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CONDITIONAL DISCRIMINATION IN MENTALLY RETARDED ADULTS: THE EFFECT OF TRAINING THE COMPONENT SIMPLE DISCRIMINATIONS

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Two subjects with retardation who exhibited generalized identity matching, but who had extensive histories of failure to acquire arbitrary matching, were exposed to a series of conditions designed to train separately the components of a two-choice conditional discrimination. First, the successive discrimination between the sample stimuli was established by programming a different schedule of reinforcement in the presence of each sample stimulus. Schedule performance was acquired and maintained by both subjects, but neither acquired arbitrary matching. To train the simultaneous discrimination between the comparison stimuli, 1 subject was then exposed to a series of simple discrimination reversals and subsequently failed to acquire arbitrary matching. Both subjects acquired arbitrary matching under a procedure that maintained both the sample and the comparison discrimination by first presenting entire sessions composed of one sample–comparison relation and then gradually reducing the number of consecutive trials with the same sample until sample presentation was randomized (schedule performance was maintained). Removal of the schedule requirement had no effect on arbitrary matching accuracy. Both subjects subsequently demonstrated control by relations symmetric to the trained relations.

Key words: conditional discrimination, matching to sample, differential sample responses, symmetry, button press, mentally retarded adults

A conditional discrimination is a second order discrimination in which a response to a discriminative stimulus is reinforced only if another (conditional) stimulus is present. Conditional discrimination is often studied with a two-choice arbitrary matching-to-sample procedure. Each trial begins with the presentation of one of two sample stimuli, A1 or A2. A response to the sample results in the presentation of two comparison stimuli, B1 and B2. Responses to B1 in the presence of A1 and to B2 in the presence of A2 are followed by reinforcers. Sample stimulus order varies unsystematically across trials.

This conditional discrimination procedure has been widely used to study learning, memory, and perception. It also has become a useful classroom procedure in both regular and special education settings. The procedure's usefulness notwithstanding, variables that influence acquisition of conditional discrimination are rarely examined explicitly. It is not yet known, for example, why developmentally limited human subjects have difficulty acquiring conditional discriminations (e.g., Gollin, 1966; McIlvane, Kledaras, Killory-Andersen, & Sheiber, 1989). Further, it is not known why such difficulties are often task specific. One often encounters, for example, mentally retarded subjects who easily learn to select comparison stimuli that are identical to the sample but do not acquire arbitrary matching despite protracted exposure to teaching conditions. Moreover, when standard training methods fail, the experimenter/teacher finds little information to guide remedial teaching.

The present study sought methods of teaching mentally retarded subjects who had extensive histories of failure to acquire accurate arbitrary matching performances. The working hypothesis was that the subjects lacked critical prerequisite component skills. An arbitrary matching performance consists of two com-

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ponent discriminations: a successive discrimination between the samples and a simultaneous discrimination between the comparisons (Carter & Eckerman, 1975). Separate training of the component discriminations may hasten acquisition of the conditional discrimination. For example, successive discriminations between samples have been established by requiring differential responses to the stimuli. Pigeons' conditional discrimination is reportedly enhanced when subjects are required, in the presence of each stimulus, to peck different key locations (Eckerman, 1970) or in patterns established by different reinforcement schedules (Cohen, Looney, Brady, & Aucella, 1976). Differential sample schedules have also facilitated acquisition in intellectually normal children (Sidman et al., 1982).

There are at least two ways in which such differential response procedures could influence conditional discrimination learning. First, the procedure may simply pretrain the successive discriminations between the sample stimuli (Cohen et al., 1976). Second, the sample-specific behavior may exert stimulus functions, controlling comparison selection (Cohen, Brady, & Lowry, 1981; Urcuioli & Honig, 1980) and possibly preventing the development of direct control over comparison selection by the sample stimuli (Urcuioli, 1984, 1985). When sample-specific behavior is no longer required, continued accuracy suggests the discrimination pretraining possibility (e.g., Sidman et al., 1982; human subjects) whereas reduced accuracy suggests control by the differential responses (Sidman et al., 1982; monkey subjects). There are very little data on these issues, however.

The present series of studies asked whether the acquisition of arbitrary matching to sample could be promoted if training procedures explicitly established successive discrimination of the samples and simultaneous discrimination of the comparisons. The procedures allowed an analysis of the contribution of each component discrimination to acquisition. The primary questions were as follows: Would retarded subjects who had failed to acquire arbitrary matching show differential schedule performance to two different sample stimuli? If so, would sample-schedule requirements alone lead to acquisition of conditional discrimination? If not, would additionally establishing the simultaneous comparison discrimination prove sufficient? Given that arbitrary matching was established, would accuracy be maintained if the sample-schedule requirement were removed?

GENERAL METHOD

Subjects

Two retarded males qualified for the study after extensive unsuccessful efforts to teach them arbitrary matching. RH and RZ were 25 and 34 years old, respectively. IQ scores (WAIS-R) were 66 for RH and 57 for RZ. Both displayed generalized identity matching, exhibited functional speech, and participated in vocational training programs.

Apparatus

Subjects sat at a table supporting a stimulus display box that housed an Apple® IIE microcomputer, an interface device, and a DSI tray feeder. Three 5 cm by 5 cm windows, spaced 2.5 cm apart, were mounted in the front wall of the box 105 cm from the floor. During sessions, the computer's monochrome monitor was positioned so that stimuli displayed on the screen were centered in the display windows. Under each window was mounted a spring-loaded button with an exposed diameter of 2.5 cm. A container into which the feeder dispensed pennies was located to the subject's lower left.

