

Guiding Visual Attention During Acquisition of Matching-to-Sample

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Abstract

Matching-to-sample skills are involved in language acquisition and the development of basic reading and counting abilities. The rapid, even errorless, induction of matching performances in young children and individuals with mental retardation was demonstrated here through the structuring of a visual array so as to promote detection of the relevant stimulus. Implications for theory and application are discussed.

A central question for psychological researchers, cognitive and behavioral, concerns how an individual first comes to “notice” differences between stimuli in a visual array. Historically, behavioral researchers have focused on factors that affect the “orienting responses” (Spence, 1940) or observing behaviors (Dinsmoor, 1985; Wyckoff, 1952) of participants in discrimination-learning experiments. This general problem is related to the difficulty of predicting the first occurrence of stimulus control in a situation requiring visual discrimination (Ray & Sidman, 1970; Skinner, 1957). As Ray and Sidman noted, the stimulus control of behavior cannot be generated by “the *potential* availability of reinforcement . . . Other factors generate the control, reinforcement maintains it” (p. 193). Contemporary cognitive and perceptual researchers have shown that certain characteristics of a visual array and the stimuli contained therein can guide attention to particular locations or objects in the display (e.g., Carlin, Soraci, Dennis, Strawbridge, & Chechile, 2002; Mack & Rock, 1998; Wolfe, Cave, & Franzel, 1989; Yantis, 1996). This work suggests a solution to the problem of generating the “first instances” of stimulus

control. For example, if a visual array is designed to direct attention to the critical stimulus (i.e., the target), then that stimulus is likely to be the one to which a response (e.g., touching) is directed. The difficulty of directing attention initially to the relevant stimulus in a visual array is at the heart of many instructional problems encountered with young children and individuals with mental retardation. Thus, the integration of these two domains of research, cognitive and behavioral, may provide us with knowledge relevant to designing more efficient training procedures for these populations.

Despite the wealth of research on visual search by individuals with and those without mental retardation, few investigators have used current knowledge about the variables that influence visual search to develop methods to *facilitate* search (cf. Serna & Carlin, 2001; Soraci, Carlin, & Wiltse, 1998). Recently, Carlin et al. (2002), utilizing a guided-search methodology, showed that individuals with mental retardation can limit visual search to elements of a visual array most likely to be the target (i.e., those that share the predefined target’s color), while inhibiting attention

to elements unlikely to be the target (i.e., those of other colors). These results indicate that individuals with mental retardation can demonstrate important visual selective attention skills when arrays are structured appropriately. More importantly, these results show that basic properties of visual arrays can be manipulated systematically to enhance visual search efficiency.

Another series of studies (e.g., Soraci et al., 1987, 1991) demonstrated rapid production of oddity performance via application of perceptually based interventions. Oddity tasks require the participant to choose the "different" stimulus from an array in which the distractors (incorrect stimuli) are multiple identical copies of a stimulus. Children with mental ages (MAs) below 5 years, both typically developing and those having mental retardation, experience difficulty with this task (e.g., Ellis & Sloan, 1959; Greenfield, 1985), especially on reversal trials on which a target that was correct on a previous trial becomes a distractor on a subsequent trial.

One method that produced oddity performance with individuals who have low MAs involved increasing the number of identical distractors in the choice array from two to eight (see Figure 1). The rationale for this manipulation was based on previous research with human beings (e.g., Treisman & Gormican, 1988) and pigeons (e.g., Zentall, Hogan, Edwards, & Hearst, 1980). This research demonstrated that given sufficient target-distractor disparity, the visual search for and observing of the target is dramatically facilitated when the target is presented among a large number of identical distractors. (For overviews of this and related research see Duncan and Humphreys, 1989; Eckstein, Thomas, Palmer, and Shimozaki, 2000, and Pashler, 1987). A naturalistic example would be searching for a red shirt in a field of blue shirts; the red target is found immediately and easily (as compared with search for a red shirt surrounded by shirts of many different colors). Thus, our manipulation of increasing the number

of identical stimuli in the array from two to eight was designed to provide an enhanced surround to facilitate detection of the odd target. Young children at risk for mental retardation who previously had failed a three-element oddity task demonstrated rapid acquisition of oddity performance after this intervention was introduced. Further, all of the children continued to respond on the basis of oddity when the standard three-element array was re-presented and when novel stimuli were introduced.

