*EFFECTIVENESS AND PERSISTENCE OF PRECURRENT
MEDIATING BEHAVIOR IN DELAYED
MATCHING TO SAMPLE AND
ODDITY MATCHING WITH
CHILDREN*

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Two kinds of mediating behavior were compared with respect to their effectiveness in variable-delay matching-to-sample and oddity-matching tasks. Each of four 5-year-old children was trained to emit either differential or common mediating responses. The differential mediating response consisted of pressing a specific computer key corresponding to either of two possible sample stimuli (a red or a green square). The common mediating response consisted of pressing one of the two response keys regardless of the sample. The differential-response subjects did not show the typical, delay-related decrease in matching-to-sample performance that characterized the behavior of common-response subjects. An oddity-matching task was then introduced, and subjects were instructed to use the mediating keys however they preferred, including not at all. Differential-response subjects continued to respond on the originally trained mediating keys in response to sample presentation and later reversed their choice responding, thus accommodating the oddity-matching requirements. Common-response subjects continued to emit the previously trained mediating response and experienced limited success in oddity matching. Results were interpreted in terms of stimulus control, instructional control, and experimental history.

Key words: matching to sample, mediating behavior, precurrent behavior, stimulus control, instructional control, key press, children

Memory can be analyzed in terms of overt behavior and its relationship with controlling environmental stimuli. The controlling variables include both the reinforcing consequences of behavior and the stimuli that come to set the occasion for responding. As antecedent stimuli come to control behavior, the extent to which a previously acquired response will be performed at a later time ("remembering") depends upon the maintenance of the originally established stimulus control. Alternatively, failure of a response to occur (i.e., "forgetting") may be characterized as a loss of stimulus control.

From this perspective, memory has been studied in animals using delayed matching-to-sample procedures (e.g., Blough, 1959; D'Amato & O'Neill, 1971; Ferster, 1960;

Tranberg & Rilling, 1980). In typical delayed matching to sample, a sample stimulus is presented for a brief period. A brief delay interval follows the stimulus presentation; then comparison stimuli are presented, and the subject must respond to the correct comparison stimulus (i.e., the stimulus that matches the original sample stimulus). This task is considered a short-term memory task in the behavioral literature because the organism must remember the sample stimulus for a short period of time (Carter & Werner, 1978). Typically, matching accuracy decreases with increasing delay intervals. Blough (1959), however, observed that pigeons maintained accurate matching performance at long delay intervals by emitting sample-specific, stereotypical responses during the delay interval. Blough postulated that each sample-specific behavior pattern represented a separate response chain that maintained control, by the sample stimulus, of subsequent responding.

If mediating behavior improves subsequent matching performance, the behavior is termed *precurrent*. Skinner (1968) defined precurrent behavior as any response made by the organism that increases the effectiveness of some subsequent behavior (the current operant) in obtaining a reinforcer. Thus, the differential

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mediating behavior observed by Blough (1959) could be described as precurrent because it facilitated subsequent, accurate matching behavior over long delay intervals.

The assumed ability of the human to engage in covert mediating responses complicates studies of precurrent mediation of responding. A direct way to study precurrent processes is to examine the function of external, measurable, mediating behavior. Parsons, Taylor, and Joyce (1981) successfully accomplished this task in assessing the effectiveness of three discrete kinds of overt mediating behavior on subsequent matching-to-sample performance in children. Their study used five stimulus lights arranged in a Greek cross pattern. Children were presented with either a bright or dim light on a center key and were required to press the sample (i.e., to make an attending response). This press initiated a delay interval during which subjects emitted a previously trained mediating response on the keys above and below the sample key. Children in the differential-response group were instructed to press the top key if the sample stimulus was bright and to press the bottom key if the sample was dim. Children in the common-response group were required to press the top key regardless of the sample stimulus. Subjects in the nondifferential-response group were trained to press either the top or the bottom key regardless of the sample. The first previously trained mediating response following the delay interval was reinforced by presentation of the comparison stimuli on keys to the left and right of the sample key. The length of the delay interval was varied, with the result that repeated key presses ensured the most rapid presentation of the comparison stimuli. Children in the differential-response group matched accurately at delay intervals up to 10 s. Common- and nondifferential-response groups matched accurately with short delays but only at chance levels with delays of 10 s.