General Procedure for Teaching a Conditional Discrimination Under Trial-and-Error Conditions

Each trial began with the presentation of one of the two sample stimuli in the center display window. The two sample stimuli occurred equally often in a session and were presented quasi-randomly with the restriction that the same sample stimulus appear no more than three times in a row. A press on the center button produced the two comparison stimuli in the outer windows; each comparison stimulus occurred an equal number of times in each position and was never in the same position more than three consecutive trials. Additional responses on the sample button had no consequences. Pressing the button under the correct comparison produced a 1-s, computer-generated jingle and the delivery of a penny; pressing the button under the incorrect comparison produced a 1-s buzzer. Either consequence initiated a 2-s intertrial interval (ITI) that was reset contingent upon sample-button presses. All sessions contained 32 trials. Sessions were conducted 4 or 5 days per week. Two or three sessions occurred per day during the initial arbitrary matching baseline and one or two sessions were conducted per day through the remainder of the experiment.

Preexperimental History

Both subjects first demonstrated 100% accuracy in two 32-trial identity matching sessions involving 10 stimuli including those shown in Figure 1 and six more of similar type; the first two trials of the first session were prompted physically. The subjects were then exposed to several conditions designed to teach the arbitrary matching task shown in Figure 1. The apparatus and general procedure were as previously described.

Subject RZ was given 46 32-trial training sessions. The first seven were trial-and-error sessions. ("Trial-and-error" will refer to training involving the terminal task presented under conditions of differential reinforcement.) Accuracy was never above chance. Nine sessions composed of only one trial type from the arbitrary matching task intermixed with identity matching trials involving each of the comparison stimuli from the arbitrary matching task were conducted. This procedure was discontinued when performance on the identity matching trials deteriorated. Next, RZ was given 30 sessions in which both arbitrary matching trial types were presented in alternating blocks of trials. As training progressed, block size was decreased when accuracy was high and increased when accuracy was low. When sessions were composed of two blocks of 16 trials, RZ sometimes achieved 90% accuracy. Most errors, however, occurred on the first or second trial of each block, suggesting mere simple discrimination of the comparison stimuli and mid-session discrimination reversal. When sessions had four blocks of eight trials, accuracy never exceeded 78%.

Subject RH performed at chance levels in three initial trial-and-error sessions. Next he was given 37 sessions with the blocked trial procedure, also unsuccessful. Ten further trial-and-error sessions produced no increase in accuracy. RH then was given a 90-session instructional sequence that sought to teach the arbitrary matching task with an exclusion procedure. The general strategy was to juxtapose arbitrary matching trial types and identity matching trials with the same sample and incorrect comparison. The identity matching trials may have served to train the rejection of the incorrect comparison in the presence of that particular sample (Dixon & Dixon, 1978). However, median arbitrary matching accuracy was 56% for the last 16 sessions, and there was no increasing trend.

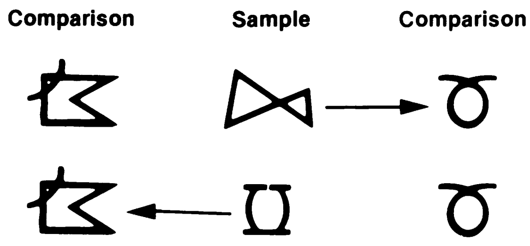

Fig. 1. Training trials to which subjects were exposed preexperimentally. The arrow points from the sample to the corresponding correct comparison (the arrow did not appear in the display).

EXPERIMENT 1

Procedure

Experiment 1 contained three phases: (a) a baseline phase in which a new conditional discrimination was presented under trial-and-error training conditions, (b) a phase that established differential schedule performance in the presence of each sample stimulus, and (c) conditional discrimination training sessions in which the sample-schedule performance was maintained.

Baseline conditional discrimination training. Figure 2 shows the stimuli used for conditional discrimination training. The procedures were as described in the general procedure section. The subjects were familiar with laboratory procedure, so no instructions were given. Because both subjects had an established history of failure to acquire arbitrary matching, brief baselines were planned, with the provision that they be continued if an upward trend was observed.

Sample-schedule training. A trial began with the onset of the sample stimulus in the center window. Completion of the schedule requirement (on the center button) produced the jingle and the delivery of a penny and initiated a 5-s ITI. Responses during the ITI delayed onset

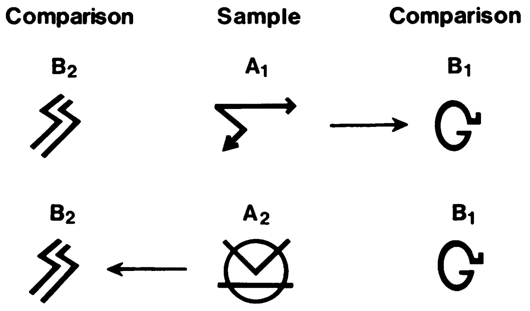

Fig. 2. Training trials to which subjects were exposed in Experiments 1, 2, and 3. The arrow points from the sample to the corresponding correct comparison (the arrow did not appear in the display).

of the next trial for 5 s. No instructions were given.