Having facilitated the performance of oddity via manipulations designed to enhance the search for and observation of the target stimulus, our next objective was to use these types of interventions to facilitate the acquisition of matching-to-sample performances. Rapidly establishing a repertoire of matching is of considerable importance for both practical and theoretical reasons (Dube & Serna, 1998). Matching tasks are used extensively in instructional procedures (e.g., Stomer, Mackay, & Stoddard, 1992), for assessment (e.g., Dunn & Dunn, 1981; Leiter, 1979), for language acquisition (Markman, 1988; Wilkinson & McIlvane, 1997), and to examine generalized same-different learning (McIlvane, 1992; Soraci, Carlin, & Chechile, 1998). With some individuals, brief training using differential reinforcement may suffice to establish identity matching. However, for many others, repeated sessions may be necessary (e.g., Dube & Serna, 1998; Pilgrim, Jackson, & Galizio, 2000). For this reason, it remains important to investigate procedures that may establish matching performances rapidly. In the present experiment we examine a method with the potential to do that. In addition, the method is based on a novel linkage between perceptual, cognitive, and behavioral research.

The identity-matching task used in the present study requires conditional discrimination because the particular comparison stimulus that matches the sample on some trials is incorrect on others (cf. Dube & Serna, 1998). Thus, the matching task may be said to involve judgments of the *similarity* of the sample and the correct comparison. In contrast, the oddity task shown in Figure 1 demands selection based only on *differences* among the stimuli displayed concurrently (i.e., the target is defined on each trial only with respect to a set of distractors). Although these descriptions imply differing requirements of the two tasks, the similarity of the procedural arrangements should be noted. In particular, consider that each match-

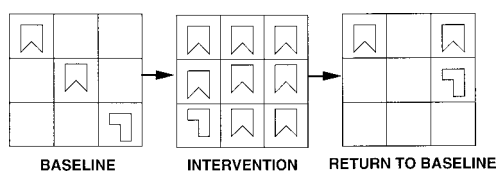


Figure 1. Examples of the three-element oddity task used during baseline, the nine-element intervention task, and the return to baseline.

ing-to-sample trial involves a simultaneous discrimination among the comparison stimuli that are presented. This same type of discrimination is required on a trial of the oddity task. This commonality suggested to us that it may be possible to facilitate the acquisition of visual matching to sample by using the same method (i.e., increasing the number of stimuli in the choice array that match one another) discussed earlier with respect to the oddity task (Soraci, Carlin, & Wiltse, 1998).

Toward this objective, we used a novel methodology for teaching two-choice identity matching, which is the same perceptually based manipulation known to enhance detection of an odd stimulus. We employed nine-element arrays on the initial training trials to “guide” observing behavior to the comparison stimulus that was correct (i.e., the one identical to the sample), thus increasing the likelihood that the correct stimulus would be selected and the selection reinforced. Note that the sample may play no role in determining comparison selection in the initial training trials. The second component of the training procedure involved gradual reduction in the number of comparison stimuli across trials. This was done to reduce the guiding function of the perceptual manipulation and to allow the discriminations among the comparisons to come under control of the sample stimuli. The aim was to establish two-choice matching-to-sample performance.

Method

Participants

Twenty-eight children (16 males, 12 females) who failed a test of two-choice identity matching-to-sample participated. The 12 children with mental retardation (6 males, 6 females) were recruited from local schools that serve individuals with mental retardation. Their chronological ages (CAs) ranged from 11.5 to 20.1 years ($M = 14.8$, $SD = 2.54$), and their average mental age (MA), as assessed using the Peabody Picture Vocabulary Test-Revised (PPVT-R), was 5.52 years ($SD = 2.42$). The 16 children without mental retardation (10 males, 6 females) were recruited from local day care centers and preschools. Their CAs ranged from 3.17 years to 4.92 years ($M = 4.14$ years, $SD = .65$). The average MA of these children matched the average MA of the children with mental retardation (PPVT-R, $M = 5.20$ years, $SD = 1.38$).