According to Skinner (1968), precurrent behavior may require explicit training but, once established, its maintenance depends on its effect in aiding performance of the current operant (e.g., matching performance). Based on this, Parsons et al. (1981) predicted that the differential response would persist in the absence of its comparison-producing requirement; the enhancing effect of this response on subsequent matching would result in its main-

tenance. Because they do not aid matching behavior, the common and nondifferential responses should not persist in the absence of an experimentally programmed requirement for their occurrence.

The present study employed a delayed matching-to-sample task using delay intervals similar to those used by Parsons et al. (1981) to study the behavior of kindergarten children. No mediating response was required in the baseline phase. Subjects were then trained to perform one of two distinct mediating responses during the delay interval, corresponding to the differential and common groups of the Parsons et al. study. The nondifferential response was not used in the present study because Parsons et al. obtained results nearly identical to common-response results with the nondifferential response. An appropriate mediating response during the last 0.5 s of the scheduled delay interval was required to produce the comparison stimuli. Matching accuracy correlated with each mediating response was assessed at each delay interval.

In the final condition, subjects were informed that choosing the nonmatching stimulus was correct (oddity matching) and that any mediating response, including nonresponding, was acceptable in accomplishing this end. This tested whether the effective, or precurrent, mediating behavior (the differential response) would persist and be adapted to the new oddity-matching circumstances, and whether the ineffective mediating behavior (the common response) would disappear. Behavior could adapt to the new condition in two ways: (a) responding could continue on the originally trained mediating key for any sample stimulus, with the choice of the comparison stimulus changing to accommodate the oddity condition, or (b) responding could be interchanged between the two mediating keys for the sample stimuli, with the relationship between mediating key and comparison stimulus remaining in correspondence with previous training.

METHOD

Subjects

Four student volunteers (all 5 years old), attending the same kindergarten class of a local elementary school, served as subjects. Parental consent was obtained for each subject. The age requirement ensured that subjects were com-

parable to those studied by Parsons et al. (1981). Although gender was not a relevant variable, one individual of each gender participated in each experimental condition. All subjects met the inclusion criteria of near-average reading performance (number and letter recognition) and normal or corrected-to-normal vision. When colors were projected on a screen, all subjects were able to name each color correctly, within 3 s of presentation.

Apparatus and General Features of the Task

The study was conducted outside of school hours in the first author's house, which was conveniently located with respect to the subjects' homes. Subjects were tested in a room (3.5 m by 4.5 m) containing two chairs, a desk (for the experimental apparatus), and a set of bookshelves. To prevent distraction the bookshelves were placed behind the subject during testing.

An IBM PC® microcomputer generated all stimuli and presented them on an IBM PC® color display monitor. The monitor screen measured 32 cm diagonally. The program allowed the presentation of square (4 cm by 4 cm) sample, comparison, and mediating stimuli.

The computer initiated a trial by presenting a sample stimulus (red or green) in the center of the monitor. The sample was presented until the subject pressed a black key in the center of the computer keypad; this "attending response" resulted in darkening of the sample stimulus, thus beginning a delay interval.

The delay interval varied randomly among five values, which were 1.0 s, 3.0 s, 5.0 s, 10.0 s, and 15.0 s. During the delay interval, the computer presented single digits in the center of the screen at a rate of approximately one per second. Subjects were instructed to read these digits aloud; this prevented covert rehearsal. During baseline and oddity-matching phases of the experiment these digits were presented alone. During phases requiring a specific mediating response, single white squares appeared above and below the digits. Mediating responses were performed by pressing white keys above and below the attending response key, corresponding to the white squares on the screen.

During baseline and oddity-matching phases, termination of the delay interval automatically resulted in darkening of all delay-

interval stimuli and presentation of the comparison stimuli. During phases requiring a mediating response, the comparison stimuli appeared only if the correct mediating response occurred during the last 0.5 s of the delay interval. If the correct response did not occur, the delay-interval stimuli darkened for 1.0 s and a new sample stimulus was presented. The precise response required depended upon the particular condition (see Procedure).

