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THE EXPERIMENTAL ANALYSIS OF HUMAN BEHAVIOR BULLETIN

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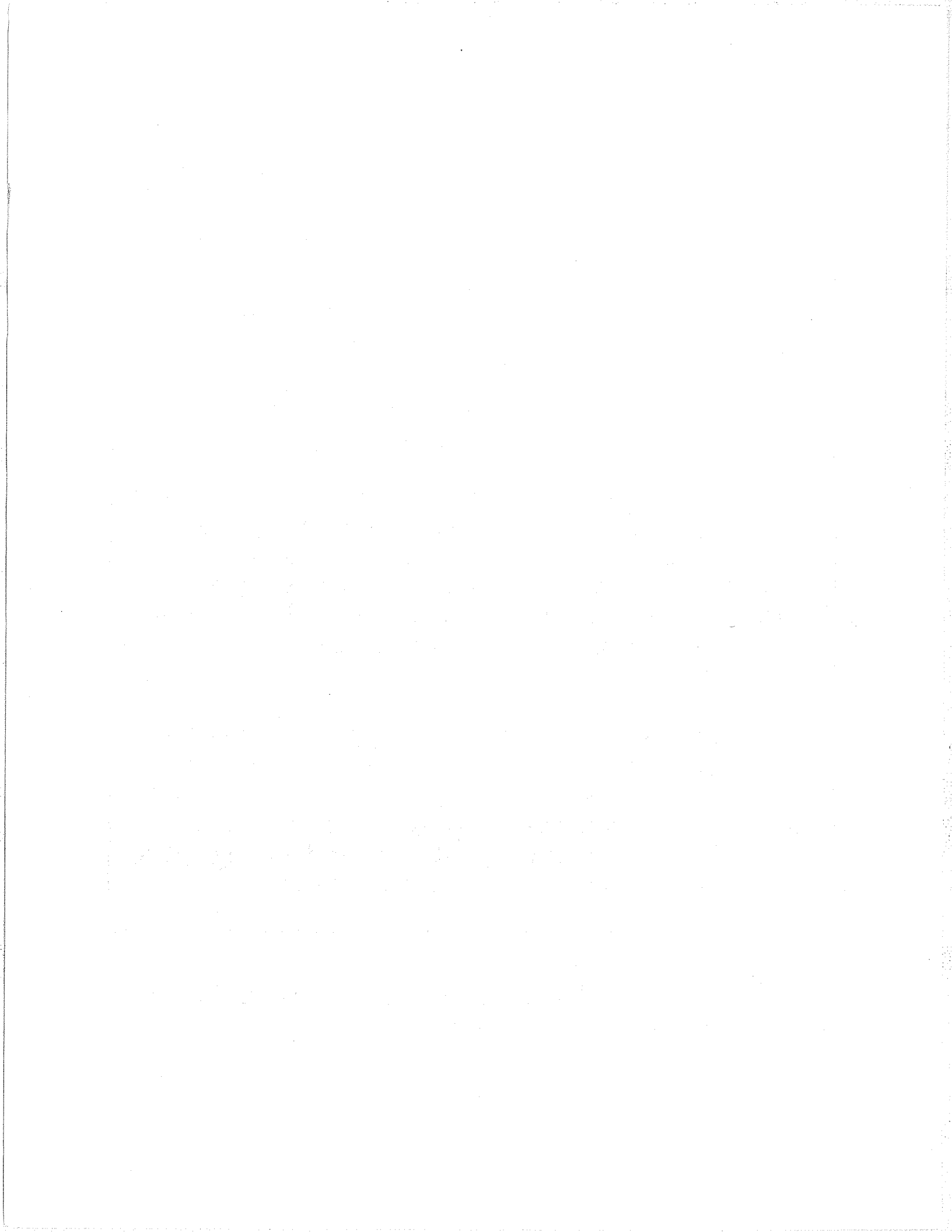
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RELATIVE SAMPLE RECENCY AND PROACTIVE INTERFERENCE IN ADULTS WITH MENTAL RETARDATION

HARRY A. MACKAY AND D. DANIEL GOULD

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and
New England Center for Autism

This research examined the performance of adults with mental retardation on a delayed spatial matching-to-sample (MTS) task. Like most MTS procedures, this task involved repeated presentations of the same stimuli across trials. It is well suited, therefore, to analyze the effects of proactive events on current performance, that is, the degree to which events on preceding trials affect performance on the current trial. One view of delayed matching performance (D'Amato, 1973) suggests that the subject's task is a temporal discrimination--to select the stimulus that had served as the sample most recently. The present study focussed on two temporal variables that might affect the discrimination of sample recency, intertrial interval (ITI) and delay durations.