Subjects were first trained to respond under a differential reinforcement of low rate 3-s (DRL 3) schedule in the presence of sample A1. The contingency was met when an interresponse time (IRT) of 3 s occurred. When responding became stable, subjects were trained to respond under a fixed-ratio 8 (FR 8) schedule in the presence of A2. Following stable responding, the two different samples were alternated quasi-randomly within each session until responding became stable under both schedule contingencies.

Conditional discrimination training with sample schedules. This was as described in the general procedure section, except that completion of a schedule requirement produced the two comparison stimuli, and the ITI was 5 s. This condition continued for a minimum of 12 sessions until the final five sessions showed minimal variability and no systematic trend in conditional discrimination accuracy.

Results and Discussion

Figure 3 displays accuracy from all conditional discrimination sessions and a measure of differential schedule performance for the last three sessions under sample-schedule training and for all sessions of the subsequent conditional discrimination training. The measure of differential responding within each session was derived by calculating the mean IRT for each trial and determining the percentage of trials of both types (FR and DRL) with mean IRTs outside of the range for the opposing trial type. For example, DRL trials should have higher IRTs than FR trials. If the highest mean IRT for an FR trial in a session was 0.4 s and three DRL trials had mean IRTs that were less than or equal to 0.4 s, the measure of differential responding would be 91% (29 of 32 trials). FR trials with IRTs within the range of DRL trials would similarly reduce this measure. Thus, 100% differential responding indicated that there was no overlap of IRTs between the FR and the DRL trials. By the end of training, schedule performance was well differentiated for both subjects, and this was maintained throughout the subsequent conditional discrimination training.

As shown in Figure 3, accuracy was at chance levels for both subjects in the initial conditional discrimination training phase. Under conditional discrimination training with sample schedules, conditional discrimination accuracy ranged from 31% to 53% with a median of 38% for Subject RH. Performance was characterized by neither a position bias nor a strong stimulus bias. Subject RH terminated Sessions 91, 94, and 100 after 22, 9, and 8 trials, respectively. For Subject RZ, conditional discrimination accuracy with sample schedules in effect ranged from 34% to 71% with a median of 50%. In the last five sessions for this subject, conditional discrimination accuracy was at or near 50% correct, with responding almost exclusively to the right-hand button.

In summary, differential responding was acquired by both subjects, and it was well maintained in the context of the conditional discrimination. However, this was not sufficient to produce acquisition of the conditional discrimination.

Additional procedures for Subject RZ. RZ was exposed to additional procedures (marked by arrows in Figure 3) designed to eliminate position-controlled responding. First, all correct comparisons were presented in the nonpreferred position. The position preference reversed in two sessions, but reexposure to conditional discrimination training with sample schedules produced exclusive responding to the right button. Because previous identity matching performance was not characterized by position-controlled responding, RZ was next exposed to four identity matching sessions that contained all four stimuli involved in the arbitrary matching sessions and eight additional stimuli of similar complexity. Virtually perfect

