Generalization of Relational Matching to Sample in Children: A Direct Replication

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The ability of preschool age children to perform generalized relational matching to sample tasks with and without an overt mediating stimulus was examined. This experiment was a direct replication of a study by Lowenkron (1984) and examined a behavioral model relevant to complex human behavior that he later came to call *joint control.* Children were trained to code two-dimensional stimuli with the help of a handheld mediating stimulus. They were later tested for generalization of relational matching to sample with and without the mediating stimulus. Results indicated high levels of generalized matching to sample with the mediating stimulus and lower levels without. Findings also indicated that generalization was somewhat stronger with symmetrical shapes than with asymmetrical. Results are discussed in terms of a radical behavioral interpretation of complex human behavior.

Key words: naturalistic teaching approaches (NTA), applied verbal behavior (AVB), natural environment training (NET), natural language paradigm (NLP), pivotal response training (PRT)

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Radical behaviorism has been concerned with the explanation of many levels of human behavior for over 50 years. Skinner authored book chapters entitled "Thinking" (1953, 1957) and "Private Events in a Natural Science" (1953) and a chapter titled "Thinking" (1953, 1957), as well as a section on private events, in the "Tact" chapter (Skinner, 1957) in which he explicitly dealt with complex human behavior and addressed this behavior as being evoked by environmental events and controlled by the consequences it produced. The *environment* in this context refers not only to external events or publicly accessible stimuli but also to other physical phenomena including those only observable by one individual. As Skinner explained, "When we say that behavior is a function of the environment, the term *environment* presumably means any event in the universe capable of affecting the organism. But part of the universe is enclosed within the organism's own skin" (Skinner, 1953, p. 257). According to this conceptualization, the term *behavior* includes activities of an organism that are both public as well as those that are private, or not directly accessible to others. Likewise the events that control behavior may be either public or private, but these private environmental events and private behavior need not be assigned any special status; rather they function in the same ways as public environmental events and public behavior (Skinner, 1953).

Events that are not observable by others have, however, caused some problems in a scientific account of human behavior. This need not be due to any unique qualities or functioning these events might have, but because the practices of science and especially experimentation typically rely heavily on observation of the phenomena in question (Skinner, 1987). The inability to observe covert behavior and stimuli may have directly limited behavioral experimentation in some areas of human functioning but may also have caused other indirect problems to the science of psychology. Cognitive psychologists seem to view these problems of observation not as limitations in terms of experimentation but as limitations in the scope of behavioral theory (Baars, 1988; Barsalou, 1992). To these psychologists, behaviorists' focus on overtly demonstrable phenomena has contributed to the so-called cognitive revolution by not addressing some of the most interesting aspects of human behavior (Barsalou; O'Donohue, Ferguson & Naugle, 2003). Although this may be the perceived view, behavioral theory can and does address complex and even covert human behavior (Skinner, 1953, 1957). Admittedly, experimentation in these important areas has been limited.

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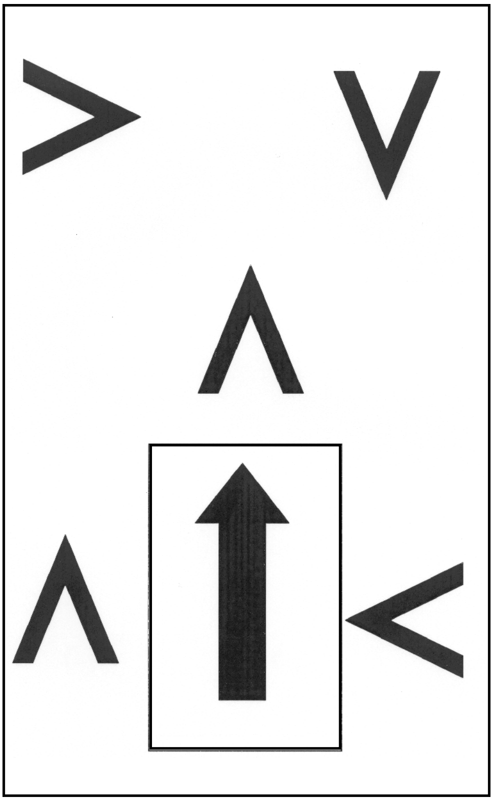


Fig. 1. Example training/probe stimuli with image of arrow card in position to code sample stimulus. Sample stimulus shown in middle of figure surrounded by comparison stimulus array.