At the end of the delay interval, the computer presented red and green comparison stimuli to the right and left of the original sample's central position. The side on which each color was presented was varied randomly over trials. During matching-to-sample phases, a correct response was defined as a press on a blue key to the left or right of the attending response key, whichever corresponded to the position of the comparison stimulus that matched the original sample stimulus. Such a response resulted in a brief (3.0 s) computer-generated tune. The tune did not follow incorrect selections. For the oddity-matching condition, a correct response was defined as a press on the key corresponding to the nonsample stimulus. Matching to the sample stimulus resulted in the brief silent interval. Following the termination of the musical presentation (in the case of correct responses) or a corresponding period of silence (in the case of incorrect responses), a new trial began.

Testing was performed in daily 40-trial sessions. On each trial the computer recorded the presence or absence of appropriate mediating behavior (in phases requiring such a response) and scored the selections of comparison stimuli as either correct or incorrect. At the end of each session subjects were allowed to choose one consumable item (e.g., a candy) for participating.

Procedure

Design. The number and types of phases experienced by each subject varied because of constraints on subject availability. During the first (baseline) phase, all subjects were exposed to the delayed matching-to-sample task without any mediating responses having been trained. In the second phase subjects were required to perform either a differential or a common mediating response during the delay interval. Two subjects were exposed to each

mediating response condition. In the third phase all subjects were switched to an oddity-matching task. Following the completion of the oddity-matching phase, one common-response subject (Subject 1) and one differential-response subject (Subject 2) were unable to continue with the experiment due to family vacations. The remaining differential subject (Subject 3) was switched to baseline (mediating-response prevention) and then back to oddity matching to obtain a within-subject replication of the oddity-matching effects. The remaining common-response subject (Subject 4) experienced four additional phases. These phases consisted of (a) differential response, (b) reversal to baseline (mediating-response prevention), (c) differential response, and (d) oddity-matching response. These phases allowed a within-subject reversal and replication of the effects of a differential mediating response as well as an additional look at the oddity-matching performance. Subjects 1, 2, and 3 received five sessions in each phase. Subject 4 received five sessions in each of the first three phases and three sessions in each of the subsequent four phases.

Rehearsal prevention. Before the first experimental session subjects were instructed in the correct performance of the rehearsal-prevention task. Subjects read each digit aloud as it was presented on the screen. This task was attempted reliably by each subject in the study, although occasional mistakes were made.

Baseline. Subjects were tested individually in each phase of the experiment. On the first day of the study the experimenter read the following set of instructions and modeled the delayed matching-to-sample task.

In a moment you will be presented with a lighted square. The square will be either red or green. It is your job to remember the color of the square. When you have looked at the squares for a few seconds press the black button (DEMONSTRATE). As you can see, a list of numbers will now come on to the screen. I want you to say each number as it is presented (DEMONSTRATE). After awhile, two colored squares will appear on the screen. One square will be green, the other square will be red. Your job is to press the blue key on the keyboard that is on the same side as the square you were supposed to remember (DEMONSTRATE). Are there any questions?

The demonstration was carried out with

three practice examples. Under baseline conditions subjects did not perform a mediating response during the delay interval. Baseline continued until the function relating the percentage of correct matching responses to each delay interval was stable, as assessed by visual inspection. This criterion for switching phases was used throughout the study. Following baseline, subjects performed one of two mediating responses that generated comparison stimuli.

Differential mediating response. One member of each gender was exposed to each of the two mediating-response conditions. Subjects in the differential-response condition pressed the top key on the keypad if the stimulus was red and the bottom key if the stimulus was green. A correct mediating response during the last 0.5 s of the programmed delay interval generated comparison stimuli. Incorrect mediating responses, or response absence, resulted in darkening of all stimuli and presentation of a new sample stimulus. The following instructions were read to subjects:

We are now going to try something a bit different. Now, while you are reading the numbers on the screen, you will have to press one of these buttons (POINT). Pressing these buttons will make the two colored squares appear. If you do not press the buttons, the squares will not appear. When the square you are trying to remember is red, you must press the top button; when it is green you must press the bottom button. Just like before, it will sometimes take a long time before the squares appear (DEMONSTRATE). Are there any questions?