Consider a delayed MTS task in which a circle and a triangle are the comparison stimuli and the samples in two successive trials were a circle (trial n-1) and then a triangle (trial n). The delay duration on each trial was 10 s and the ITI was 2 s. At the time of choice on trial n the triangle was the sample 10 s ago and the circle was the sample 22 s ago. The ratio of these two times (2.2, see upper left in Table 1) may index the difficulty of the recency discrimination: the larger the ratio, the easier the discrimination. For example, increasing the ITI duration increases the time between events on successive trials and, hence, may make the discrimination of sample recency easier. With respect to the example, increasing the ITI from 2 to 5 s increases the ratio to 2.5 (not shown in Table 1). The results of a number of studies with a variety of

subjects are consistent with the notion that increased ITI duration may make MTS and other tasks easier (D'Amato, 1973; Grant, 1975; Herman, 1975; Jarrard & Moise, 1971; Loess & Waugh, 1967; Maki, Moe, & Bierley, 1977; Roberts & Kraemer, 1982).

Table 1

		Trial n delay		
		10	20	40
Trial n-1 delay	10	2.2	1.8	1.3
	20	3.2	2.1	1.55
	40	5.2	3.1	2.05

Effects of changing delay duration are illustrated in Table 1. For example, if the delay on both trials is 40 rather than 10 s as in the preceding example (the ITI duration remains 2 s), the discrimination-difficulty ratio decreases to 2.05 (lower right in Table 1). The greater difficulty of discrimination, reflected in the lower ratios obtained with longer delay durations, could be the basis for the poorer performance usually found to occur (e.g., D'Amato, 1973; Ellis, 1963; Jarrard & Moise, 1971).

Another effect of delay duration is also reflected in Table 1. The values of the cells in each column are of particular interest because they suggest that the difficulty of the discrimination required on the current trial should be a function of the duration of the delay arranged on the trial preceding it. More specifically, the difficulty of performing a match after a given delay, say 10 s (left column) should decline if a longer delay (e.g., 20 or 40 s) is arranged in the preceding trial. Fewer errors could be expected under the conditions described by successive cells from top to bottom of each column in Table 1. Only a few studies have addressed this possibility (e.g., Turvey, Brick, & Osborne, 1970). Results suggested that the difficulty of the recency discrimination on the current

We acknowledge the continuing support of the National Institutes of Child Health and Human Development. Data collection was supported by Grant #HD 17445. Manuscript preparation was supported by #HD 25995. Support from the Department of Mental Retardation of the Commonwealth of Massachusetts (Contract 3403-8403-306) is also gratefully acknowledged.

trial may be a function of the delay duration on the preceding trial (cf. Baddeley, 1976).

GENERAL METHOD

Individuals with moderate mental retardation served. They worked at a computer-controlled stimulus-response panel consisting of a row of eight Plexiglass keys (each 2.5 cm square). Each key (designated for convenience as key 1 at left to key 8 at right) could be illuminated with blue light, the brightness of which was controlled by electronic fading circuitry.

Every trial began when a white light located above the keys came on and one key was lighted as the sample. After the subject pressed this key, its light went out, and a delay (retention interval, 1 s minimum) began. During the delay, a red light replaced the houselight and a barrier was lowered to prevent key pressing. At the end of the delay, the barrier was raised and the white light replaced the red one. All eight keys were dark. A press on the key that had been illuminated as the sample produced a token reinforcer (see below), turned off the houselight, and began the ITI. A press on any other key terminated the trial and began a blackout of approximately equal duration to the reinforcer cycle. The ITI followed.

Sessions consisted of two to four 40-trial blocks and lasted from 20 to 40 min. In each block, each of the eight keys appeared unsystematically as the sample on five trials. Blocks were separated by about 3 min. At the end of each session, tokens were exchanged for soda, food, or money.

Preliminary training used a fading method adapted from Mackay and Brown, 1971 (see also Mackay, 1991). At first, both the sample and the matching (correct) key were cued by bright light. The brightness of the matching key then was faded out gradually as a function of performance. Correct and incorrect selections decreased or increased, respectively, the brightness of the correct key on the following trial. After reliable performance of 0-delay matching had been achieved without brightness cues, the barrier was introduced and training continued until reliable performance with the 1 s delay occurred.

STUDY 1: DELAY TITRATION

Ten subjects participated. A titrating delay procedure was used to assess performance with delays longer than 1 s. Delay duration increased

by 1 s after a correct trial and decreased by 1 s after an error. The ITI was always 2 s. For each block of 40 trials, a critical delay was determined, defined as the longest delay at which correct performance occurred on at least two trials. That value then was halved to yield the delay duration for trials in the next block. Sessions were repeated until the maximum delay duration (20 s) had been achieved in four trial blocks or until 400 trials were completed.

RESULTS

Overall performance with the titrating delay procedure was first characterized by calculating the mean critical delay for four blocks of trials containing the longest critical delays. These delays ranged from 6.5 s (two subjects) to 20 s, the maximum (four subjects).