Apparatus

We used a Macintosh PowerPC 4400/200 computer fitted with a MicroTouch GoldStar touch-sensitive screen (MicroTouch Systems Inc.[®]) to control session events and record responses automatically.

Stimuli

Forms. The stimuli were five white geometric forms: (a) a circle with a radius of 1.6 cm; (b) a square with sides of 3.25 cm; (c) a triangle with base of 3 cm and sides of 3.3 cm; (d) a hexagon with a height of 3.2 cm, a width of 3.2 cm, and sides of 1.6 cm; and (e) a rectangle with dimensions of 1.25 cm \times 3.5 cm.

Visual array. The forms displayed as comparison stimuli were presented within an invisible 3 \times 3 grid that measured 13 cm \times 13 cm. The nine cells of this grid were black to maximize contrast with the white forms. The sample stimulus was centered above this comparison array.

Procedure

General procedure. Sessions were conducted in a quiet room at the participant's school. The participant sat facing the computer that was placed on a low table at eye level and arm's length. The experimenter sat beside the participant who could not observe the experimenter and the apparatus simultaneously. Minimal verbal instructions were given at the start of each session. At the beginning of the initial session, the experimenter explained the touch screen function and told the participant that he or she was going to play a game called “Find the Stars.” Each match-to-sample trial began with the presentation of the sample stimulus. Participants were instructed to touch the sample, which resulted in immediate presentation of the comparison array. The sample and all comparisons remained visible until a response occurred. Participants were informed that the colored stars would appear (duration 1 second) when they touched the correct comparison. Praise and a brief melody accompanied the starburst. They were not informed that identity matching was the basis for correct selections. An incorrect selection was followed by a 1-second timeout with a blank screen. The subsequent trial began following a .5-second intertrial interval.

Two-choice matching-to-sample: Baseline and post-training tests. A pretest measured each participant's pretraining (i.e., baseline) performance on an

identity-matching task. Consistent with multiple-baseline experimental procedures designed to assess the causal role of a training procedure (Hersen & Barlow, 1976), different lengths of baseline were used. Baseline sessions lasted 20 trials for 6 individuals with mental retardation and 6 individuals without mental retardation. Forty baseline trials (i.e., two sets of 20 trials) were presented to 4 individuals with mental retardation and 9 individuals without mental retardation. The remaining 2 individuals with mental retardation had baselines of 30 and 46 trials, and the final child without mental retardation had a baseline of 28 trials. Individuals with pretest accuracy scores above 70% were not included in the study.

After the sample was touched on each trial, two comparison stimuli appeared. The positions of the comparisons changed unsystematically from trial to trial, and unused keys remained black. Each of the five geometric forms served as the sample and the correct comparison on four trials in each 20-trial block. The same stimulus was never the sample on more than two consecutive trials and never appeared with the same incorrect comparison in a particular session.

This two-choice identity-matching task was repeated as a posttest for all participants who successfully completed the training sequence. The posttest was terminated after 10 consecutive correct trials or a total of 20 trials. Individuals with mental retardation also completed a maintenance test that was conducted from 3 to 160 days after the posttest.

Training program. Figure 2 illustrates trials of the training procedure, in which the structure of the visual display was changed systematically by reducing the number of incorrect comparison stimuli as a function of the accuracy of a participant's performance. The first training step was designed to facilitate detection of the correct comparison stimulus. After the participant touched the sample, nine comparison stimuli appeared, one being identical to the sample and designated correct. The other eight stimuli, the incorrect comparisons, differed from the sample in shape but were identical to one another. Touching the form that was identical to the sample produced the auditory-visual starburst display. Any other selection was an error and produced a blank screen.

The visual displays were changed systematically across blocks of up to 20 trials as a function of the performance of the individual participant.