Common mediating response. Subjects in the common-response condition pressed the top key regardless of the sample stimulus color. A correct mediating response during the last 0.5 s of the programmed delay interval generated comparison stimuli. This constraint was imposed for both common and differential responses to maintain high rates of precurrent responding throughout the delay interval. Incorrect responses, as in the differential condition, resulted in darkening of all keys and the presentation of a new sample stimulus. Instructions were identical to those given differential-response subjects, except that the child was instructed to press the top button "no matter whether the square is red or green."

Oddity matching. In the oddity-matching condition subjects were informed that the task

now involved choosing the nonsample stimulus and that any mediating behavior, including not responding, was acceptable. The computer generated comparison stimuli at the termination of the delay interval regardless of the subject's delay-interval behavior. The following instructions began this phase:

We are now going to try something a bit different. Now, instead of choosing the square that is the same as the one you see first, you must choose the one that is different from the one you see first (DEMONSTRATE). You can press either or both of the white keys to help you to choose the correct square, or you can choose not to press any keys at all to help you choose the correct square. Are there any questions?

Mediating-response prevention. In this reversal phase subjects were given the following instructions:

We are now going to try something a bit different. I want you to do the same thing as you were doing yesterday (either oddity matching or matching to sample) except that you are not to press the white keys while you are waiting for the red and green square to appear. Are there any questions?

As in the original baseline the computer presented the comparison stimuli noncontingently following the termination of the delay interval. The instructions were completely successful in eliminating presses on the white keys.

RESULTS

The dependent measures were the proportion of correct matching responses and mediating responses per session. In each figure the connected points represent the proportion of correct matching responses read from the ordinate of the graph; the numbers accompanying each point represent the proportion of correct mediating responses. Because mediating-response performance was usually high and often 100%, these data will not be described in detail for each subject.

Figure 1 shows the proportion of correct responses for Subjects 1 and 2, summed over all trials in a given phase, plotted at each delay interval. Inspection of the baseline data for both subjects reveals that the proportion of correct matching responses decreased from very high levels to near-chance levels with increas-

ing delay intervals (Panel 1). For Subject 1, institution of the common response had no effect on this trend (Panel 2). For Subject 2, institution of the differential response completely removed delay-related deficits (Panel 2). Switching both subjects to an oddity-matching task resulted in no appreciable change in overall matching performance from the previous phase (Panel 3).

Under oddity-matching conditions the common mediating response persisted in Subject 1 and the differential mediating response persisted in Subject 2. The common-response subject responded almost exclusively on the top mediating key (as originally trained). On rare occasions (twice in the first session and twice in the second session of this phase), however, this subject made several consecutive responses on the bottom mediating key. In every trial of each session, with the exception of Session 13, the differential-response subject responded in the originally trained manner; that is, when the sample was red the subject pressed the top key; when the sample was green the subject pressed the bottom key. In Session 13 the subject responded on the nontrained key on three consecutive trials. The last of these trials resulted in an incorrect selection of the comparison stimulus.

Figure 2 illustrates the proportion of correct responses for Subject 3 at each delay interval. The baseline data obtained for this subject are very similar to the baseline data of Subjects 1 and 2 (Panel 1), in that correct matching proportions decreased rapidly with increasing delay intervals. Institution of the differential mediating response again resulted in near-perfect matching (Panel 2). This performance was maintained over the subsequent oddity-matching phase (Panel 3), as was observed in Subject 2. Performance decreased markedly to baseline proportions when mediating behavior was eliminated (Panel 4). A return to the oddity-matching conditions and removal of the response restriction resulted in a return to near-ceiling performance (Panel 5).

In the initial oddity-matching phase, Subject 3 responded exclusively in the originally trained differential manner in allocating his mediating responses. In the final three sessions, however, the subject responded on the originally trained keys until the comparison stimuli were presented, then pressed the nontrained mediating key once, and then made the comparison se-

SUBJECT 1

SUBJECT 2

Fig. 1. Proportion of correct responses for Subject 1 and Subject 2, summed over all trials of a given delay interval in each experimental phase. (The designation preceding the slash indicates the experimental task for that phase; the designation following the slash indicates the instructed mediating response for that phase.) The numbers accompanying each data point designate the proportion of trials in which mediating responses occurred. Numbers do not accompany baseline data points because mediating responses were not operative in this phase. In response optional phases, the proportion represents the mediating response that had been instructed in the previous phase. In response prevention phases, the proportion represents all key presses.

