the previous study, Barnes-Holmes and colleagues discussed the extent and nature of the training history required to establish responding in accordance with relational frames (e.g., Boelens, 1994; Horne & Lowe, 1996) and suggested the likelihood that once the most basic relational unit is established through training in mutual and combinatorial entailment, fewer trained instances of combinatorial entailment would be necessary to expand this relational response (see Hayes & Wilson, 1996). Clearly, the current data provide support for this interpretation. Specifically, P1 required explicit training in the relation of opposite using two, three, four, and five coins before responding in accordance with opposite generalized, without explicit training, to six, seven, and eight coins/objects. This specific effect was also observed with P2 who required explicit training with six coins before the opposite responding generalized to seven, eight, nine, and ten coins/objects. A similar effect was observed with P3 after training with only three coins.

The experiment for each child may be considered in terms of two broad stages. The first stage consisted of establishing the basic relational repertoire, whereas the second stage was concerned with increasing the complexity and

flexibility of that repertoire. The results obtained across each of the children during the second stage were relatively consistent. For example, for each child contextual control by would/would-not and control by the two contingency reversals required limited amounts of training. Furthermore, generalization tests across all three children were highly consistent. The first stage of the experiment, however, may appear somewhat more disparate across participants than the latter stage. More specifically, a number of interventions were employed in response to the idiosyncratic relational deficits that emerged for each child. For example, P1 displayed considerable difficulty in training on the opposite relations among four coins in horizontal positions, whereas P2 and P3 did not. Nevertheless, the latter participants showed great difficulty in training on four coins in random positions, whereas P1 did not -- once responding to four coins in horizontal positions had been established.

In response to these and other individual differences across participants, two key training interventions were employed. First, all three children failed to complete training with four coins presented in random positions without first being trained on two and three coins in random positions. Second, all three participants were also exposed to an intervention that involved specifying the relation of sameness among the relevant stimuli participating in a frame of opposite. This intervention appeared to work for P1 and P2, but not for P3 (he eventually trained when three trials containing horizontal presentations were conducted before each block of eight trials containing random presentations). Although they may appear disparate, these two key interventions are consistent with RFT and with behavior analytic principles more generally (see final paragraph). Parenthetically, the functional separation of mutual and combinatorial entailment, indicated by the former intervention, has been reported in a number of previous studies with both children and adults (e.g., Healy, et al.,

2000; Lipkens, et al., 1993; Pilgrim & Galizio, 1990, 1995; Pilgrim, Chambers, & Galizio, 1995). The Lipkens, et al. study in particular demonstrated, not unlike the current study, that mutual entailment appears to develop before combinatorial entailment.

On a related issue, the current findings with regard to the use of the 'sameness' instruction provide some preliminary evidence that an existing relational frame may be useful for facilitating the emergence of new or novel relational patterns (see Hayes, et al, 2001). That is, the 'sameness' instruction appeared to facilitate opposite responding with P1 and P2. The possibility that different patterns of relational framing may overlap functionally presents an important empirical issue for researchers in this area, and the current findings constitute the first evidence that such overlap may in fact occur. Nevertheless, we remain cautious at this point because the 'sameness' intervention did not immediately facilitate opposite responding for both participants (and failed to work at all for P3). This is clearly an issue that requires systematic experimental analysis, not least because the applied implications of such work would likely be broad in scope.

The present study was clearly generated by RFT, but alternative interpretations of the current data are possible. For example, participants often chose multiple coins or objects in particular sequences, and thus one might interpret these performances in terms of sequence classes or order relations (see Green, Stromer, & Mackay, 1993). One problem in doing so, however, is that all three participants spontaneously reversed their response sequences during some of the test trials, and this pattern contradicts one of the key definitions of a sequence class or order relation (i.e., such relations are asymmetrical). In any case, even if one employs the language of sequence classes, the current data clearly extend the research in this area by demonstrating that such classes can come under complex forms of contextual control

(Many/Few and Would/Would-Not), and can be manipulated via contingency reversals. Furthermore, the directly trained sequence responses that define such classes can generalize to novel stimuli, even when those stimuli are greater in number than those presented during the initial sequence class training. At the very least, therefore, the RFT-based research presented here has helped to supplement and extend previous findings reported in the literature on stimulus classes.