Lowenkron (1984) conducted two experiments that sought to account for the development and generalization of complex discriminations through the use and manipulation of overt stimuli. The experiments examined the ability of 3.5- to 5.5-year-old children to perform relational matching to sample tasks with and without the help and mediation of observable coding responses. Through arranging a rather clever analog to this hypothetical process, Lowenkron examined whether selection of the correct comparison stimulus in a relational matching to sample task was dependent on the presence of two stimuli. The task for the participants in this experiment was to select a comparison stimulus that was rotated 90 degrees clockwise from a sample stimulus, given a sample in the middle of an array and four comparisons in various rotations surrounding the sample. Participants were taught to *code* the two-dimensional sample and comparison stimuli by lining up a card with an arrow on it in a particular orientation along the axis of symmetry (see Figure 1), to rotate the card and then to select the only stimulus that the then rotated card would line up with in the same manner. The *joint control* that was examined through this preparation was the *match* between the rotated arrow card (transformed coding stimulus) and the corresponding comparison stimulus. This experiment tested for generalization of comparison selections with new, untrained shapes, and for comparison selection with and without the availability of the arrow card (and thus the coding stimulus produced by the card). Primary findings of this experiment were that a high degree of correct comparison selection was made with both trained and untrained shapes when stable coding responses and stimuli were present (higher with trained shapes) and significantly fewer correct responses were made when coding was not available. Another finding Lowenkron reported was that participants made more correct selections with new, untrained shapes that were symmetrical than with those that were asymmetrical.

Lowenkron's (1984) study was an important step in a behavioral account of complex human behavior but unfortunately has not made a great impact on the psychological community. Although both his findings and the theoretical model that the experiment was based on were interesting, they were difficult to make use of. While his written descriptions were clear enough, the graphical displays were both complicated and unusual enough that they were difficult to evaluate for the purpose of determining experimental control. As a potentially important field of study, more research and dissemination should be done in the area of joint control. Thus, the purposes of the current research were to provide independent replication of the phenomena described by Lowenkron as well as to further disseminate the joint control model. The current research replicated the procedures of Experiment 1 of Lowenkron's study, procedures which were developed to examine whether joint control is necessary to evoke correct selection responses in a relational matching to sample task and whether this stimulus control arrangement produces stronger generalization. The original study as well as this replication sought to answer this question by arranging and studying non-covert, analog forms of joint control.

Table 1
Materials, stimuli and targeted participant tasks by experiment phase.

	Materials and Stimuli Available	Participant Task
Pretraining: Sample Coding Training	Handheld arrow card available. Verbal cue, "Where does it go?" Sample S shown on computer screen, visual cues on screen used to indicate arrow card placement. Cues then faded.	Coded sample stimuli by placing arrow card in specific position relative to axis of symmetry (symmetrical shapes only) of shape.
Pre-training: Comparison Coding Training	Handheld arrow card available. Comparison stimuli shown on computer screen. Single comparison shown at first. Additional distracter comparisons added after mastery with each number of comparisons. Verbal cue, "Where is it?"	Ss taught to code the stimulus that corresponded to the arrow card when the arrow card was given in a particular orientation.
Pre-training: Orientation Rotation Training	Handheld arrow card available. Verbal cue, "How do you turn it?" Rotation cues shown on computer screen at 90, 180, 270 and 360 degree position plus rotation cues on arrow cards.	Trained Ss to rotate arrow card 90 degrees clockwise from position at beginning of trial.
Pre-training: Final Training	All verbal cues faded systematically. Comparisons first displayed after sample was coded, then comparisons and samples displayed at same time. Handheld arrow card available.	Ss trained to code sample in the presence of sample plus comparisons, rotate arrow card then select corresponding comparison. 12 trials.
Probe: Training Set Baseline	Training set shapes shown on computer screen. Each screen included sample in the middle plus comparisons in each corner. Handheld arrow card available.	Ss Tested for coding sample in the presence of sample plus comparisons, rotating arrow card, then selecting corresponding comparison. Twelve trials.
Probe: Transfer Set 1	Computer screens with training set shapes, including samples plus comparisons; interspersed with similar screens containing new shapes. Handheld arrow card available.	The task was the same as in Training Set Baseline, above, except consisted of 24 trials instead of 12.
Probe: Coding Response Prevention	Same arrangement as Transfer Set 1 except handheld arrow card NOT available.	The task was similar to that in Training Set Baseline, above, except that the arrow card was NOT available.
Probe: Transfer Set 2	Computer screens with training set shapes, interspersed with similar screens containing second set of new shapes. Handheld arrow card available.	The task was the same as in Training Set Baseline, above.