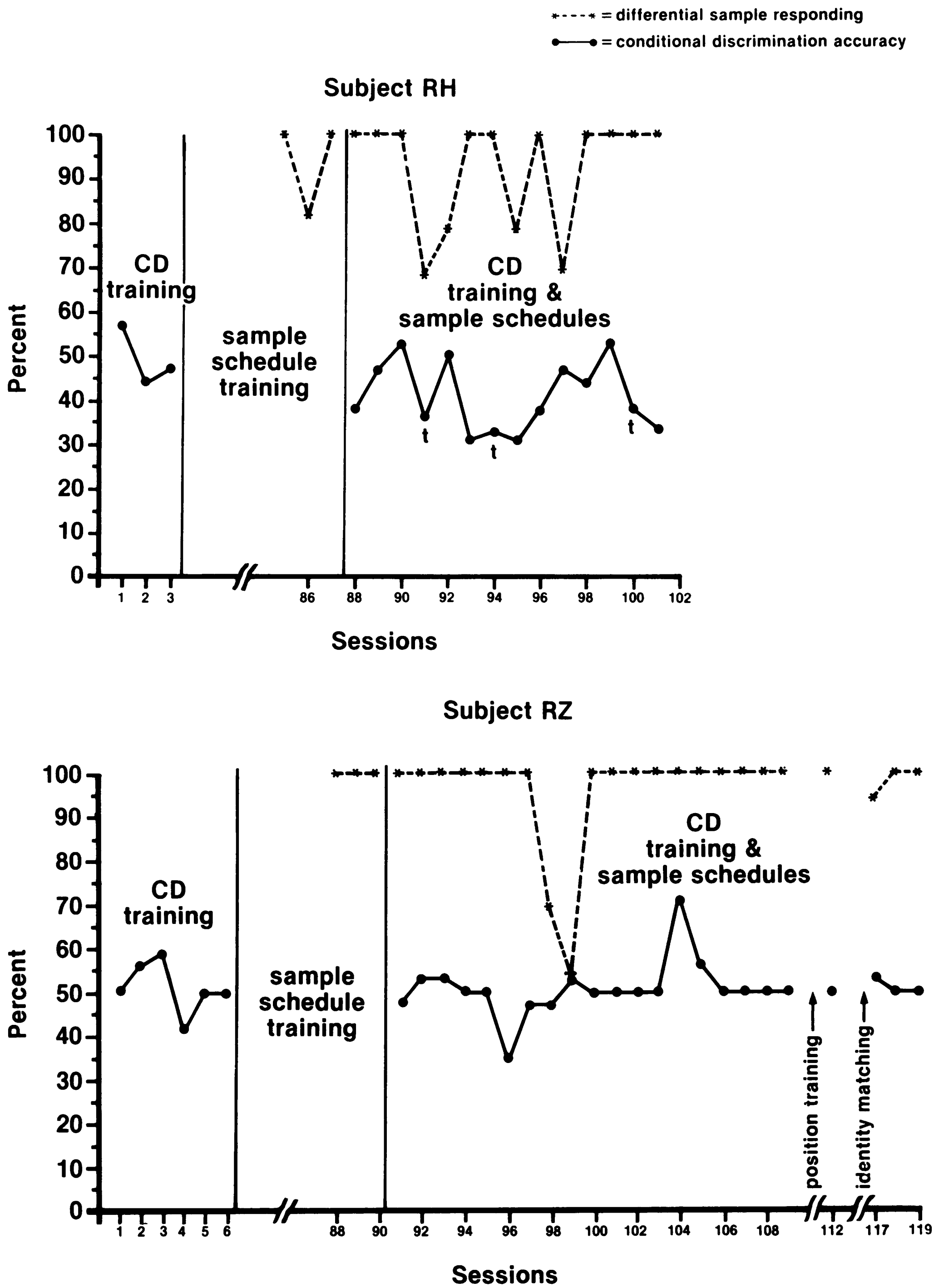

Fig. 3. Percentage of correct comparison selections in the conditional discrimination (closed circles) and the percentage of nonoverlapping differential sample responses (asterisks) for both subjects for all three phases of Experiment 1. The latter measure was derived by calculating the mean interresponse time for each trial and determining the percentage of trials of both types (DRL and FR) with mean IRTs outside of the range for the opposing trial type. Data for only the final three sessions of sample schedule training are shown. Data points labeled "t" are from sessions terminated early by the subject.

performance was demonstrated by the third and fourth sessions. These manipulations showed that the stimuli involved in the arbitrary matching task could enter into a conditional relation (identity matching) and that the reinforcement contingencies in effect were sufficient to bring this about. However, in three subsequent arbitrary matching sessions with schedule requirements, all but one response was to the right-hand button.

EXPERIMENT 2

Experiments 2a and 2b were designed to determine whether the present subjects, who had acquired the successive discrimination between the samples, would acquire the conditional discrimination after acquiring the comparison discrimination.

Experiment 2a Method and Results

In Experiment 2a, Subject RZ was exposed to sessions designed to train the comparison discrimination in isolation and then to the conditions existing at the end of Experiment 1—the complete conditional discrimination with the sample schedule requirement.

In comparison discrimination training sessions, a trial began with the presentation of the two comparison stimuli in the outer display windows. Each comparison stimulus occurred equally often in each position and was never in the same position more than three consecutive trials. Responses to any key during the 5-s ITI reset the ITI. The middle key was inoperative during trials. Each correct response produced the jingle and a penny, and each incorrect response produced the buzzer. One comparison stimulus was designated correct for an entire session. Sessions with a given correct stimulus were presented until errors were confined to the first two trials, then, in the next session, the other stimulus was designated correct until the same criterion was met. After three alternations, the correct comparison was changed each session regardless of performance until two consecutive sessions of at least 94% correct responding occurred. A total of 17 sessions was required to meet this criterion.

Four "review" sample-schedule sessions (with no comparison stimuli) were conducted. The measure of differential responding was 100% across all four sessions. The conditional discrimination with sample-schedule condition was then reintroduced. Across eight sessions, differential responding to the sample was below 100% only once (to 91% in the seventh session). However, accuracy of comparison selections ranged from 31% to 50% with no trend. Interestingly, the subject did not show position-controlled responding, as he had in Experiment 1.

In summary, acquisition of both the sample discrimination and the comparison discrimination were not sufficient to produce acquisition of the conditional discrimination. However, differences in procedure between the two training components warranted consideration. Although sample discrimination was maintained during conditional discrimination training, the comparison discrimination was merely demonstrated prior to conditional discrimination training. Experiment 2b addressed this concern.

Experiment 2b Method and Results

In this phase, the two conditional discrimination trial types were presented in alternating blocks with the sample-schedule contingencies in effect. First, sessions composed entirely of one of the two trial types were conducted; in essence, these were comparison discrimination training sessions with the samples present. Subject RH was required to exhibit 100% performance, and Subject RZ was required to exhibit 90% performance in each type of session (the less stringent criterion resulted from the similarity of this procedure to previous comparison discrimination training). Next, sessions containing two blocks of trials were presented (e.g., one sample appeared for the first 16 trials, and the other appeared for the second 16 trials). When errors occurred only in the first two trials of each block, showing maintenance of the simple comparison discrimination with a single, mid-session reversal, blocks of eight trials were presented. Subsequent increases in the number of reversals per session occurred when accuracy was at least 94% and there were no errors in the first two trials in each block. The number of trials per block was next decreased to four, and then sessions with irregularly sized blocks of three, four, and five trials were presented. Finally, the conditional discrimination training with sample-schedule condition was presented (randomized presentation of trial types). Failure to make progress at any point in the sequence resulted in a return to the previous session type and to the performance criterion previously used for that session type.