Figure 1 shows a detailed analyses of representative subjects' delay titration data collapsed across delays. The gradients reflect responses per opportunity as a function of the deviation of response location from the correct key. Responses shown at the 0 value represent correct key presses. Data to the left (-) and right (+) indicate errors; numbers reflect the deviations (number of keys) of errors from the correct key. The largest deviation, 7, resulted when key 1 was pressed when key 8 was correct and vice versa. The presses per opportunity scores reflect the fact that progressively more central correct key position progressively reduced opportunities for larger deviations.

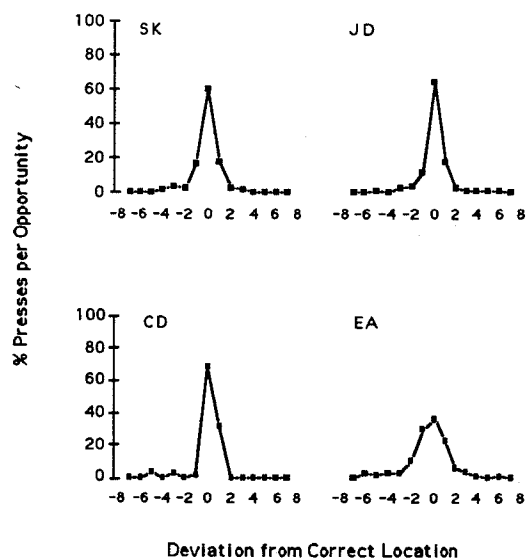


Figure 1

Gradients differed slightly across subjects but most were like those for SK and JD. The peak at around the 0 point shows that key selection was strongly controlled by the sample location. When errors occurred, most responses fell within one or two keys of the correct key. Subject EA made the most errors and the errors were widely distributed thus yielding the flatter gradient (lower right).

Figure 2 shows error analyses for four subjects relating the location of the correct key on trial n-1 to the trial n selection. Within each panel the two bars at the left (or right) show all trial n errors that were preceded by a trial to the left (or right) of the current correct key. Within each pair of bars the left (right) one shows the percentage of errors that were presses of keys to the left (right) of the correct key. Data for most subjects show strong influence on trial-n error behavior of the location of the correct key on trial n-1.

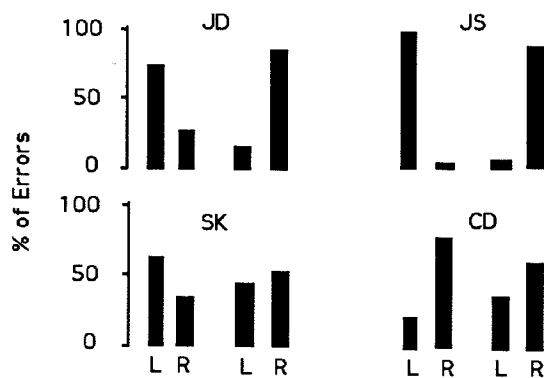


Figure 2

A chi-square test for association was conducted on a 2 x 2 matrix of the obtained error data for each subject. A significant chi-square value was obtained for nine of the ten subjects. For eight of these individuals, the position of the correct key on trial n-1 was positively related to the position of errors on trial n; one subject's errors were in the opposite direction.

STUDY 2: EFFECTS OF ITI DURATION

Six subjects participated. Delay duration was fixed in this study: 6 s for four subjects, 5 s for BF, and 2 s for EA. Programmed ITI durations were 0.5, 2, 4, and 10 s. Each ITI duration occurred on 10 consecutive trials within each 40-trial block, with order of exposure varying unsystematically across blocks. There were 80 trials for each of the ITI durations.

Calculation of temporal values. Effects of temporal variables were assessed by examining matching accuracy as a function of delay and ITI values (1) programmed by the experimenter and (2) that actually occurred. The latter was necessary because subject performance affected the values. The actual values were determined by adding the subject's response latency to the programmed interval value. For example, if a 4 s ITI was programmed and the subject's response latency was 4 s, the actual ITI was recorded as 8 s. Similarly, the actual delay was recorded as the sum of the programmed delay duration plus the response latency following white light onset. These values were used in calculating discrimination ratios that described recency discrimination difficulty.

RESULTS

For most subjects, accuracy was lowest with the shortest programmed ITI durations and highest with the longest. At the intermediate durations, there was little consistency in the relationship between accuracy and programmed ITI duration. However, when accuracy was examined as a function of the recency discrimination ratios that actually occurred (as opposed to those programmed), the direct relationship shown in Figure 3 was obtained. For these group data, the correlation between matching accuracy and the value of the recency discrimination ratio was 0.943.