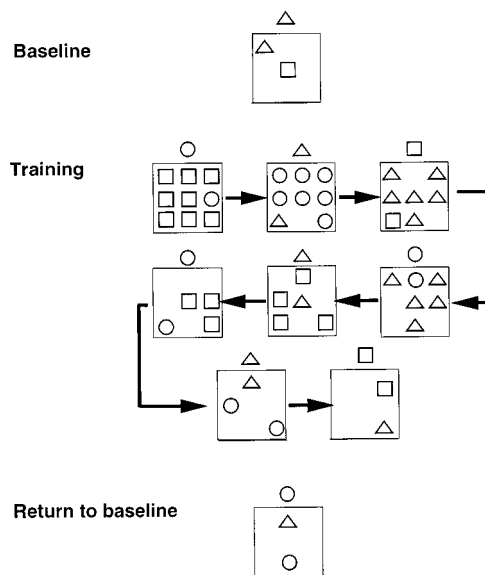


Figure 2. Illustration of (a) the two-choice match-to-sample task for baseline, (b) the training procedure in which the number of identical distractors was gradually reduced across trials, and (c) the return to the original two-choice match-to-sample task.

In the first block of trials, nine-stimulus displays were presented until three consecutive trials were correct. The number of incorrect comparison stimuli then was reduced by one, to seven, for the next block of trials. After criterion (i.e., three consecutive correct responses) was met at this stage, the number of comparisons again was reduced by one. This systematic and gradual reduction of the number of comparison stimuli continued until the display consisted of one correct and one incorrect comparison stimulus (i.e., two-choice identity matching). After criterion was met at this final training stage, training ended. If no errors occurred, the training program took 24 trials to complete. If the accuracy criterion was not met at a particular stage of the training sequence, then the stage was repeated. Failure to meet criterion after two repetitions of a particular stage terminated the session and ended the individual's participation.

Results

Pretest

The performances of participants with and without mental retardation in the 20-trial and 40-trial multiple baseline pretests are shown in Figures 3 and 4 (data to left of broken vertical lines).

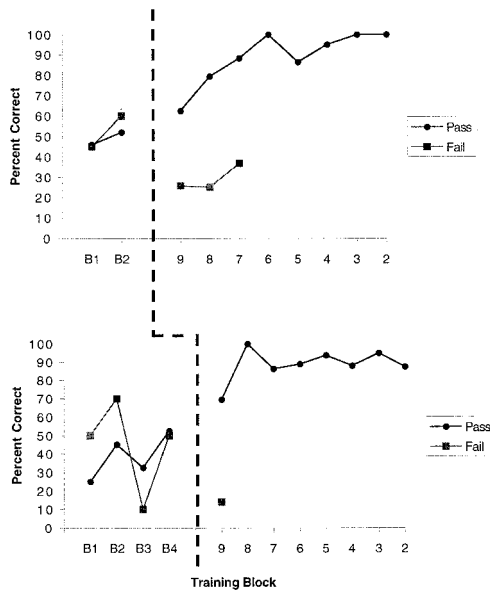


Figure 3. Mean accuracy for the children with mental retardation on 10-trial blocks of the 20- (top) and 40- (bottom) trial baselines and the eight training steps (9 to 2 comparison stimuli).

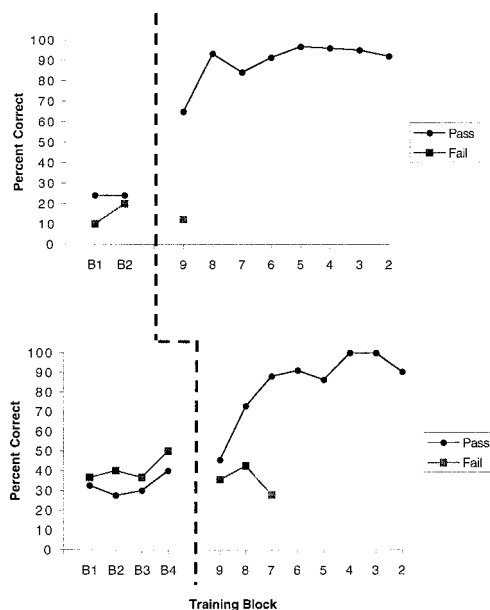


Figure 4. Mean accuracy for the children without mental retardation on 10-trial blocks of the 20- (top) and 40- (bottom) trial baselines and the eight training steps (9 to 2 comparison stimuli). Trial-by-trial baseline data for 3 participants were unavailable and are not included. The baseline accuracy scores for these participants were 50%, 32.5%, and 27.5%.