Figure 4 shows conditional discrimination accuracy and the measure of differential responding for all sessions for Subjects RH (top) and RZ (bottom). The size of the blocks of similar trial types is indicated by the numerals just above the *x* axis. For Subject RH, differential responding ranged from 72% to 100% (note that, because this measure describes the extent to which IRTs differ across the two different sample schedules, it cannot be computed for sessions with only one trial type because only one sample is presented). Conditional discrimination accuracy met criterion quickly after the first three decreases in the number of trials per block. However, after criterion was met with four-trial blocks, a session with randomized presentation of trial types resulted in 50% accuracy (Session 116). Criterion performance was reestablished with blocks of four trials, and sessions with blocks of three, four, and five trials were presented. Median accuracy over 12 sessions was 81% and highly variable, ranging from 59% to 97%. This suggested variable reinforcer effectiveness, so a response-cost contingency was added. Before each session, six dimes were placed within view of the subject, who was told that one would be taken away each time he pressed the wrong button and that he could keep the dimes that were left at the end of the session. This contingency remained in effect until the end of the experiment. Accuracy reached 100% in two sessions. Six sessions followed in which the order of the trial types was randomized; the accuracy in the last two sessions was 100%.

Subject RZ initially moved through the procedure more slowly. Schedule control was excellent, but decreasing conditional discrimination accuracy resulted in a return to the previous condition once under the Block 16 condition and three times under the Block 8 condition. However, the transitions from Block 8 to Block 4 to Block 3-4-5 and then to perfect performance with randomized presentation required only five sessions.

Discussion

In Experiment 1, 2 retarded subjects did not acquire a conditional discrimination despite differential responding to the sample stimuli. In Experiment 2a, Subject RZ was exposed to sessions in which the comparison discrimination was trained in isolation, then to sessions of conditional discrimination training with sample schedules. The conditional discrimination was not acquired under this set of procedures. Both subjects acquired the conditional discrimination in sessions with sample schedules in which the two trial types were presented in blocks of trials of the same type, and the size of the blocks of trials was decreased across sessions. This procedure differed from merely providing pretraining of the comparison discrimination in that the comparison discrimination was maintained in conditional discrimination training sessions.

In addition to maintaining the comparison discrimination, other features of the blocked trial procedure may have promoted sample control of comparison selection. Under trial-and-error conditions, reinforcement can occur on about half of the trials in the absence of control by the sample stimulus (this is often due to control by comparison position). Because the blocked trial procedure begins with comparison discrimination training, errors are likely to involve the selection of the previously correct comparison after the trial type changes. Thus, persistence in an error response produces a series of unreinforced trials. Once selections reverse reliably after one or two errors, control over comparison selection can be transferred from the consequence of an error to the sample stimulus by gradually increasing the number of comparison discrimination reversals in a session. Presumably, the maintenance of the sample discrimination facilitates this transfer. This analysis seems compatible with findings that conditional discrimination acquisition is adversely affected by either too frequent or too few reversals of the comparison discrimination (Gollin, 1965; Thomas & Goldberg, 1985; Thomas, Stengel, Sherman, & Woodford, 1987).

EXPERIMENT 3

The sample-schedule procedure may have served simply to train and maintain the successive discrimination between the sample stimuli (Cohen et al., 1976). Alternatively, the sample-specific behavior might have controlled comparison selection (Cohen et al., 1981; Urcuioli & Honig, 1980), perhaps interfering with