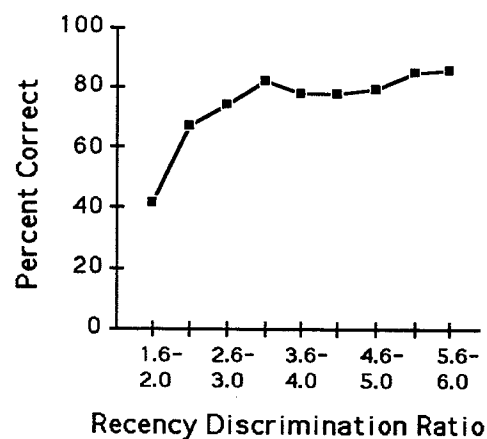


Figure 3

As before, the influence of trial n-1 on trial n was assessed by examining the location of subjects' errors in relation to the immediately preceding correct location. As in Study 1, most subjects' errors strongly reflected the effects of the location of the correct key on the preceding trial.

STUDY 3: EFFECTS OF TRIAL N-1 DELAY

Six subjects participated. The apparatus and general procedures were the same as before, but only keys 1, 4, and 7 were used as samples. This provided a symmetrical arrangement of stimulus/response locations with one key (key 4) in the center. Under these conditions, the correct keys for each two-trial sequence were carefully arranged. On even numbered trials, the correct key was always key 4. These "critical" trials were used to assess the effects of the location of the correct key on the preceding, odd-numbered trials. On these "set-up" trials, the correct key was key 1 on half the trials and key 7 on the remainder.

Delay duration on critical trials was 6 s throughout. Delay durations on set-up trials were either 1, 4, or 20 s. Each value occurred on 14 consecutive set-up trials within a 42-trial block. For each subject, the set-up delay values were counterbalanced across sessions.

RESULTS

The results relating accuracy to programmed delay duration varied across subjects. For three subjects, small accuracy increases were related to increased delay duration on set-up trials. For the others, however, accuracy increased as the set-up trial delay increased from 1 to 4 s but then declined. In contrast, matching accuracy was directly related to the recency discrimination ratios calculated from actual delay and ITI durations (correlation 0.907). The proactive effect of set-up trial location on critical-trial errors was statistically reliable (chi-square tests) for five subjects. For one subject, however, the proactive effect was in the direction opposite to the side of the set-up trial position. The remaining subject made few errors on the tests.

GENERAL DISCUSSION

The overall pattern of results is consistent with previous research showing that delayed MTS performance will be enhanced with longer ITIs and hindered with longer delays. In addition, delay duration on trial n-1 was also found to influence performance; increasing that delay increased trial n accuracy. This research is thus consistent with the temporal discrimination hypothesis (D'Amato, 1973).

Accuracy was shown to be a function of difficulty of discriminating which of two samples presented on successive trials had been the more recent. In addition, errors often reflected the failure to discriminate between the stimuli presented on trials n and n-1. When an error occurred, the incorrect key press was in the direction of the key that had been correct on the preceding trial.

Previous studies of proactive interference in humans have typically used verbal learning paradigms (e.g., paired associate learning, recall of trigrams; see Keppel, 1968). The present study extended earlier research by demonstrating interference effects in human subjects with mental retardation using a nonverbal paradigm that resembles procedures used with nonhuman animals (e.g., Medin, 1969; Wilkie, 1984, 1986). Further research with human subjects using the present procedure and other variants of the delayed MTS paradigm would help to fill methodological and theoretical gaps that separate nonhuman and human research on memory. For example, extension of the present research to include training to name key locations might further systematic analysis of the role of such verbal behavior on short-term memory performances (cf. Mackay & Ratti, 1990).

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MEMBER NEWS FOR FALL ISSUE

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INTERFERENCE IN AN IDENTITY-SORTING TASK

JESÚS ROSALES, JENNIFER PASLEY, AND JESSICA POTUCEK

University of Kansas

Studies of delayed matching-to-sample (MTS) often show that accuracy decreases as the interval between sample offset and comparison onset increases. Presumably, discriminative control has shifted from the sample stimuli to others present in the MTS format. For example, with increasing delays in brain-damaged subjects, competing control by certain comparison stimuli or positions has emerged (Sidman, 1969). Another source of competition is the stimulus-response relation that operated on the preceding trial. For example, a comparison that was the S+ of the preceding trial may be selected, even though it does not match the sample on the current trial. Such effects are sometimes labeled proactive interference, the intertrial-agreement effect, or the intrusion effect (Edhouse & White, 1988; Grant, 1975; Roberts, 1980; Roitblat & Harley, 1988; Roitblat & Scopatz, 1983; Worsham, 1975).

Certain discrimination-training procedures are designed explicitly to reduce the likelihood of control by relations operative in the preceding trials. For example, so-called "trial-unique" procedures, in which the sample and comparison stimuli appear only once during the session, have produced highly accurate delayed identity MTS performance. Interestingly, both nonhumans and developmentally limited humans have been shown to acquire MTS more slowly with standard conditional-discrimination procedures, in which the sample and comparison stimuli appear many times in each session, than with the "trial-unique" procedures (McIlvane, Dube, Kledaras, Iennaco, & Stoddard, 1990; Mishkin & Delacour, 1975; Pisacreta, 1990)—perhaps because of the competing across-trial stimulus control that the standard

procedures allow. Moreover, when highly accurate MTS acquired via the trial-unique procedure is subjected to the standard procedure, accuracy may decrease unless the shift is made gradually (cf. Dube, McIlvane, & Green, 1992; Mishkin & Delacour, 1975).