SUBJECT 3

Fig. 2. Proportion of correct responses for Subject 3, summed over all trials of a given delay interval in each experimental phase. (The designation preceding the slash indicates the experimental task for that phase; the designation following the slash indicates the instructed mediating response for that phase.) The numbers accompanying each data point designate the proportion of trials in which mediating responses occurred. Numbers do not accompany baseline data points because mediating responses were not operative in this phase. In response optional phases, the proportion represents the mediating response that had been instructed in the previous phase. In response prevention phases, the proportion represents all key presses.

lection. In the second oddity-matching phase, this latter response never occurred and the originally trained mediational response was employed exclusively.

Figure 3 illustrates the proportion of correct responses for Subject 4 at each delay interval. The baseline data demonstrate the typical delay-related decline in matching performance (Panel 1). The common mediating response showed no evidence of increasing the proportion of correct matches (Panel 2); in fact, the proportions appear slightly lower than during the baseline. Performance during the first oddity-matching phase continued to be affected by delay (Panel 3). Returning to the matching-to-sample task in the fourth phase, establishment of the differential mediating response eliminated the delay effect (Panel 4). Response prevention in the fifth phase completely eliminated the enhanced response level and restored the delay-related decrease in matching performance (Panel 5). The results obtained from reinstituting the differential response in the sixth phase closely resemble the results obtained from its introduction in the fourth phase; that is, there was no evidence of a delay-related performance decrement (Panel 6). In the final phase, a return to oddity-matching conditions yielded continued high proportions of correct responding (Panel 7). During both oddity-matching phases, Subject 4 continued to use the mediating response required in the previous phase (i.e., the common response in Phase 3 and the differential response in Phase 7).

DISCUSSION

The results of the present study replicate and extend the results reported by Parsons et al. (1981). First, only the differential response maintained matching accuracy over increasing delay intervals. This reflected the maintenance of stimulus control that had been achieved by this mediating response. Moreover, this positive differential response outcome was replicated within a subject (Subject 4) in the present study.

Contrary to the suggestion of Parsons et al. (1981), the common response, although ineffective in promoting correct responses and not resulting in production of comparison stimuli, persisted for the duration of the subsequent

oddy match. The common response not only persisted during the oddity match, but it persisted in its original form (i.e., pressing the top key). Pressing the bottom key regardless of sample color also qualifies as a common response. Subject 1 pressed the bottom key, but only occasionally. Presumably, if two equally ineffective response alternatives are available, the one with the most favorable reinforcement history will occur primarily. The fact that the common response did not simply disappear may reflect the previous reinforcement of responding on the top key. Reinforcement occurred at least 50% of the time even if the subjects were performing at near-chance levels. This result may be discussed as a type of superstitious behavior in that the reinforcer maintaining the response was not contingent on emission of the response (cf. Skinner, 1948). Similarly, because of its long history of producing comparison stimuli, common-response maintenance may have resulted from the adventitious relation between the precurrent response and onset of the comparison stimuli.

There are other possible explanations for maintenance of the common mediating response during oddity matching. The oddity-matching instructions invited use of alternative mediating responses or, indeed, none at all. However, Subjects 1 and 4, who were exposed to the common-response mediating condition, did not have an experimental history of alternative mediating responses. Further, these subjects were not provided with specific instructions regarding alternative mediating responses, except for nonresponding. Thus, they persisted in the mediational responses in which they were originally instructed.