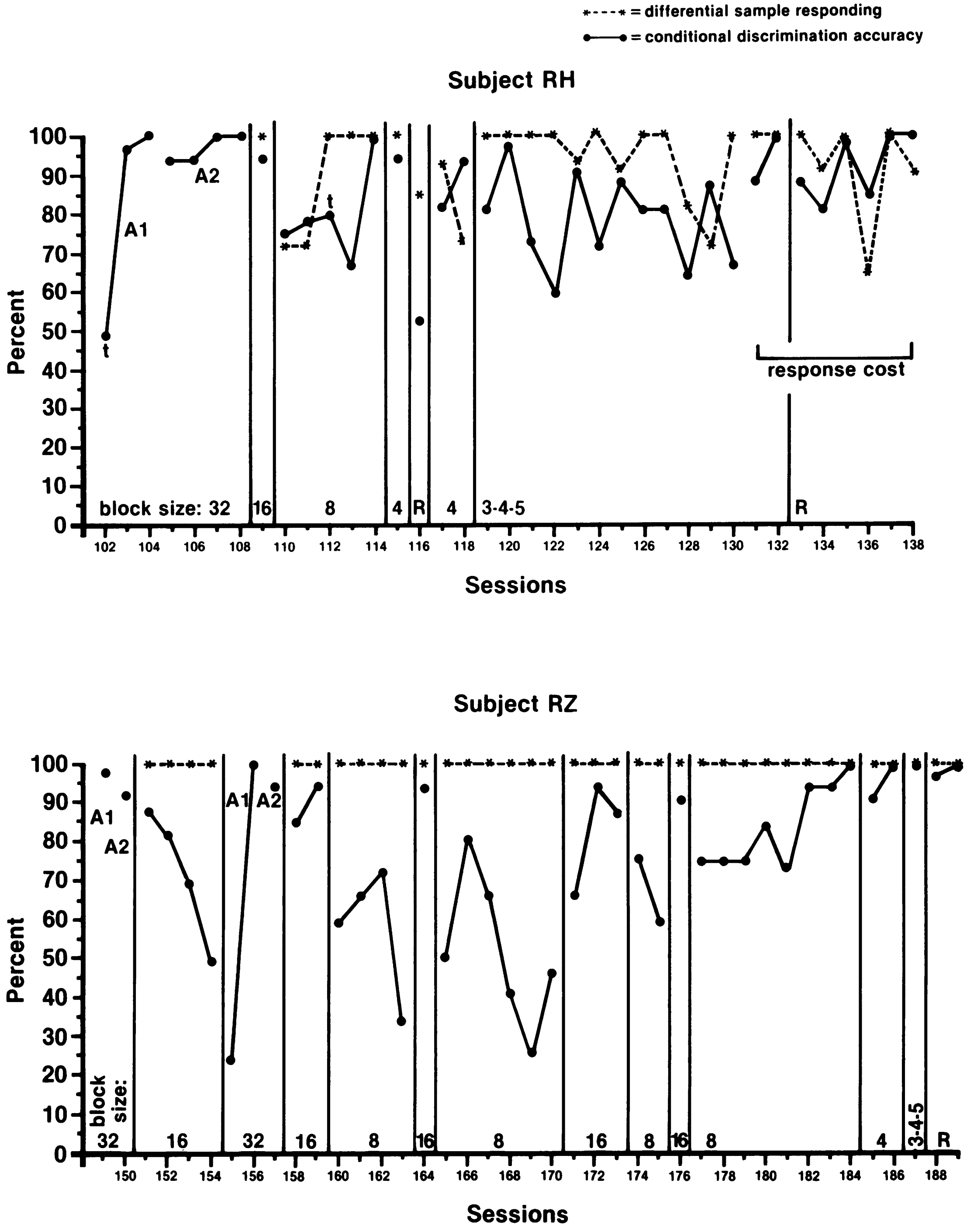

Fig. 4. Percentage of correct comparison selections (closed circles) and the percentage of nonoverlapping differential sample responses (asterisks) for Experiment 2b. The latter measure was derived by calculating the mean interresponse time for each trial and determining the percentage of trials of both types (DRL and FR) with mean IRTs outside of the range for the opposing trial type. The size of the blocks of similar trials is indicated by the numerals just above the *x* axis; "R" refers to randomized presentation of trial types. Data points labeled "t" are from sessions terminated by the subject. Data points from sessions with only one trial type (Block 32) are labeled "A1" or "A2" according to the sample stimulus appearing in all trials (see Figure 2).

the development of control by the sample stimuli (Urcuioli, 1984, 1985). Experiment 3 was conducted to determine whether the comparison selections of the present subjects were under the control of the sample stimuli.

Two tests were conducted. The first presented conditional discrimination trials without the sample-schedule requirement. The second reversed the positions of the sample and comparison stimuli to test for relations symmetric to those trained.

Procedure

The procedure for conditional discrimination training without sample schedules was identical to that at the end of Experiment 2 except that only one press of the sample button was required to produce the comparison stimuli. No instructions were given, except those relating to the response-cost procedure still in effect for Subject RH. If the conditional discrimination was maintained under these conditions, conditional discrimination sessions without trial-by-trial consequences were presented in preparation for symmetry test sessions. Prior to these sessions (and symmetry test sessions), the subjects were told that the computer would not make sounds or give pennies during the session and that they would be paid after the session. With regard to the response-cost procedure, RH was told that, at the end of the session, the computer would tell the experimenter how many dimes he could keep. Subjects were paid 1 cent for each correct trial in a lump sum, and RH received the appropriate number of dimes, with no discussion of errors.

If accuracy was maintained without trial-by-trial consequences, subjects were exposed to two sessions composed of a mixture of 22 conditional discrimination trials and 10 trials that tested sample–comparison relations symmetric to those trained. Symmetry trials reversed the sample and comparison stimuli (i.e., the B stimuli served as samples and the A stimuli served as comparisons). Symmetric relations would be indicated by the selection of A1 in the presence of B1 and A2 in the presence of B2. After test sessions, subjects received 1 cent for each correct training trial and 1 cent for each test trial regardless of performance; RH lost dimes for training trial errors but not for symmetry trial errors. A session with training trials only was conducted immediately prior to each symmetry test session.

Results

Without the sample-schedule requirement and with feedback in effect, accuracy ranged from 94% to 100% across five sessions for Subject RH and was 100% across two sessions for Subject RZ. Under no-feedback conditions, accuracy was 100% across two sessions for both subjects. Across two test sessions, the performance of Subject RZ demonstrated control by relations symmetric to the trained relations on all 20 probes; Subject RH's performance showed control by symmetry in 19 of 20 probe trials.

Discussion

The conditional discrimination accuracy of both subjects was well maintained when the sample-schedule requirement was removed. Thus, the procedure apparently served simply to train the discrimination between the sample stimuli. An alternative explanation might be that some unmeasured component of the differential response remained, and that this could account for the maintenance of accuracy. This explanation is made unlikely by the demonstration of control by the relations symmetric to the trained relations: If the conditional relation consisted of a stimulus–response–stimulus chain, the control exerted by the intervening differential response would be disrupted on symmetry test trials.