The present study examines an "identity sorting" task that has some features in common with standard MTS procedures. The study reveals that assessing identity relations by way of sorting procedures may yield surprising results: Procedures that seem functionally equivalent on their face may in fact differ in allowing unprogrammed, undesired stimulus control by the events of preceding trials.

METHOD

Subject

A 23-year-old autistic man served as the subject. He could name all the experimental stimuli and say correctly if any two of the stimuli were the same.

Stimuli

The stimuli were line drawings of six animals—elephant, rabbit, horse, butterfly, frog, and mouse—each on a separate 4 cm square white card, as shown in Figure 1.

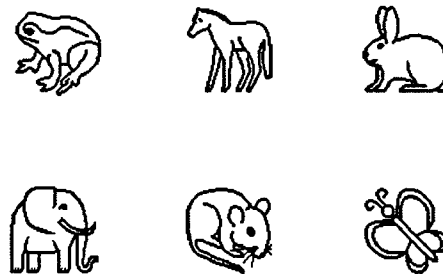


Figure 1

Experimental Conditions

Two sorting tasks were used. One was to sort by sample 10 pictures of animals into one of three side-by-side boxes. The experimenter chose two pictures as samples (Samples A and B); each end

Correspondence may be addressed to any author at the Department of Human Development, University of Kansas, Lawrence KS 66045. The authors are grateful to Dr. Lawrence Stoddard for his instructive evaluation of a preliminary report of this research, and to Dr. Donald M. Baer for repeated advice in preparing this report.

box displayed one of these two pictures, and the middle box displayed no sample. Of the 10 pictures to be sorted, some corresponded to Sample A, others to Sample B, and still others to neither A nor B. Before each sort, subjects were told, "Put in this box [pointing to the left-side box] the pictures that are the same as this" [E placed Sample A in front of the box]. E then repeated the comparable operation and instruction with Sample B and the right-side box. Then E said, "Put in this box [pointing to the center no-sample box] the ones that are different."

The subject sorted all 10 cards before feedback was given. When he had finished the deck, E said, "Let me see if you got all of them right," recovered all the pictures from the Sample-A box, and placed each card in front of that sample, one at a time, saying "Yes" for each picture correctly sorted into that box. For each incorrectly sorted picture, E placed it beside Sample A and asked, "Are these the same?" If S said "No," E then asked, "So where does it go?" The same procedure was applied to the pictures in the Sample-B box. For the pictures sorted incorrectly in the center box, E placed them beside the sample that they matched and asked, "Are these the same?" If S said "Yes," E handed S the picture and asked, "So where does it go?"

The second sorting task eliminated the "different" box. Five of the 10 cards to be sorted matched Sample A and 5 matched Sample B. Instructions and feedback were analogous to those used in the 3-box sorts.

The three successive experimental phases differed primarily in whether or not two 2-box sorts occurred before the two or three 3-box sorts required in that phase. In the first phase (sessions 1-16), S was asked to make three 3-box sorts per session; the sample stimuli changing from the first to the third sort in the order, ELEPHANT-HORSE, FROG-RABBIT, and BUTTERFLY-MOUSE (the A sample is always listed first, the B second). In the second phase (sessions 17-20), S was asked to make two 2-box and two 3-box sorts per session; the sample pairs were repeated in the 2- and 3-box sorts, in the order, ELEPHANT-HORSE (2-Box), FROG-RABBIT (2-Box), ELEPHANT-HORSE (3-Box), and FROG-RABBIT (3-Box). In the last phase (sessions 21-29), S was asked to make two 2-box and two 3-box sorts per session, now without repetition of sample pairs, in the order, FROG-ELEPHANT (2-Box), HORSE-RABBIT (2-Box), ELEPHANT-HORSE (3-Box), and FROG-RABBIT (3-Box).

Preliminary Training

Before these three phases began, 3-box sorting was trained in three stages (by instructions, questions, prompts, and feedback after each card placement—details available from the authors). At the end of Stage 1, S was sorting correctly 6 consecutive stimulus cards into two boxes, one displaying a mouse and the other without a sample. Each sorting of a card was guided by the experimenter's questions, "Are these the same?" and "So, where does it go?" At the end of stage 2, S was making two consecutive perfect sorts of 10 cards into two boxes, one with a frog sample and the other without a sample. In this stage the experimenter handed S the card to be sorted and asked, "Where does it go?" At the end of stage 3, S was making two consecutive perfect sorts into three boxes: the mouse sample on the left, the frog sample on the right, and a no-sample box in the middle. In this stage the experimenter asked questions only when errors occurred.