In the previous study by Barnes-Holmes, et al, the researchers discussed the possibility of a natural learning explanation for the data given the use of "real words", but argued against this on the grounds that no improvement occurred during a phase on non-contingent reinforcement. Once again, in the current study, we chose to trade some degree of experimental precision in favor of ecological validity in the use of a natural language format. Although this type of research is still in its infancy, the current data suggest the utility of such a trade-off and the potential contribution of the training and testing procedures employed herein provide another important reason for the continuation of the current program of research.

REFERENCES

Barnes-Holmes, Y., Barnes-Holmes, D., Smeets, P. M., Strand, P., & Friman, P. (this volume). *Establishing relational responding in accordance with more-than and less-than as generalized operant behavior in young children.*

Barnes-Holmes, Y., Barnes-Holmes, D., Roche, B, & Smeets, P. M. (2001). Exemplar training and a derived transformation of function in accordance with symmetry. *The Psychological Record, 51,* 287-308.

Barnes-Holmes, Y., Barnes-Holmes, D., Roche, B., & Smeets, P. M. (2001, b). Exemplar training and a derived transformation of function in accordance with symmetry: II. *The Psychological Record, 51*, 589-604.

Boelens, H. (1994). A traditional account of stimulus equivalence. *The Psychological Record, 44,* 587-605.

Green, G., Stromer, R., & Mackay, H. A. (1993). Relational learning in stimulus sequences. *The Psychological Record, 43,* 599-616**.**

Hayes, S. C., Barnes-Holmes, D., & Roche, B (Eds.) (2001). *Relational frame theory: A post-Skinnerian account of human language and cognition.* New York: Plenum.

Hayes, S. C. & Wilson, K. G. (1996). Criticisms of relational frame theory: Implications for a behavior analytic account of derived stimulus relations. *The Psychological Record, 46,* 221-236.

Healy, O., Barnes-Holmes, D., & Smeets, P. M. (2000). Derived relational responding as generalized operant behavior. *Journal of the Experimental Analysis of Behavior, 74,* 207-227.

Horne, P. J. & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65,* 185-241.

Lipkens, R., Hayes, S. C., & Hayes, L. J. (1993). Longitudinal study of the

development of derived relations in an infant. *Journal of Experimental Child Psychology, 56,* 201-239.

Pilgrim, C., Chambers, L., & Galizio, M. (1995). Reversal of baseline relations and stimulus equivalence: II. Children. *Journal of the Experimental Analysis of Behavior, 63,* 239-254.

Pilgrim, C. & Galizio, M. (1990). Relations between baseline contingencies and equivalence probe performances. *Journal of the Experimental Analysis of Behavior, 54,* 213-224.

Pilgrim, C. & Galizio, M. (1995). Reversal of baseline relations and stimulus equivalence: I. Adults. *Journal of the Experimental Analysis of Behavior, 63,* 225-238.

Rehfeldt, R. A. & Hayes, L. J. (2000). The long-term retention of generalized equivalence classes. *The Psychological Record, 50*, 405-428.

Saunders, R. R., Wachter, J., & Spradlin, J. E. (1988). Establishing auditory stimulus control over an eight-member equivalence class via conditional discrimination procedures. *Journal of the Experimental Analysis of Behavior, 49*, 95-115.

FIGURE CAPTIONS

Figures 1, 2, and 3.

Percentage of relation-consistent responses for Participants 1, 2, and 3, respectively on tests of the relation of opposite. Participants' responses during training are not depicted. The numbers adjacent to data points indicate the number of coins/objects used during that test. Letters adjacent to data points indicate the type of stimulus presentation or condition in operation. Data points that are not accompanied by numbers or letters involve the stimulus presentation or condition indicated by the previously marked data point.

(H = horizontal presentation of coins/objects; W = would responding; R = random presentation of coins/objects; WN = would and would-not responding; G = generalization test; F/Up = follow-up).

TABLE 1

The Trial-types involved in Four-Coin Sequences

ABCD Relations								
MANY	A*	Op.	B	Op.	C*	Op.	D	
	A	Op.	B*	Op.	C	Op.	D*	MANY
FEW	A	Op.	B*	Op.	C	Op.	D*	
	A*	Op.	B	Op.	C*	Op.	D	FEW

* Indicates correct choice(s).