GENERAL DISCUSSION

Two retarded human subjects were exposed to a differential sample response procedure that has been shown to facilitate the acquisition of conditional discrimination in pigeons. A different schedule of reinforcement was programmed in the presence of each sample, with the completion of the schedule requirement producing the comparison stimuli. Both subjects acquired differential responding, but this alone did not promote acquisition of the conditional discrimination.

Both subjects were exposed to procedures designed to train the discrimination between the comparison stimuli. One subject was exposed to a standard simple discrimination training procedure. Acquiring the simple discrimination between the comparison stimuli did not improve performance on subsequent exposure to conditional discrimination training sessions with the sample-schedule requirement, indicating that sample and comparison discrimination training are not the sole prerequisites for acquisition of a conditional discrimination. Both subjects acquired the conditional discrimination under a procedure that maintained both the sample and comparison discrimination in the context of conditional discrimination training by first presenting entire sessions composed of one sample–comparison relation and then gradually reducing the number of consecutive trials with the same sample until sample presentation was randomized.

Both subjects demonstrated control by relations symmetric to the trained relations. These findings, along with the maintenance of accuracy after removal of the sample-schedule requirement, show that the use of the differential sample-schedule procedure did not interfere with the development of control by the sample stimulus; such interference has been shown in pigeons (Urcuioli, 1984, 1985) and monkeys (Sidman et al., 1982). This extends earlier findings with intellectually normal children (Sidman et al., 1982). Taken together, these results suggest that the mechanism by which differential responses to the sample facilitate the acquisition of conditional discriminations by human subjects differs from that of pigeons. In these human subjects, the differential responses apparently served to establish and maintain a discrimination between the sample stimuli. If the differential responses directly controlled comparison selection, as they do for pigeons, the conditional discrimination would not have been maintained in the absence of the schedule requirement, and symmetry would not have been demonstrated.

The question of the necessary and sufficient conditions for the development of arbitrary matching to sample is complex, and can be addressed on several levels. For present purposes, it may be helpful to distinguish between the necessary component skills and the procedures that are necessary to establish these skills. By definition, the component skills required for arbitrary matching include a discrimination between the comparison stimuli and control by the sample stimulus over the specific comparison stimulus selected. The latter requires a successive discrimination between the sample stimuli. There are probably many procedures that are sufficient to establish these component skills; indeed, most normal subjects and some retarded subjects learn these component discriminations when presented with the whole conditional discrimination task. Thus, it may not be possible to specify generally necessary procedures, but only the necessary component skills and procedures that are sufficient to establish them.

Although the procedures used in this study were sufficient to establish arbitrary matching in the present subjects, the generality of this finding across subjects has yet to be determined. Skills possessed by the present subjects prior to beginning the experimental procedures may have facilitated acquisition. For example, the subjects readily demonstrated generalized identity matching. Although it is unclear whether identity matching per se facilitates subsequent arbitrary matching, it familiarized the subjects with the format of the matching task. Also, these subjects learned the component simple discriminations under differential reinforcement, with no supplementary training procedures. Other subjects with similar skills would probably experience similar success, although this remains to be tested. An important goal of this research program is to test the effectiveness of the procedures with lower functioning subjects who may not have these skills. Such subjects may require additional training components. Fortunately, the literature contains well-developed procedures for remediating some of the potential performance deficits noted above (e.g., stimulus fading procedures for teaching simple discriminations; Sidman & Stoddard, 1967).

The results suggest that explicit component training procedures were necessary for the present subjects. This conclusion is strengthened by the results of a final manipulation (not described above). Both subjects were exposed to 10 arbitrary matching training sessions involving a new set of stimuli under trial-and-error conditions; accuracy was at chance levels. Although the present study did not isolate fully the effects of the training components, there is evidence for the importance of the differential sample response. Both subjects had been exposed previously to the blocked-trial procedure without sample discrimination training, and neither acquired the conditional discrimination (see preexperimental history).

The present subjects demonstrated generalized identity matching readily, but acquired arbitrary matching only after extensive training. This discrepancy suggests that, although the tasks are similar procedurally, different component skills are necessary for successful performance. In discussing these differences, it may be helpful to contrast the typical performance of human subjects on these tasks with that of pigeons. Carter and Eckerman (1975) have shown that, for pigeons, the rate at which both identity and arbitrary matching-to-sample problems are learned "may be accounted for by the discriminability between sample stimuli and between comparison stimuli, with the former playing the more important role. Identity between a sample and one of the comparison stimuli appears to play no role for pigeons" (p. 664). Carter and Werner (1978) extended this notion to oddity matching. Thus, regardless of the type of matching task involved, pigeons learn a set of specific sample–comparison relations. When presented a new identity problem after a history of identity matching, performance falls to near chance (Farthing & Opuda, 1974); that is, generalized identity matching has not been demonstrated with pigeons.

In contrast, demonstrations of generalized identity and oddity matching are common with human subjects (e.g., Saunders & Sherman, 1986; Sherman, Saunders, & Brigham, 1970; Stromer & Stromer, 1989). Thus, after the relevant history, human subjects perform perfectly on identity tasks or oddity tasks with which they have had no prior experience. Further, human subjects who demonstrate generalized oddity matching do not necessarily learn specific sample–comparison relations (Stromer & Stromer, 1989). In contrast to generalized identity and oddity, each new arbitrary matching problem involves learning specific sample–comparison relations on the basis of differential reinforcement.