Method

Participants, Apparatus, and Location

Four children between the ages of 3.11 and 5.0 participated in this study. Requirements for participation included being between the ages of 3.6 and 5.5 years, no known cognitive disability and communication in English as the primary language. Sessions for all children were conducted in extra rooms in their preschools. In all sessions, the child was seated in front of a laptop computer that was placed on a small classroom table. The experimenter was seated next to the child and an assistant was seated behind or to the side of the child to collect data. For sessions in which interobserver data were collected, an additional assistant was present and also seated behind the child.

Stimuli were displayed on the screen of the laptop computer (Acer TravelMate 521 TE with a 14“ TFT color screen). Participants used a 7.6 cm x 12.7 cm index card with a black arrow printed on it and a 2.5 cm wooden cube attached as a handle to code both sample and comparison stimuli. Seven different printed and laminated token boards with values ranging from 12 to 18 (M=15) were used to hold accumulated tokens. Data were collected on customized data sheets. A digital countdown timer was used to indicate the end of each reward break period.

Design and Procedures

Research design. A test-retest multiple-treatment reversal design was used. Experimental phases included four pre-training phases in which participants were taught all of the component responses necessary for the experimental phases. These were followed by four probe phases: training set baseline, transfer set 1, coding response prevention and transfer set 2. Each phase is described in more detail below. See Table 1 for a comparison of stimuli available during each phase as well as tasks to be accomplished during each phase. The primary dependent variable in the experimental phases was percentage of correct comparison selection responses. Independent variables included the shapes displayed (training set, transfer sets 1 and 2) and the availability of the sample coding operandum.

General procedures. Throughout each training and testing phase, correct responses were followed by delivery of a token onto one of a set of variable ratio (VR) 15 token boards and a brief praise statement such as “Good!” or “That’s it!” Incorrect responses during training were followed by the experimenter saying “No,” a 5 s time out and computer screen blackout and repetition of the trial. Incorrect responses during tests were followed by the above correction procedure for training set shapes and omission of the token and praise statement for transfer-set shapes. Each time a token board was filled, the participant exchanged the accumulated tokens for two and a half minutes of access to small toys or edibles, chosen from a portable toy box provided by the experimenter and containing a variety of toys and candy.

Pre-training: Sample-coding training. Children were shown two-dimensional shapes (samples) in the center of a computer screen and taught to “code” the sample’s orientation by placing an index card with an arrow on it in the appropriate orientation relative to the sample shape (see Figure 1). Following the cue, “Where does it go?,” children were prompted to place the handheld arrow card on top of an arrow cue on the computer screen. Following each four consecutive correct card placements, one in each 90-degree rotation, the arrow placement cues displayed on screen were faded through a series of six steps of successively smaller cues. The above training and fading steps were followed for each shape of the training set. The shapes were then displayed with a mastery criterion of two consecutive correct placements of the arrow card (*coding* of the sample) with each shape in each rotation. The shapes were then displayed in interspersed order with a criterion of 16 consecutive correct placements, one with each shape, in each rotation. The next training step was to add comparison shapes to the samples, one after each four consecutive correct card placements. Following any incorrect placements, the experimenter said, “No,” blacked out the computer screen and repeated the trial. Mastery criterion for sample coding training was four consecutive correct trials with each shape in each rotation and with all four comparison shapes displayed.

Pre-training: Comparison-coding training. Following sample coding training, participants were then taught to code the comparison shapes (two-dimensional stimuli similar to the sample shapes but rotated 0, 90, 180, and 270 degrees and displayed in the four corners of the computer screen rather than in the center of the screen as were the sample stimuli). The first step of comparison coding training involved the display of one comparison stimulus per screen. The arrow card was handed to the participant in the position in which it would correspond to the available stimulus. The experimenter then asked, "Where does it go?" and prompted placement of the arrow card with the comparison stimulus. Following four consecutive correct trials, one to a shape in each corner, the next set of shapes from the training set was taught, followed by the third then the fourth shapes.

The next step added a second stimulus to another corner of the screen and required that the participant select the correct comparison based on the position of the arrow card as it was handed to them. Attempts by the participants to rotate the card were followed by "No," five seconds of blackout, and a return of the card to its initial rotation while it was still in the S's hand. Other incorrect responses were followed by "No" and five seconds of blackout. After eight consecutive correct responses with each shape and with two comparisons displayed on the screen, a third comparison shape was added and similar procedures were followed using similar mastery criteria. Similar steps were again followed to increase to four shapes displayed. Following mastery with all four stimuli displayed on the screen, the verbal cue was faded using a progressive time delay procedure. The final training criterion for this phase was eight consecutive correct trials, two with each shape, with all four comparisons displayed and no verbal cues.