TABLE 2

The Trial-types involved in Five-Coin Sequences

ABCDE Relations										
MANY	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	
	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	MANY
FEW	A	Op.	B*	Op.	C	Op.	D*	Op.	E	
	A	Op.	B*	Op.	C	Op.	D*	Op.	E	FEW

* Indicates correct choice(s).

TABLE 3

The Trial-types involved in Six-Coin Sequences

ABCDEF Relations												
MANY	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	
	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	MANY
FEW	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	
	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	FEW

* Indicates correct choice(s).

TABLE 4

The Trial-types involved in Seven-Coin Sequences

ABCDEFG Relations														
MANY	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	Op.	G*	
	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	Op.	G*	MANY
FEW	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	Op.	G	
	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	Op.	G	FEW

* Indicates correct choices.

TABLE 5

The Trial-types involved in Eight-Coin Sequences

ABCDEFGH Relations																
MANY	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	Op.	G*	Op.	H	
	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	Op.	G	Op.	H*	MANY
FEW	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	Op.	G	Op.	H*	
	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	Op.	G*	Op.	H	FEW

* Indicates correct choices.

TABLE 6

The Trial-types involved in Nine-Coin Sequences

ABCDEFGHJ Relations																		
MANY	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	Op.	G*	Op.	H	Op.	J*	
	A*	Op.	B	Op.	C*	Op.	D	Op.	E*	Op.	F	Op.	G*	Op.	H	Op.	J*	MANY
FEW	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	Op.	G	Op.	H*	Op.	J	
	A	Op.	B*	Op.	C	Op.	D*	Op.	E	Op.	F*	Op.	G	Op.	H*	Op.	J	FEW

* Indicates correct choices.

TABLE 7

The Trial-types involved in Ten-Coin Sequences

ABCDEFGHJK Relations																			
MANY	A*	Op	B	Op	C*	Op	D	Op	E*	Op	F	Op	G*	Op	H	Op	J*	Op	K	
	A	Op	B*	Op	C	Op	D*	Op	E	Op	F*	Op	G	Op	H*	Op	J	Op	K*	MANY
FEW	A	Op	B*	Op	C	Op	D*	Op	E	Op	F*	Op	G	Op	H*	Op	J	Op	K*	
	A*	Op	B	Op	C*	Op	D	Op	E*	Op	F	Op	G*	Op	H	Op	J*	Op	K	FEW

* Indicates correct choices.

TABLE 8

Sequence of Training and Testing, Number of Training Trials, and Test Outcomes for Participant 1

Condition	Training/Test Exposures	Stimulus Session	Set	Training/Test Type	No. of Training Trials/ Test Outcomes
Baseline	1 Test	1	1	Would 4Hz	F
Intervention	Training	1	1	Would 4Hz	16*
	Training	2	1	Would 2Rm	20
	1 Test	2	2	Would 2Rm	P
	Training	2-3	2	Would 3Hz	40*
	Training	4	2	Would 2Rm	18
	1 Test	4	3	Would 2Rm	P
	Training	4	3	Would 3Hz	16*
	Training	5	3	Would 3Hz (Same)	17
	2 Tests	5-6	4	Would 3Hz; 3Rm	P;F
	Training	6	4	Would 3Rm	25
	2 Tests	7	5	Would 3Rm; 4Hz	P;F
	Training	8	5	Would 4Hz (Same)	13
	3 Tests	8-9	6	Would 4Hz; 4Rm; 5Hz	P;P;F
	Training	10	6	Would 5Hz	9
	6 Tests	10-12	7	Would 5Hz; 5Rm; 6Hz; 6Rm; 6 Would/Not; 6 Gen. (Cups)	P;P;P;P P;P
Follow-Up	1 Test	13	8	6 Would/Not	P
Reversal 1	Training		13	8 Would 4Hz	9
	8 Tests	13	9	Would 4Hz; 4Rm; 5Hz; 5Rm; 6Hz; 6Rm 6 Would/Not; 6 Gen. (Books)	P;P;P;P;P;P P;P
Reversal 2	Training		14	10 6 Would/Not	8
	2 Tests	14	11	7Rm Would/Not; 8 Gen. (Pencils)	P;P

P = Pass; F = Fail: Reading from left to right
* Indicates that the subject failed to reach the mastery criterion during training.
Hz = Coins presented in horizontal positions.
Rm= Coins presented in random positions.
Same= Intervention involved the use of the “sameness” relation.
Gen.= Generalization test.