Accuracy typically was below 50% (chance level in the two-choice situation).

Training

Twenty-one of the 28 participants (75%) completed the training sequence successfully (9 of the 12 individuals with mental retardation and 12 of the 16 individuals without mental retardation). For those who successfully completed training, the average number of training trials required was 47.81 ($SD = 27.68$, range = 24 to 105). The average numbers of training trials required for the 9 individuals with mental retardation ($M = 48.44$, $SD = 34.34$) and the 12 individuals without mental retardation ($M = 47.33$, $SD = 23.13$) did not differ. The number of trials to errorless (TTE) performance was recorded as an index of the efficiency of the training procedure. The mean TTE score for the 21 participants that successfully completed training was 31.62 ($SD = 33.44$). The mean TTE scores for the individuals with mental retardation ($M = 29.56$, $SD = 39.46$) and those without mental retardation ($M = 33.17$, $SD = 29.90$) did not differ.

Figures 3 and 4, which highlight the multiple baseline features of the experimental design, show accuracy data for the participants with and without mental retardation, respectively. When the nine-stimulus displays were introduced immediately following the initial baseline components (20 or 40 trials), average accuracy for participants who acquired the terminal matching-to-sample performance shows that errors occurred initially, but highly accurate performances developed rapidly. Such accurate, often perfect (see below), performances then were well-maintained across successive blocks of training trials. In contrast, the participants who failed to acquire the terminal performance made many errors early in the training sequence with displays that contained 8, 7, and 6 identical distractors.

Three subgroups of children were evident following analyses of individual performance patterns. Thirteen individuals (6 with mental retardation, 7 without mental retardation) completed training very rapidly (i.e., 39 trials or fewer) and with few or no errors. This fast acquisition group all had TTE scores below 32 ($M = 7.23$, $SD = 8.92$, $Md = 5.00$). A second group of 8 individuals (3 with mental retardation, 5 without mental retardation) required 60 to 105 trials to complete the training sequence. Individuals in this slow acquisition group all had TTEs above 54 ($M =$

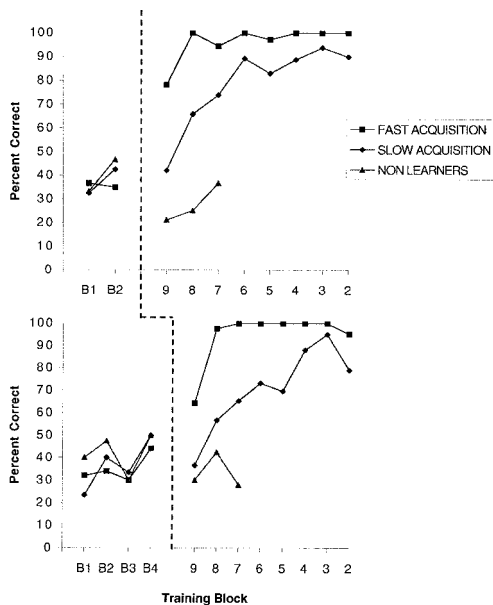


Figure 5. Mean accuracy for the three subgroups (fast and slow acquisition, and nonlearners) on 10-trial blocks of the 20- (top) and 40- (bottom) trial baselines and the eight training steps (9 to 2 comparison stimuli).

71.00, $SD = 13.48$, $Md = 75.50$). Finally, 7 individuals (3 with mental retardation and 4 without mental retardation) did not complete training successfully. Four of these participants failed to advance beyond the initial nine-choice stage of training. Of the remaining 3 individuals, 2 advanced to the seven-choice stage but failed to meet criterion and the other failed to advance beyond the eight-choice stage.