It follows that, for humans, identity and oddity matching require different component skills than does arbitrary matching. With regard to generalized identity and oddity, Stromer and Stromer (1989) noted that "Perhaps too much emphasis has been placed on the separate functions of sample and comparison stimuli . . ." and suggested that discriminative control may be based on the whole stimulus array and be ". . . shared by any stimulus array that conforms to identity or oddity configurations" (p. 63). If this is correct, there are major differences in the components required for arbitrary matching as opposed to identity or oddity matching. Generalized identity and oddity matching require neither successive sample discriminations nor specific trained sample–comparison relations. The question that remains is the extent to which this applies to human subjects who do not display generalized identity matching. Would such subjects, like pigeons, acquire identity and arbitrary matching problems at similar rates?

The present subjects failed to learn under trial-and-error conditions but learned after being taught the separate component skills. One wonders whether, after having learned several conditional discriminations by the component skills method, these subjects would learn via trial-and-error methods. Such a finding would indicate that after being taught the component skills separately, the subjects could now learn them within the context of the complex match-to-sample task. This, of course, would be a positive finding for those interested in teaching persons with moderate and severe retardation.

REFERENCES

Carter, D. E., & Eckerman, D. A. (1975). Symbolic matching by pigeons: Rate of learning complex discriminations predicted from simple discriminations. *Science,* **187,** 662–664.

Carter, D. E., & Werner, T. J. (1978). Complex learning and information processing by pigeons: A critical analysis. *Journal of the Experimental Analysis of Behavior,* **29,** 565–601.

Cohen, L. R., Brady, J., & Lowry, M. (1981). The role of differential responding in matching-to-sample and delayed matching performance. In M. L. Commons & J. A. Nevin (Eds.), *Quantitative analyses of behavior: Vol. 1. Discriminative properties of reinforcement schedules* (pp. 345–364). Cambridge, MA: Ballinger.

Cohen, L. R., Looney, T. A., Brady, J. H., & Aucella, A. F. (1976). Differential sample response schedules in the acquisition of conditional discriminations by pigeons. *Journal of the Experimental Analysis of Behavior,* **26,** 301–314.

Dixon, M. H., & Dixon, L. S. (1978). The nature of standard control in children's matching-to-sample. *Journal of the Experimental Analysis of Behavior,* **30,** 205–212.

Eckerman, D. A. (1970). Generalization and response mediation of a conditional discrimination. *Journal of the Experimental Analysis of Behavior,* **13,** 301–316.

Farthing, G. W., & Opuda, M. J. (1974). Transfer of matching-to-sample in pigeons. *Journal of the Experimental Analysis of Behavior,* **21,** 199–213.

Gollin, E. S. (1965). Factors affecting conditional discrimination in children. *Journal of Comparative and Physiological Psychology,* **60,** 422–427.

Gollin, E. S. (1966). Solution of conditional discrimination problems by young children. *Journal of Comparative and Physiological Psychology*, **62**, 454–456.

McIlvane, W. J., Kledaras, J. B., Killory-Andersen, R., & Sheiber, F. (1989). Teaching with noncriterion-related prompts: A possible subject variable. *Psychological Record*, **39**, 131–142.

Saunders, R. R., & Sherman, J. A. (1986). Analysis of the "discrimination-failure hypothesis" in generalized matching and mismatching behavior. *Analysis and Intervention in Developmental Disabilities*, **6**, 89–107.

Sherman, J. A., Saunders, R. R., & Brigham, T. A. (1970). Transfer of matching and mismatching behavior in preschool children. *Journal of Experimental Child Psychology*, **9**, 489–498.

Sidman, M., Rauzin, R., Lazar, R., Cunningham, S., Tailby, W., & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior*, **37**, 23–44.

Sidman, M., & Stoddard, L. T. (1967). The effectiveness of fading in programming a simultaneous form discrimination for retarded children. *Journal of the Experimental Analysis of Behavior*, **10**, 3–15.

Stromer, R., & Stromer, J. B. (1989). Children's identity matching and oddity: Assessing control by specific and general sample-comparison relations. *Journal of the Experimental Analysis of Behavior*, **51**, 47–64.

Thomas, D. R., & Goldberg, H. (1985). Conditional discrimination learning by pigeons: The role of training paradigms. *Bulletin of the Psychonomic Society*, **23**, 256–258.

Thomas, D. R., Stengel, T., Sherman, L., & Woodford, M. (1987). Factors affecting conditional discrimination learning by pigeons. *Journal of the Experimental Analysis of Behavior*, **48**, 277–287.

Urcuioli, P. J. (1984). Overshadowing in matching-to-sample: Reduction in sample-stimulus control by differential sample behaviors. *Animal Learning & Behavior*, **12**, 256–264.

Urcuioli, P. J. (1985). On the role of differential sample behaviors in matching-to-sample. *Journal of Experimental Psychology: Animal Behavior Processes*, **11**, 502–519.

Urcuioli, P. J., & Honig, W. K. (1980). Control of choice in conditional discriminations by sample-specific behaviors. *Journal of Experimental Psychology: Animal Behavior Processes*, **6**, 251–277.

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