RESULTS

Figure 2 indicates stimulus cards sorted to Sample A, Sample B, and neither A nor B (within the dotted box), during the 3-box sorting task. In general, the location to which stimuli were correctly sorted in earlier sorts interfered with control by the samples in later sorts. In Phase 1, sorting was usually highly accurate in the first sort and much less accurate in the second and third sorts. Errors usually involved sorting pictures to their formerly correct box: For example, in the second sort, elephant was most often sorted to Sample A and horse to Sample B, even though these boxes now displayed pictures of frog and rabbit respectively. Similar disruption occurred in the 3-box sorts of Phase 2, which were conducted after an immediately previous history of virtually perfect 2-box sorts with the Sample A and B stimuli. (Data from the 2-box sorts are not shown; there were no errors in Phase 2 and only 3 errors across 18 sorts in Phase 3). Note that in the fourth set, elephant and horse were always sorted to their previously correct location. In contrast, stimuli that had not appeared as samples in previous trials were usually correctly sorted into the "neither" box (e.g., butterfly and mouse in the fourth sort of Phase 3, and, to a lesser extent, butterfly and mouse in the third sort of Phase 1).

DISCUSSION

The rejection-response option in the identity sorting task—the “different” box—made possible the presentation of pictures that were not identical to either sample. If the only operative stimulus control over sorting was the identity relation, and if the earlier instructions about the “different” box remained operative, then the stimuli that were different from both samples should have been placed in the “different” box in every case. With the subject of this study, however, control by identity depended on the subject’s immediate history with the stimuli to be sorted. In the first task of each session, identity control of selection was predominant. By contrast, accuracy in subsequent sorts in each session was lower, reflecting at least two types of sorting errors: (1) placing stimuli that corresponded to the samples of earlier tasks with those that matched the samples of the later tasks, and (2) placing pictures that were identical to the current samples in an incorrect position that had been the correct position for that picture earlier in the session. These were errors only from the experimenter’s point of view; they indicated competing control by events that occurred earlier in the session.

When the 2-box sorts occurred before 3-box sorts (Phases 2 and 3), undesirable control by previous sample stimuli became evident in the first 3-box sort. This sort had been free of consistent error patterns in Phase 1. The less accurate 3-box sort, therefore, was probably influenced by what response had been reinforced in the immediately preceding 2-box sorts. Note also that identity sorting was almost error-free in the 2-box sorts. This accuracy was maintained even for the sample stimuli that were sorted together in the 3-box sorts of Phases 2 and 3 (e.g., Frog-Elephant and Horse-Rabbit).

The 2-box and 3-box sorts might be seen as only subtly different versions of otherwise similar procedures for studying identity relations. The obvious difference in the stimulus control evident in these formats, however, raises important issues pertinent to training and maintenance of identity relations, and perhaps other relations. First, when procedures demonstrate apparent identity control under one set of circumstances, we may not confidently assume that comparable identity relations will be evident under different circumstances. Second, and more important, full analysis

of the circumstances under which identity relations are evident will require analyses of more than one procedure. In efforts to reduce problems of competing stimulus control in certain experimental preparations, some experimenters have tended to restrict their research (and sometimes their conceptualizations) to the procedures that maximize the stimulus control of interest. This approach relegates any failures in that stimulus control to the category of procedural artifacts, perhaps implying that the relevant processes are not in themselves important and in need of analysis. Overman and Doty (1980), for example, argued that short-term memory should not be studied in delayed identity MTS formats that use repetitive sample stimuli, to avoid the potential problems of across-trial control. A similar recommendation was made for training simultaneous identity MTS (Pisacreta, 1990). If these suggestions are followed strictly, the resulting research will not address the important fact that otherwise, many subjects would display competing, across-trial discriminative control in the identity format—a control that might be avoided by multi-format training. Also ignored would be the analysis of why identity MTS performances initially disrupted by repeated-sample procedures can eventually be made perfect in subsequent repeated-sample procedures by appropriate training (Dube et al., 1992; Mishkin & Delacour, 1975). Although the arrangement of favorable conditions for studying certain processes is important, it seems equally important to reveal sources of competing control that make certain conditions unfavorable. By doing so, the analysis will be more nearly complete. More complete analysis is important for scientific reasons, and to improve our ability to teach effectively. For example, if the concern is to teach identity relations to improve everyday functioning of people with mental retardation, a comprehensive analysis is necessary. Showing that an individual can be taught identity control under only a restricted set of procedures is not enough; we need methods that establish stimulus control dependable across various formats.

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RESEARCH IN PROGRESS

POSSIBLE EFFECTS OF THE PROCEDURE TO TEACH CONDITIONAL DISCRIMINATIONS ON THE OUTCOME OF TESTS FOR STIMULUS EQUIVALENCE AND TRANSFER OF FUNCTIONS

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The original purpose of this research was to investigate effects of nodal distance on transfer of discriminative functions. Subjects learned a series of conditional discriminations, each referred by a pair of letters: thus, in conditional discrimination AB, samples were A1 and A2 and comparison stimuli were B1 and B2. Selections of B1 were reinforced in the presence of sample A1, and selections of B2 were reinforced in the presence of

sample A2. For all subjects, a modified version of the blocking procedure (Saunders & Spradlin, 1989) was used to train a conditional discrimination in a pretraining phase; all subsequent conditional discriminations were trained by "trial-and-error."