Pre-training: Orientation rotation training. Participants were taught to rotate the handheld arrow card with a small black tab in one corner when it was placed on a computer screen with marker lines at each 90 degree rotation point. Experimenters cued participants to look at the marks on the card and demonstrated rotation of the card. At the beginning of each trial, experimenters asked, "How do you turn it?" After every four consecutive correct trials, the tabs displayed on the cards and rotation marks displayed on the screen were faded out until participants could rotate the arrow in the correct direction and for only 90 degrees. The rotation marks were faded over four steps and the tabs on the cards were faded over seven steps. Incorrect responses were followed by pointing out the tabs and lines and demonstrating correct rotation. Gestural prompts were paired with verbal prompts to direct children's attention to the tabs and lines and to their function. Experimenters did not say "No."

After this training with the cards, each shape was projected alone in the center of the screen and participants were taught to code the sample orientation (paired with the cue, "Where does it go?") and to rotate their arrow cards (paired with the cue, "How do you turn it?"). Incorrect responses were followed by "No," plus a 5 s screen blackout. Verbal cues were faded using progressive time delay until 16 correct responses without verbal cues occurred.

Pre-training: Final training. A final training phase was employed in order to teach participants to complete the previous separately taught responses together and in order. In the first step, the sample was displayed alone on the screen. After correct sample coding, the comparisons were immediately added and the cue "Where is it?" was given.

Selection of the correct comparison was then reinforced as above. Errors resulted in a 5 sec. blackout and a "No". Changes in the orientation of the card after a correct rotation were manually prevented by the experimenter, a "No" was given and the trial was allowed to continue. After six successive correct trials, comparisons were then added immediately after the correct sample coding but before the arrow card rotation. After six more correct successive trials, comparisons were then displayed at the same time as the sample. The cue "Where is it?" was given at the same time that the comparisons were added. Training then continued until an additional 12 successive correct trials occurred without the verbal cue. Following an error, two successive correct trials were required in the previous phase, with prompts used as necessary.

Training set baseline (Probe phase). In the first experimental phase, children were asked to code the sample, rotate the card 90 degrees clockwise and select the appropriate comparison shape (i.e., the one whose orientation then matched the orientation of the card they held in their hand) using the set of training set shapes (see Figure 2). All shapes in the training set were symmetrical.

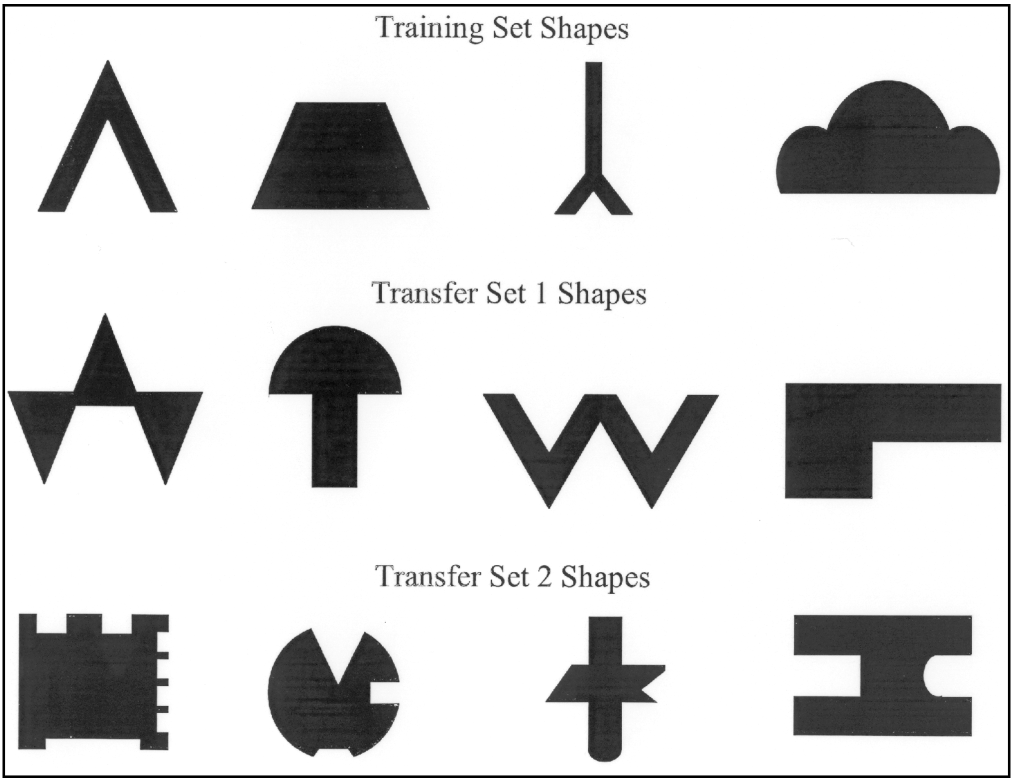


Fig. 2. Training Set, Transfer Set 1 and Transfer Set 2 shapes.