TABLE 9

The Trial-types involved in Two-Coin AB Sequences

AB Relations				
MANY	A*	Op.	B	
	A	Op.	B*	MANY
FEW	A	Op.	B*	
	A*	Op.	B	FEW

* Indicates correct choices.

TABLE 10

The Trial-types involved in Two-Coin BC Sequences

BC Relations				
MANY	B*	Op.	C	
	B	Op.	C*	MANY
FEW	B*	Op.	C	
	B	Op.	C*	FEW

* Indicates correct choices.

TABLE 11

The Trial-types involved in Three-Coin Sequences

ABC Relations						
MANY	A*	Op.	B	Op.	C*	
	A*	Op.	B	Op.	C*	MANY
FEW	A	Op.	B*	Op.	C*	
	A	Op.	B*	Op.	C*	FEW

* Indicates correct choices.

TABLE 12

Sequence of Training and Testing, Number of Training Trials,

and Test Outcomes for Participant 2

Condition	Training/Test Exposures	Session	Stimulus Set	Training/Test Type	No. of Training Trials/ Test Outcomes
Baseline	6 Tests	1	1-3	Would 4Hz	FFFFFF
Intervention	Training	2	3	Would 4Hz	16
	1 Test	2	4	Would 4Hz	F
	Training	2-3	4	Would 4Hz	35
	2 Tests	3	5	Would 4Hz; 4Rm	P;F
	Training	4	5	Would 4Rm	16*
	Training	4-5	5	Would 4Rm (Same)	24*
	Training	6-7	5	Would 3Rm	72*
	Training	7	5	Would 2Rm	16
	1 Test	7	6	Would 2Rm	P
	Training	8-10	6	Would 3Rm	64*
	Training	11-13	6	Would 3Rm (Same)	115
	1 Test	13	7	Would 3Rm	F
	Training	14	7	Would 3Rm	8
	2 Tests	14	8	Would 3Rm; 4Rm	P;F
	Training	14-15	8	Would 4Rm	40
	2 Tests	15-16	9	Would 4Rm; 5Hz	P;F
	Training	16	9	Would 5Hz	15
	3 Tests	16-17	10	Would 5Hz; 5Rm; 6Hz	P;P;F
	Training	17-18	10	Would 6Hz	20
	4 Tests	18-19	11	Would 6Hz; 6Rm; 6 Would/Not; 6 Gen (Pencils)	P;P;P P
Reversal 1	Training		19	11 Would 4Hz	25
	1 Test	19	12	Would 4Hz	F
	Training		20	12 Would 4Hz	13
	3 Tests	20-21	13	Would 4Hz; 4Rm; 5Hz	P;P;F
	Training	22	13	Would 5Hz	8
	7 Tests	22-24	14	Would 5Hz; 5Rm; 6Hz; 6Rm 6 Would/Not; 6 Gen. (Spoons)	P;P;P;P FP;P
Reversal 2	Training		24	14 6 Would/Not	19
	5 Tests	24-25	15	6 Would/Not; 7Rm; 8 Gen. (Beads); 9 Gen. (Cups); 10 Gen. (Pasta)	P;P;P P;P

P = Pass; F = Fail: Reading from left to right
FP indicates that the subject failed the first exposure to a test, and passed the second exposure to the same test.
Hz = Coins presented in horizontal positions.
Rm = Coins presented in random positions.
Same = Intervention involved the use of the “sameness” relation.
Gen. = Generalization test.