Figure 5 presents accuracy data for these three groups of participants (each including individuals with and without mental retardation) in a form that shows the transitions from the 20- and 40-trial baselines to the training conditions. For the fast acquisition group, errors were few, even on the trials that immediately followed the change from a two-choice to a nine-choice display (i.e., baseline to training). After these initial trials, these participants only rarely made errors. Relative to these participants, those in the slow acquisition group made more errors immediately after the shift to training, and some continued to make errors, at least intermittently, as training progressed. However, even relatively low percentages may reflect the development of good stimulus control because few trials were involved in calculating the accuracy levels for training blocks. For example,

an error on the first trial with the new display for a given training block and then criterion performance of three correct trials yields an accuracy score of 75%. Two errors followed by three correct trials produces a score of only 60%.

Posttest and Maintenance

One of the 3 participants without mental retardation who completed training in the minimum of 24 trials was not available for further testing and, therefore, did not complete the posttest. Of the 20 participants who advanced to the posttest, 14 performed perfectly, and 3 others had accuracy scores above 90%. One individual in each group had an accuracy score of 70%, and one individual with mental retardation had a score of 40%. The latter individual was the only participant who completed training but did not demonstrate improvement from pretest to posttest. This individual, therefore, was not given a maintenance test. Of the 8 individuals with mental retardation who were given a maintenance test, 7 performed perfectly and the final individual responded correctly on 60% of the trials. The latter individual was the one who responded correctly on only 70% of the posttest trials.

Correlational Analyses

Descriptive variables (i.e., CA, MA, group, number of pretest trials) were correlated with outcome variables (i.e., training success, training trials, TTE, percentage correct during training) to determine whether the bases for individual differences in performance could be identified. There were no statistically significant correlations found among these variables. Thus, individual differences were not a function of intellectual level (i.e., MA), CA, or pretest performance.

Discussion

The results of the present study demonstrate a novel and efficient method for facilitating the acquisition of identity matching in children with and without mental retardation. Effective matching-to-sample performance was produced by structuring the visual array so as to enhance detection of the difference between the correct (matching) comparison and eight incorrect comparisons. The number of comparisons then was gradually reduced in order to eliminate the perceptual support of performance. Seventy-five percent of the par-

ticipants completed the training program, and almost all of these children performed perfectly on a subsequent posttest. Further, 7 of the 8 children with mental retardation performed perfectly on a maintenance test given several days after the posttest.

The efficiency of the current procedure is noteworthy. The performances of the 13 individuals in the fast-acquisition group were remarkable. Three of them completed the eight-step training sequence without errors (in the minimum of 24 trials), and the remaining 10 did so with 10 or fewer errors. These performances occurred immediately following pretests in which many errors occurred, thus attesting to the efficacy of the perceptual manipulation employed. The participants' initial responses were directed to the correct comparison by the structure of the visual array.

When errors did occur during training, they most often appeared on the earliest trials with the nine-stimulus array. Eliminating these errors is important, and one way to achieve that goal is to ensure in preliminary trials that the "odd" stimulus in nine-stimulus arrays actually is selected reliably before further training proceeds. Such stimulus control of selection is one prerequisite for transition to the initial steps of the training procedure examined here.

A question raised by the current data concerns the bases for individual differences in the effectiveness of training. The intervention designed to guide attention to the critical comparison was remarkably effective for many individuals but was not sufficient for others. Correlational analyses, which should be interpreted with caution because of the small number of participants, suggests that the individual differences were not related to CA, MA, or pretest performance. Another possibility is that the individuals for whom training was ineffective may be less sensitive to visual differences in form, therefore making the perceptually based manipulation ineffective and search for the correct comparison more difficult. This is consistent with earlier work in our laboratory (Carlin, Soraci, Goldman, & McIlvane, 1995) that has demonstrated individual differences in visual search for form-defined targets. These intragroup differences in visual search are particularly pronounced for individuals with mental retardation. Duncan and Humphreys (1989, 1992) showed that visual search rates are greatly affected by the similarity of the target and nontarget stimuli employed. As target–nontarget disparity in-

creases, detection of the target occurs much more rapidly. Thus, increasing the disparity between the target (correct) and the other comparisons in the context of the present procedure may increase the range of individuals with whom the method may be applied. Research is needed to examine whether the individual differences uncovered by our visual tasks have diagnostic value for the design of training procedures.