Transfer Set 1: Test for generalization (Probe phase). In this phase participants were shown sets of two-dimensional stimuli composed of shapes from the training set and Transfer Set 1 shapes and asked to code the samples and comparisons in the same manner as in the training set baseline phase. This phase tested for generalization of the previously trained responses in the absence of specific training with the second set of shapes. The Transfer Set 1 test for generalization was a 48-trial probe that included 24 trials using the training set stimuli and 24 trials with the Transfer Set 1 stimuli. This same 48-trial probe was used in the next phase, coding response prevention. Of the four shapes in Transfer Set 1, three were symmetrical and one asymmetrical.

Coding response prevention (Probe phase). This phase involved administering the 48-trial test for generalization (see above) without allowing children access to the arrow card, hence preventing coding responses (any attempts to code stimuli using hands or fingers were blocked).

Transfer Set 2: Test for generalization (Probe phase). This phase was similar to the Transfer Set 1 test described above, however with a new set of shapes. Three of these shapes were asymmetrical and one was symmetrical while the opposite was true for Transfer Set 1 shapes. Children who scored less than 90% correct in the Transfer Set 2 test for generalization were retrained to code both sample and comparison shapes with Transfer Set 2 shapes and following all of the steps described for the training set. Following this retraining, the Transfer Set 2 test for generalization was re-administered.

Interobserver agreement. Interobserver agreement (IOA) was assessed in over 50% of combined training and probe sessions on the final stimulus selection response (selection of comparisons). IOA was calculated by dividing agreements by agreements plus disagreements and multiplying by 100. IOA ranged from 98 to 100% and averaged over 99%.

Results

The percentage of correct comparison selection responses for individual participants is

Table 2
Means and ranges of correct selection % for all participants across each experimental probe phase, by shape set and shape symmetry.

	Mean % correct	Range	Training Set Shapes	Transfer Set Shapes	Symmetrical Shapes	Asymmetrical Shapes
Training Set Baseline	84.4	66–100	82.4	N/A	82.4	N/A
Transfer Set 1	82.1	56–95	95.7	68.3	86.1	53.4
Coding Response Prevention	40.8	25–58	43.5	41.7	43.4	36.6
Transfer Set 2	88.2	64–98	98.8	69.1	93.8	67.5

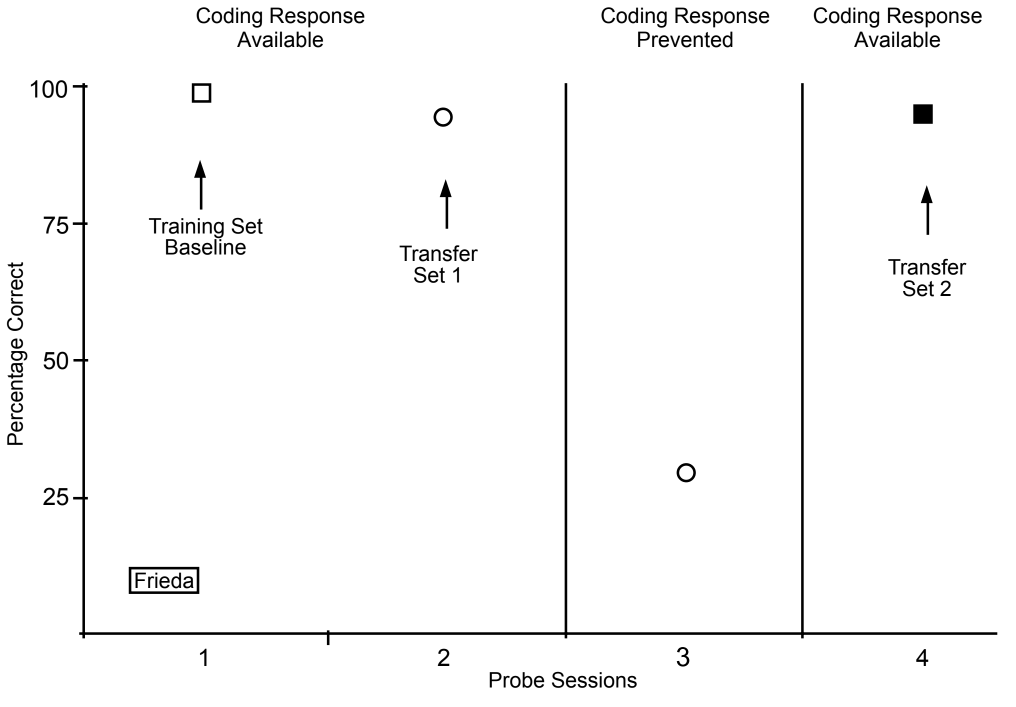
depicted in Figures 3 through 6. A summary of the results across all participants is shown in Table 2. As can be seen in Figures 3 through 6, as well as in Table 2, all participants performed substantially better in all phases in which the coding response was available than they did in the phase in which it was not. As shown in Table 2, performance averaged between 82% and 88% correct responses for the three phases in which coding responses were available, while the average correct selection percentage when coding responses were prevented was 40.8%.