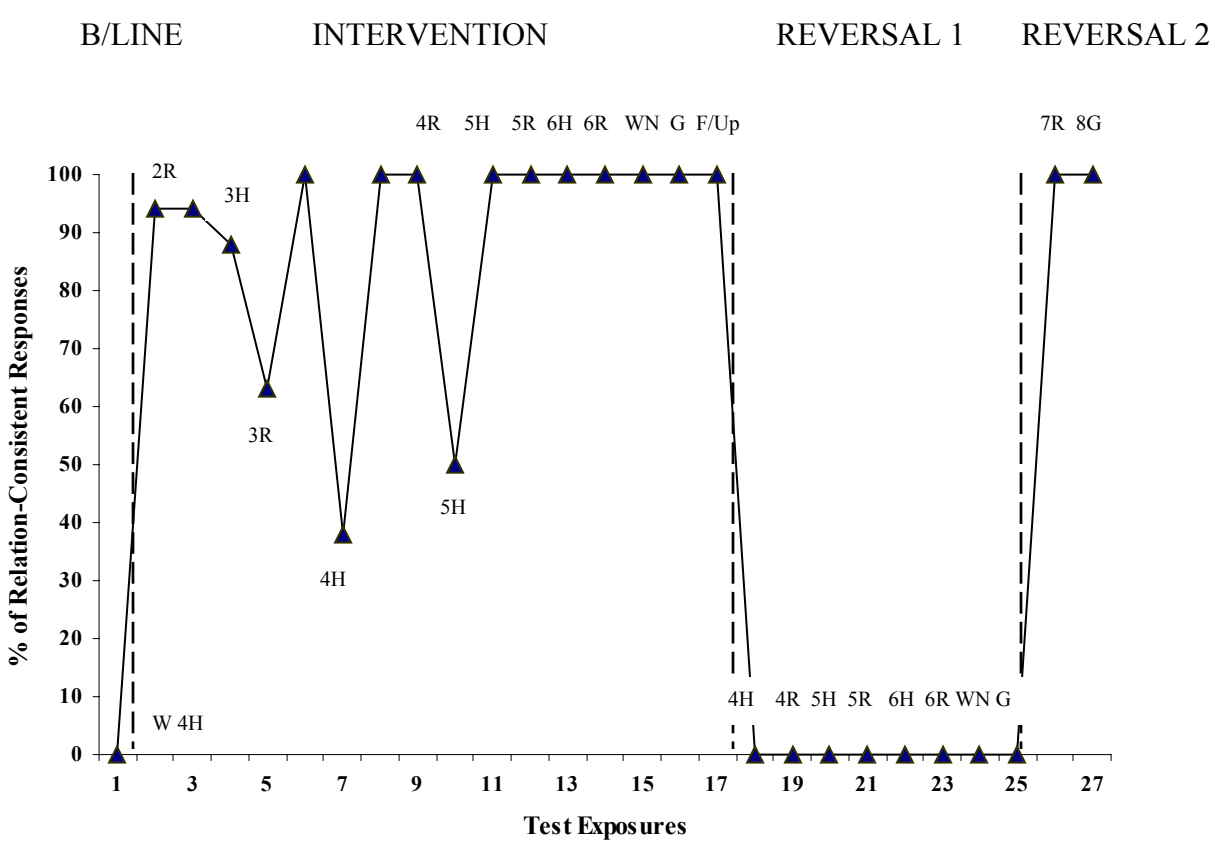
TABLE 13

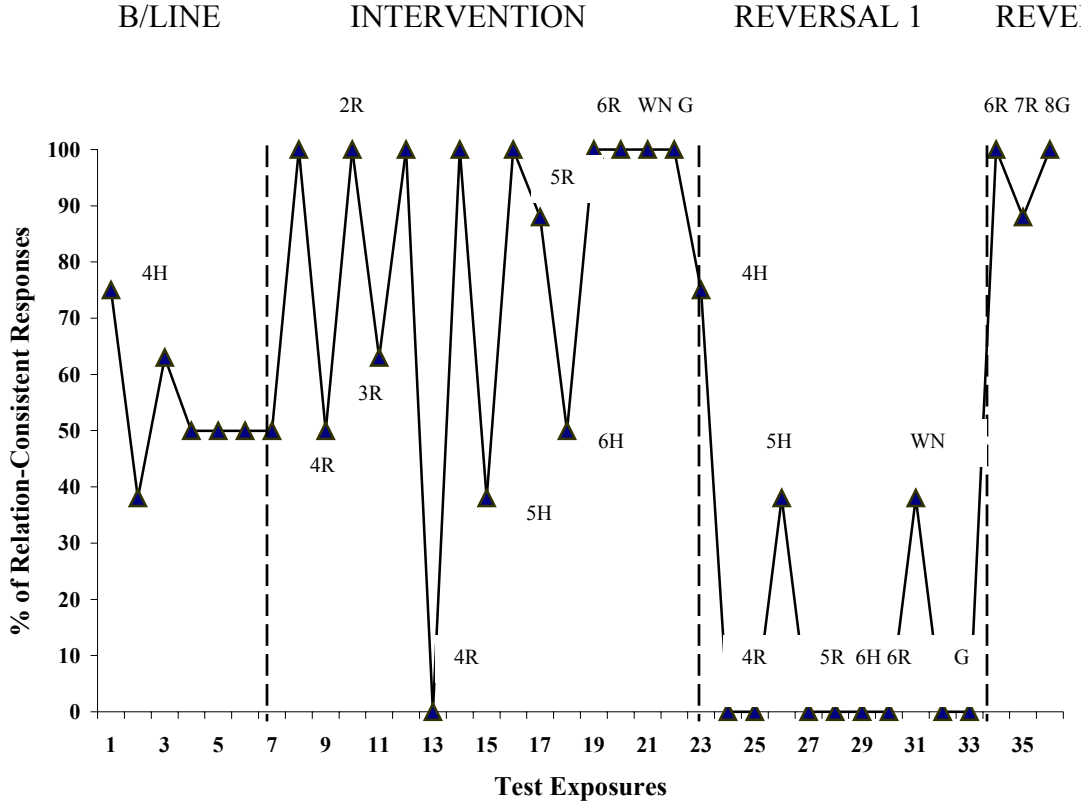
Sequence of Training and Testing, Number of Training Trials,