The intervention used in the present study involves a transition from perceptual guidance of comparison selection to identity matching. The initial stimulus arrays included a high number of identical stimuli that did not match the sample. Responding was likely to be guided by the perceptual structure of the display. This perceptual support then was systematically reduced by gradually removing nonmatching stimuli from the displays across trials. In the final discrimination with two comparison stimuli, selections of correct matches must have been based on identity with the sample because the perceptual support was eliminated completely. When did selection based on identity first occur? If the shift to identity matching occurred early in the training sequence, then it may be possible to eliminate several steps and, thereby, increase training efficiency. Most participants did not make errors in the later stages of training (e.g., with arrays of four or fewer elements), suggesting that identity matching may have been established already. The final stages of training may be unnecessary in such cases.

The generally poor performances of the children in the initial baseline trials confirmed the inefficiency, and even suggested the ineffectiveness, of trial-and-error training. This observation is consistent with experience in our laboratory and a substantial literature extending over many years (e.g., Dube & Serna, 1998; Mackay & Sidman, 1968; Pilgrim et al., 2000). In a summary of several years of research, Serna, Dube, and McIlvane (1997) reported that other procedures involving standard fading and prompting methods established identity matching in only 32% of the participants with mental retardation. For the remaining participants, more extensive and prolonged procedures (i.e., 10 or more sessions) were required. Clearly, there is a need for methods that rapidly establish the conditional discriminations involved in matching-to-sample. The present procedure meets that need for many individuals. Furthermore, the method is straightforward and does not require the costly and labor-intensive produc-

tion of stimuli for fading procedures that use stimulus-shaping techniques.

An important extension of the present work would be examination of the effectiveness of the method for establishing arbitrary stimulus relations critical for numerical and linguistic skills. For example, to teach quantity–numeral relations, researchers could present two dots as a sample and the printed numeral 2 and eight 1s as comparisons in the first stage of training. Other quantity–numeral relations would be established concurrently. In terms of language development, an unfamiliar spoken sample (e.g., “bellows”) could be presented with a comparison array that includes a bellows and eight pictures of another object. Using this form of the task, the individual may learn to relate the verbal label “stapler” with the picture of a stapler. Thus, the present methodology has considerable generality across stimuli and is applicable to situations in which arbitrary visual–visual or arbitrary auditory–visual relations are the focus of intervention.

The attempt to establish complex discriminations like matching-to-sample and oddity by manipulating the structural characteristics of visual arrays brings to mind Shepard and Podgorny’s (1978) recommendation to acknowledge the important relationship between perceptual and cognitive processes. A determination of the role of perceptual factors in concept acquisition and higher cognitive processes is a problem that pervades a range of psychological approaches. Cognitive psychologists have tended to focus on mediational mechanisms involved in higher-order strategic processes, whereas perceptual researchers have investigated the stimulus factors underlying complex information-processing (Gibson, 1979; Soraci et al., 1993). In the present study, matching-to-sample, a potentially rule-based performance of high generalizability (and in that sense similar to oddity) was induced via a perceptually based manipulation that enhanced detection of the matching target. This is an empirical instantiation of the interaction of perceptual and cognitive mechanisms in facilitating a complex skill.

In summary, results of the present study indicate the efficacy of a perceptually based manipulation to facilitate the acquisition of identity matching in children who were initially unsuccessful on this task. The structure of stimulus displays was used to “guide” visual attention and enhance the “noticing” of the relevant stimulus, issues that are related to the historically important

question of the role of observing behavior in discrimination learning.

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