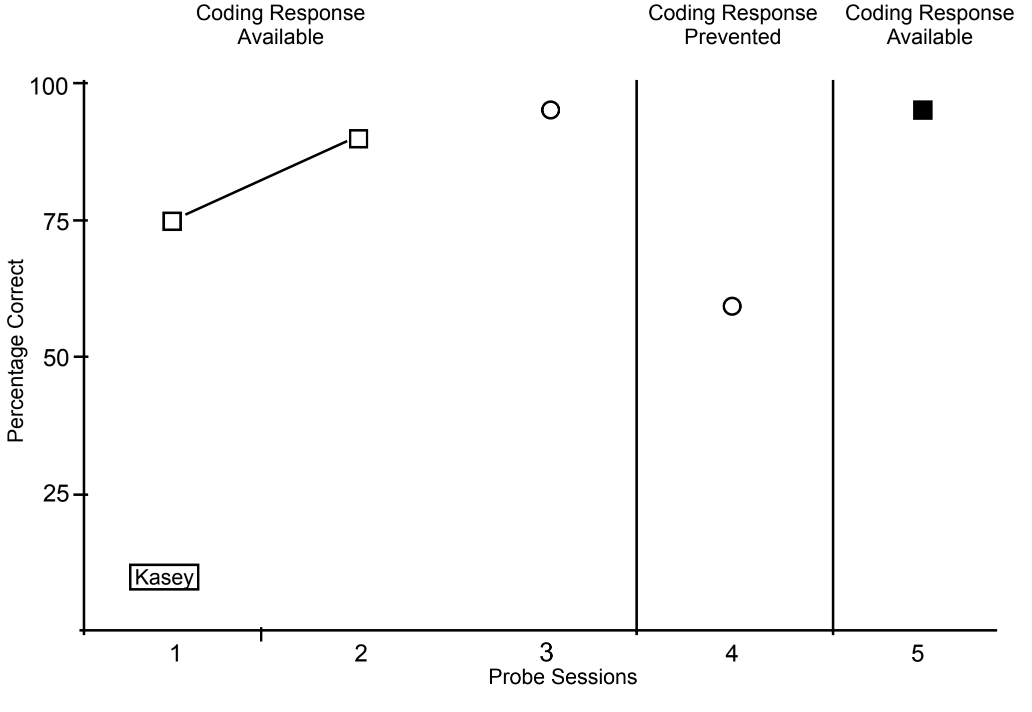
One child (Frieda) met the training set baseline criterion of 92% in her first exposure to the training set probe, with 100% correct selections. The other three children required two to four sessions to reach this criterion. Generalization to the first new set of shapes (Transfer Set 1) was typically quite strong, although with one exception; Sheila only made correct comparison selections with the first transfer-set shapes 56% of the time. Average generalization to the second set of transfer shapes was higher than with the first set across the group of four participants. All participants scored higher on the second set of transfer-set shapes than on the first, except Kasey, who scored 95% correct on both generalization probes. The performance of two participants (Nina and Sheila) did not meet the 90% criterion for Transfer Set 2. Both of these participants were retrained to code the transfer-set shapes following all of the coding training steps used with the training set shapes prior to the training-set baseline probe. The Transfer Set 2 generalization probe was re-administered following this re-training. Following re-training, Nina's performance on the Transfer Set 2 generalization probe increased from 83% to 98% while Sheila's performance decreased from 71% to 56%.