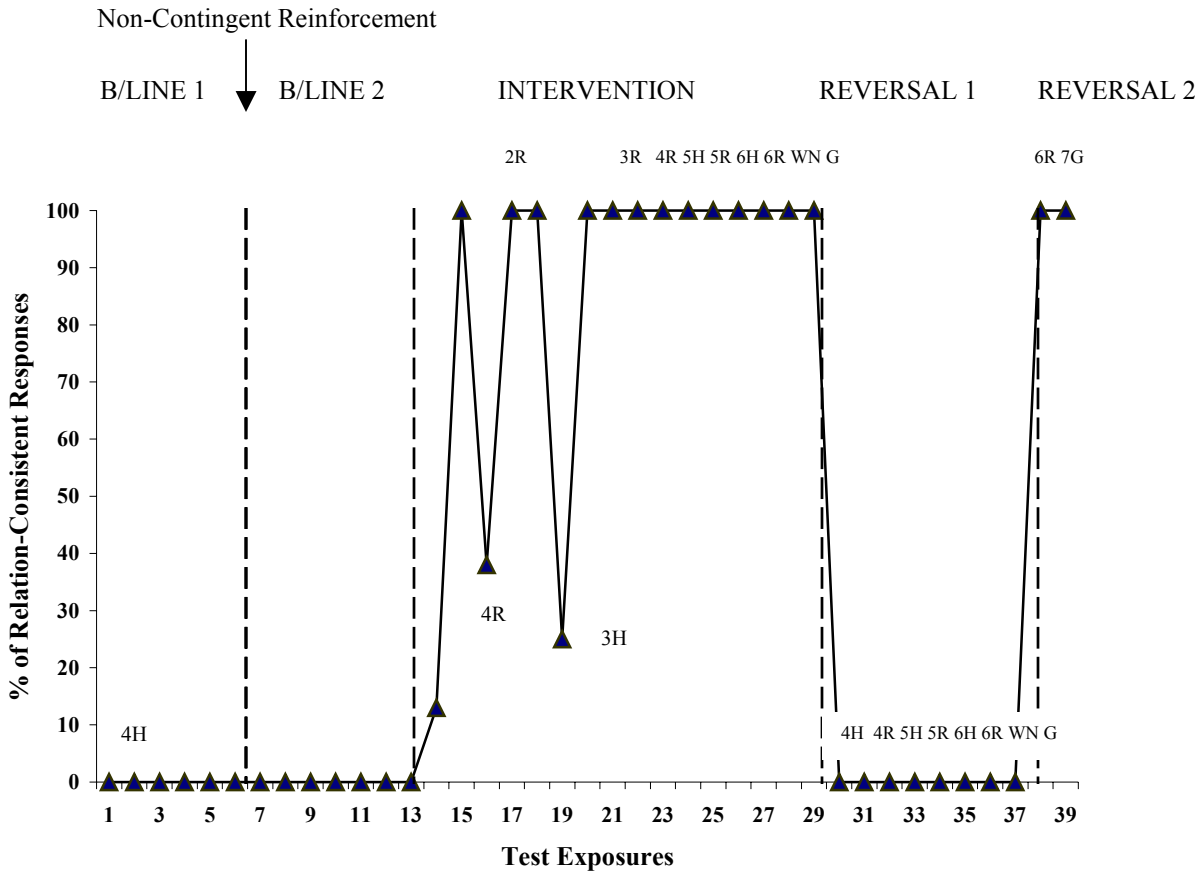
and Test Outcomes for Participant 3

Condition	Training/Test Exposures	Stimulus Session	Set	Training/Test Type	No. of Training Trials/ Test Outcomes
Baseline 1	6 Tests	1-3	1-3	Would 4Hz	FFFFFF
Non-Cont'g Reinforcement	Training	4-9	3	Would 4Hz	224*
Baseline 2	8 Tests	10-11	3-6	Would 4Hz	FFFFFFFF
Intervention	Training	12-13	6	Would 4Hz	20
	1 Test	13	7	Would 4Hz	F
	Training	14-16	7	Would 4Hz	48
	2 Tests	16-17	8	Would 4Hz; 4Rm	P;F
	Training	17-25	8	Would 4Rm	84*
	Training	26	8	Would 3Rm	16*
	Training	26	8	Would 2Rm	18
	1 Test	27	9	Would 2Rm	P
	Training	28	9	Would 3Rm	16*
	Training	29-31	9	Would 3Rm (Same)	42*
	Training	31	9	Would 2Rm	16
	1 Test	31	10	Would 2Rm	P
	Training	32	10	Would 3Hz	18
	1 Test	33	11	Would 3Hz	F
	Training	33	11	Would 3Hz	10
	1 Test	33	12	Would 3Hz	P
	Training	34-35	12	Would 3Rm	32*
	Training	36	12	Would 3Hz	8
	1 Test	36	13	Would 3Hz	P
	Training	36-39	13	Would 3Rm (3 Hz trials before each block)	76
	8 Tests	40-41	14-15	Would 3Rm; 4Rm; 5Hz; 5Rm; 6 Hz; 6Rm;	P;P;P;P;P;P
				6 Would/Not; 6 Gen. (Pencils)	P;P
Reversal 1	Training		41	15 Would 4Hz	17
	8 Tests	42	16	Would 4Hz; 4Rm; 5Hz; 5Rm; 6Hz; 6Rm	P;P;P;P;P;P