Subjects whose prior experience had included only the common response did not spontaneously generate the differential response, even though it would have been to their advantage to do so. Anecdotal evidence was provided by Subject 4 in the third session of the common-response phase. After only a few trials, the subject embarked on an unbroken series of 21 correct responses, apparently mediated by the common response. In response to questioning, the subject indicated that he was visually fixating on a point slightly to the left of the delay-interval numbers when the sample was green and fixating directly on the numbers when the sample was red. After requesting the

SUBJECT 4

Fig. 3. Proportion of correct responses for Subject 4, summed over all trials of a given delay interval in each experimental phase. (The designation preceding the slash indicates the experimental task for that phase; the designation following the slash indicates the instructed mediating response for that phase.) The numbers accompanying each data point designate the proportion of trials in which mediating responses occurred. Numbers do not accompany baseline data points because mediating responses were not operative in this phase. In response optional phases, the proportion represents the mediating response that had been instructed in the previous phase. In response prevention phases, the proportion represents all key presses.

subject to use only the keys to aid his performance, the session was repeated. However, this subject did not use a differential response on the mediating keys in the subsequent oddity-matching phase. There are many examples in the literature of generalization not occurring across settings or across similar responses. The fact that this differential response did not generalize to the computer keys supports the argument for actively programming generalization (Kirby & Holborn, 1986; Stokes & Baer, 1977).

Subjects whose training had included only the differential response used this response in subsequent oddity-matching phases and maintained nearly perfect performance. All subjects adapted to the oddity-matching condition by changing the choice of the comparison stimulus rather than the choice of the mediating key. This shift in the choice of the comparison stimulus, rather than in the choice of mediating response, may simply have been a factor of instructional control. The oddity-matching instructions specified a change in the target current behavior rather than in the precurrent mediating behavior. The issue is equivocal, however, as to whether the structure of the instructions or the past history with instructions is the critical variable, because instructions specifying current behavior by no means preclude changes in precurrent behavior. The behavior activated by the instruction presumably depends on past history with instruction-following and on experience with the contingencies to which the instructions apply. If, in a subject's past experience with the contingencies changes in mediating behavior had been required to perform instructed current behavior, the mediating behavior would presumably change. In the present study, the differential mediating response is learned within the experimental situation without prior experience and is potentially appropriate for choosing either comparison stimulus; thus, it is not surprising that the mediating response remains unchanged.

Additionally, in a child's learning history it is more likely that instructions will be applied to the child's current than to precurrent operants. Parents, immensely powerful in shaping the child's behavior, typically apply instructions to a child's current operants rather than to precurrent behavior that facilitates these operants. As a result of this prior learning,

instructions specifying choice of a response would more likely control the actual choice behavior rather than the mediating behavior that facilitates the choice. This seems to have occurred in the present study. Thus, the behavior change occurred when the comparison key was about to be chosen, rather than in the form of a mediating response. A subsequent study employing instructions specifying precurrent rather than current behavior would be valuable in determining the importance of this feature of instructional control. In addition, an uninstructed oddity match might affect the precurrent operant differently than the present procedure did.

Other evidence suggests that contingency control may have exerted an effect on the mediating behavior. In a few instances Subjects 2 and 4 reversed their responding on the mediating keys with respect to the sample stimulus. Many of these instances resulted in the emission of an incorrect response and a prompt return to the originally trained mediating strategy.

Subject 3 produced an unexpected variation on the differential response in the first oddity-matching phase. This consisted of responding on the originally trained response key, then pressing the opposite mediating key before selecting the comparison stimulus. By adding this intermediate step, the subject was able to preserve the originally trained components of the response chain. He performed the originally trained mediating behavior in response to the sample stimulus and preserved the original correspondence between the mediating key on which he made his final response and the choice of the comparison stimulus.

In conclusion, maintenance of a particular precurrent response will often depend on the extent to which it enhances performance of the current operant. In some cases, however, a nonprecurent response may be maintained in the presence of a current response even though the level of reinforcement is not enhanced. This may be due to the prior reinforcement correlated with this behavior or to its experimental history, especially of control by instructions. Finally, the effect of instructions on precurrent and current responses presumably depends on the behavioral specifics of the instructions, the individual's past history with instructions, and the individual's experience with the contingencies to which the instructions relate. In the

present study, the instructions specified current behavior, the subjects' past histories with instructions likely were related to current, rather than to precurrent, responses, and the mediating responses were novel. Thus, instructions exerted their effects at the level of the current operant.

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