Table 2 depicts performance within each experimental condition by shape set or shape feature (symmetry). When performance is separated by shape sets it may be seen that overall performance was better with training set shapes than with transfer-set shapes. Likewise, performance was generally better with symmetrical than with asymmetrical shapes. Additionally, performance generally improved over time. That is, in the case of the training set shapes, a set of stimuli to which the participants were exposed a number of times, with the exception of the coding response prevention condition, overall performance improved each time those shapes were encountered. Similar patterns may be seen when shapes are grouped by symmetry or asymmetry.

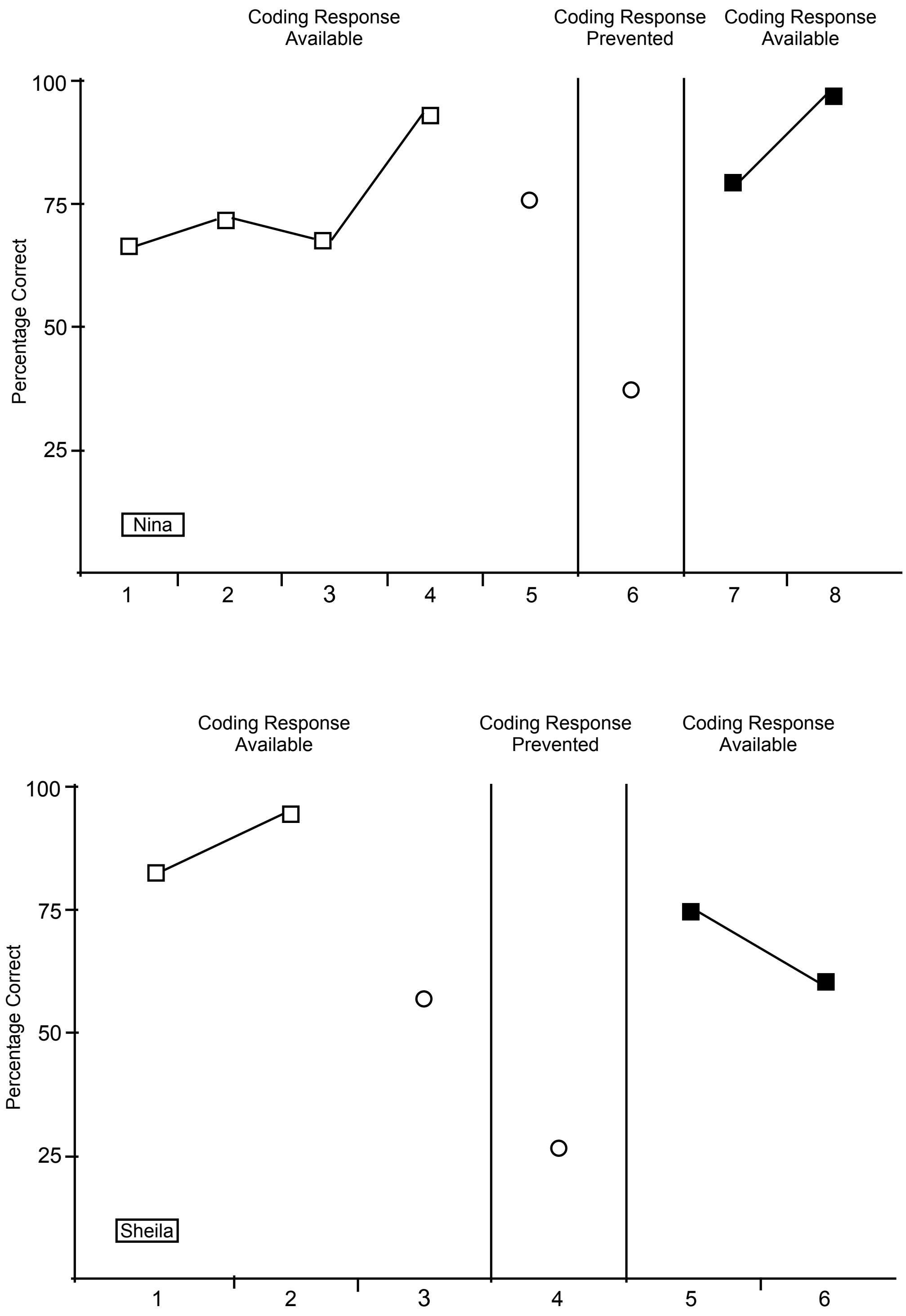
DISCUSSION

The current study examined the generalization of relational matching to sample in preschool-age children. Perhaps the most noteworthy of the current findings was that generalization of relational matching to sample was de-





Figs. 3 (top) and 4 (bottom). Percentage of correct comparison selection responses for each participant across each experimental probe phase. (Continued in Figs. 5 and 6).