Students from the Federal University of Sao Carlos were subjects in the first study. An IBM-PC microcomputer was used to present abstract pictures (identified by alphanumeric combinations). Subjects responded by typing the "arrow" key that corresponded to the location of the stimulus. Six subjects (Group 1) learned a series of conditional discriminations involving 4 nodes: AB, BC, CD, DE, and EF. A simple simultaneous discrimination was then trained: selections of A1 (S+) were reinforced and selections of A2 (S-) were

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followed by negative feedback. Subjects were then exposed to a mixed baseline, including trials from the simple discrimination and all conditional discriminations, and feedback for correct responses was removed.

For five other subjects (Group 2) the conditional discrimination training involved a single node: AB, AC, AD, AE, and AF (one sample: many comparisons). Subjects then learned the simple discrimination with A1 as S+ and A2 as S-, and were exposed to the mixed baseline without feedback.

Both training conditions could result in two equivalence classes: A1/B1/C1/D1/E1/F1, and A2/B2/C2/D2/E2/F2. S+ and S- functions acquired by A1 and A2, respectively, could transfer to the other class members. Probes were presented to verify class formation and transfer of discriminative functions. No subject in Group 1 showed evidence for class formation or transfer. All subjects in Group 2 showed class formation and transfer.

These results were replicated with Groups 3 and 4, which had the samples and comparisons reversed. Conditional relations were BA, CB, DC, ED, and FE for Group 3, and BA, CA, DA, EA, and FA (many comparisons: one sample) for Group 4. None of the five subjects in Group 3 showed either class formation or transfer. All five subjects from Group 4 showed class formation and transfer.

In the second study, subjects were staff members of a school in Massachusetts. The apparatus was a Macintosh computer; subjects responded by moving the cursor to the desired location and pressing the button on the mouse. Two groups of five subjects each received training similar to Group 1 and 2 of the first study. All conditional discriminations were trained with an on-screen prompt. On the first few trials of each new conditional discrimination, the phrase "when this is here" was written below the sample, and the phrase "pick this" was written below the correct comparison stimulus. All subjects in both groups formed equivalence classes and showed transfer of functions. To rule out communication between subjects as a factor in the discrepancy between data in both studies, we included two additional subjects in Group 1. Neither had contact with the previous subjects. Both showed class formation and transfer.

The second study was a replication of the first with a different subject population and minor procedural variations. Although the subject populations differed (Brazilian college students and American professionals), a major feature of

stimulus control research (and behavioral research in general) is the replicability of basic findings with widely different subject populations. Therefore, it is more likely that procedural variations affected results.

As McIlvane and Dube (1992) pointed out, apparently similar conditional discrimination performances may involve different "stimulus control topographies." Different training procedures may favor different stimulus control topographies. With training by trial and error, it is likely that subjects learn some discriminations by sample-S+ control and others by sample-S- control. The prompt used in the second study may have biased subjects toward sample-S+ control. In addition, the difference in response topographies may have also affected results. In Study 1, when subjects responded using the keyboard, observation of the S+ stimulus was not required. In Study 2, however, when subjects responded using the mouse, observation of the S+ stimulus was required because subjects needed to move the cursor directly to the S+ stimulus. This may have further biased subjects toward forming sample-S+ relations. It is likely that instructing and reinforcing sample-S+ relations was a critical variable because sample-S- control may result in the formation of classes different than those intended by the experimenter (cf. Carrigan & Sidman, 1992; Saunders & Green, 1992). If this procedural variable was responsible for the failure to replicate, it is necessary to explain why only the groups with a class structure with many nodes were affected. Further studies will investigate the effects of the procedural variables just described.

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SUMMARIES OF 1991 STUDENT PAPER COMPETITION WINNING PAPERS

Stimulus Equivalence as a Theoretical Framework for the Study of Category Learning in Children

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When developmental psychologists study such phenomena as language, concept formation, categorization, and symbolic representation, they tend to follow an established tradition of describing the conceptual mechanisms, processes, or cognitive structures that are thought to underlie the behaviors to which the phenomena refer. That this is the goal of such investigations is usually explicit. While description is necessary for an adequate theory of development, it is not sufficient. Nevertheless, developmental psychologists are dealing with a range of complex human behaviors such as thinking, remembering, categorizing, and using symbols which are not only appropriate but important topics of study.

While developmental psychology points to and describes complex behaviors that behavior analysts should find interesting, behavior analysis, with its explicit concern with identifying the determinants of behavior, will be more fruitful in accounting for how these basic but complex human activities occur. The purpose of this paper is to explore the application of a behavior analytic approach to the study of concept formation/category learning. In particular, it is argued that stimulus equivalence provides an excellent conceptual framework to explain and extend the traditional literature on the development of categorization.