				6 Would/Not; 6 Gen. (Tapes)	P;P
Reversal 2	Training		42-43	16 6 Would/Not	20
	3 Tests	43	16-17	6 Would/Not; 7 Gen. (Spoons);	P;P
				8 Gen. (Cups)	P

P = Pass; F = Fail: Reading from left to right
* Indicates that the subject failed to reach the mastery criterion during training.
Hz = Coins presented in horizontal positions.
Rm = Coins presented in random positions.
Same = Intervention involved the use of the "sameness" relation.
Gen. = Generalization test.


B/LINE
INTERVENTION
REVERSAL 1
REVERSAL 2
4R 5H 5R 6H 6R WN G F/Up
7R 8G
2R
3H
3R
4H
5H
W 4H
4H 4R 5H 5R 6H 6R WN G
% of Relation-Consistent Responses
Test Exposures
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27


B/LINE
INTERVENTION
REVERSAL 1
REVERSAL 2
% of Relation-Consistent Responses
Test Exposures
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
4H
2R
4R
3R
4R
5R
5H
6H
6R WN G
4H
4R
5H
5R 6H 6R
WN
G
6R 7R 8G


Non-Contingent Reinforcement
B/LINE 1
B/LINE 2
INTERVENTION
REVERSAL 1
REVERSAL 2
2R
3R 4R 5H 5R 6H 6R WN G
6R 7G
4R
3H
4H
4H 4R 5H 5R 6H 6R WN G
% of Relation-Consistent Responses
Test Exposures
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39