Figs. 5 (top) and 6 (bottom).

pendent on the availability of supplementary stimulation produced by coding responses to the sample and comparison stimuli. This finding replicated the primary finding of Lowenkron (1984). This dependence of effective generalized relational matching to sample performance on the presence of the stimulation produced by the coding response was seen most clearly in the difference in performance between the phases when sample coding was present and during the coding response prevention phase when it was not.

Not only did performance suffer with all participants without the coding response, when it was prevented, alternate forms of coding appeared. Lowenkron (1984) made similar observations. In the current study, when the arrow card was not available (coding response prevention condition) one child tried to line her thumb up with the sample stimulus and then rotate her hand. When she was prevented from doing that, she attempted to look at the sample stimulus and then turn her head, ostensibly to find the corresponding comparison. When prevented from doing that she claimed that the task was too hard without the coding response because she had to "turn the shape in her head." It seems quite plausible that as overt forms of "coding" are prevented, discouraged, or punished, increasingly covert forms of similarly functioning behavior might emerge. The same possibility was suggested by Skinner (1953). A benefit of conducting research such as this with preschool-age children is that they generally do not seem to have effective repertoires of this type of covert behavior and thus the prevention of the overt form of response (removal of the arrow card) was sufficient to effectively limit their ability to perform the matching task.

Results of the current study also showed that high levels of generalization occurred across two sets of novel stimuli and that as indicated above, while correct comparison selection was dependent on stable sample coding, stable and criterion-level sample coding of novel symmetrical and asymmetrical shapes emerged without training for two of the four participants (Frieda and Kasey). This secondary finding is not completely consistent with that of Lowenkron (1984), who observed that stable sample coding of novel stimuli was dependent on the symmetry of the stimuli. This discrepancy may be an artifact of participant variables such as the ages of the children, the youngest of whom in the current study were slightly older than in that of Lowenkron (current: 3.11 to 5.0 years old; Lowenkron: 3.5 to 5.5 years old). Indeed, in the current study, it was the two youngest children (Nina and Sheila) who performed the poorest on both tests of generalization.

Evidence for joint control of selection responses, as described above may be seen when correct selections occur in the presence of two relevant stimuli and do not occur when one stimulus is absent. In the context of the current experiment, the relational matching to sample task might be thought of as consisting of a small number of linked discrete trials, or a behavior chain. The final contingency in the chain for all probe phases was *given the available stimuli, choose the correct comparison stimulus from an array of four and receive a token*. The *available stimuli* consisted of only the comparison stimuli (coding response prevention) or the comparison stimuli plus the rotated arrow card (all other phases). Described like this, it may be seen that the two stimuli act together to cause a conditional discrimination. Since there is presumably a reinforcement history associated with selection of each of the comparison shapes, that is, selection of each shape has been reinforced at some time, more stimulation is needed in order to make a correct selection at a *particular* time, hence the need for a *conditional* discrimination. In the current experiment what is required for a correct selection is the array of comparison stimuli plus the rotated arrow card that only "matches" one stimulus in the array.

The current study involved some potential limitations that should be considered in evaluating the results as well as in designing similar research in the future. The research design consisted of a type of a test-retest design that involved administering probes that were preceded by and sometimes separated by periods of training. The results of each probe session were graphed as one data point consisting of the results of either 24 (training set baseline) or 48 trials (all other phases). A design that included continuous observations (both training and probe data) might have shown a more complete picture as it would have included changes in performance between probes. Additionally, more than one probe in each phase might have provided better information with which to assess experimental control.

Another limitation of the current study was that all participants were female. This may or may not have been relevant but could be controlled for in future studies. Possibly of more concern was the age range of participants. While the current study followed the age range specified by Lowenkron (1984), participants' ages varied from 3.11 to 5.0 years old. While one year, one month may not seem like a large discrepancy, a 3.11-year-old is 78% as old as a 5-year-old, which may be a relatively large difference. Future research may address this by examining participant pools with a smaller range of ages.

The area of joint control seems to show promise for a behavioral analysis of complex human behavior. Future research in this area might address similar phenomena in adults rather than children. Another area that may follow from this research might be the examination of a shift from overt mediation of matching to sample to covert mediation as overt behavior is extinguished or punished. An evaluation of this process would lend more credibility to the model proposed by Skinner (1953). Finding tasks that require an overt coding or mediation response for adults or even for older children may be difficult but compared to the benefits of understanding and explaining complex human behavior will likely prove worthwhile.

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