First, the paper presents findings from the traditional literature on category learning in children that are particularly relevant to the behavior analytic work on stimulus equivalence. This is followed by a discussion of relevant data from the behavior analytic literature. Finally, research issues and directions suggested by this analysis are discussed.

To illustrate the thrust of the paper, developmental psychologists are interested in categorization for the same reasons behavior analysts are excited about stimulus equivalence. That is, both are considered to be the means by which humans come to "learn about" or behave appropriately in novel situations. If categorization and the emergence of equivalence classes are essentially the same phenomenon, then the conditions under which equivalence classes emerge also point to the determinants of categorization learning in children.

The consensus among developmental psychologists seems to be that a mental representation of a prototypical example of a category arises out of direct experiences with specific instances of that category. For example, it is through various experiences with apples that what a

child learns about them is thought to be incorporated into a prototypical "apple concept." The conclusion drawn from much of this research is that the function of stimuli seems to be a more important determinant of the prototype than what are called the "perceptual properties" of stimuli. Thus, the "categories" or "classes" involved in the traditional literature on concept formation seem to be classes by virtue of shared stimulus function.

Hierarchical categorization can be viewed as a special instance of categorization. The developmental literature describes hierarchical categorization as learning that "basic-level" categories also belong to "superordinate categories." For example, there are ways in which dogs and cats are treated similarly as pets. Thus, "dogs" as a "basic-level" class and "cats" as a "basic-level" class are also said to belong to the larger "superordinate" class "pets."

What we know about stimulus equivalence is certainly relevant to categorization based on stimulus function. For example, the behavior analytic literature provides important information about the conditions under which equivalence classes emerge and hold. In particular, recent findings on the conditional, or contextual control of emergent equivalence relations demonstrates that it is only in specific contexts that responding to a given group of stimuli as equivalent will be effective. This suggests a given stimulus can belong to several different categories at once, an issue that has not been addressed in the traditional literature. This explains why a child may correctly describe a stuffed bear as belonging to many different categories, such as "things you cuddle," "pretend zoo animals," or "things you can throw in the house." Which of these the bear "is" at any given moment depends on the context.

It is suggested that contextual control also explains how classes can become functionally related to other classes in a hierarchical fashion, something that remains to be studied by behavior analysts. It may also be that we talk about "hierarchical" classes when stimuli are related by increasingly general stimulus function. This would be another interesting research question. It is suggested that new work be done to explore these and other research questions raised by the traditional developmental literature, using behavior analytic methods which point to the environment-behavior relations necessary for a complete scientific account of the phenomena.

Stimulus Classes: The Result of Differential Response and Delayed Conditional Discrimination Training

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In stimulus equivalence research with match-to-sample procedures, certain performances indicating untaught conditional relations among stimuli in a set are required in order to infer that an equivalence class has developed. This inference is based on the observed interchangeability of the stimuli in the conditional discriminations, revealing the relational properties of reflexivity, symmetry, and transitivity. In contrast, a functional class is demonstrated when (a) a set of stimuli control a common response and (b) an operation applied to a subset of the stimuli result in a corresponding change in the other members of the set. The distinction between functional stimulus classes and stimulus equivalence classes is the topic of this research. Will children match arbitrary visual stimuli that control a common response?

Thirteen preschool children were exposed to a 0 s-delay, two-choice conditional matching procedure with a differential response requirement on some trials: Dot-like stimuli appeared above and below the sample, and the children learned to touch the upper dot in the presence of samples potentially in one class (A1, B1, etc.) and to touch the lower dot in the presence of samples potentially in the other class (A2, B2, etc.). Differential responses to comparison stimuli and to sample stimuli on probe trials were never required and did not occur. In Experiment 1, differential-response identity matching was trained (A1A1, A2A2, etc.) and arbitrary matching (A1B1, A2B2, etc.) was tested. Only two children matched sample stimuli that controlled the same differential response, suggesting that for the remaining children, comparison selection on tests was not under differential response control.

Seven of the children participated in Experiment 2 wherein differential-response DE, DF, GH, and GI arbitrary conditional match training was followed by tests to establish that two pairs of equivalence classes, D-E-F and G-H-I, with no common stimuli, had developed. The children then were tested for inclusion of the A, B, and C stimuli in the equivalence classes, based on a common differential response, and for the merger of the DEF classes with the GHI classes on the same basis. Results were positive for three children. Thus, the

development and merger of functional classes with stimulus equivalence classes was observed in these children. For these three children, the definition of functional class is fulfilled because (a) a set of stimuli control a common response (touch to a particular location) and (b) an operation applied to a subset of the stimuli—establishing D and G as members of equivalence classes—resulted in establishing the remaining stimuli (A, B, and C) as members of the equivalence classes.

Consider an alternative explanation: stimulus equivalence class formation and merger with locations (or positions) as nodal stimuli in the classes. In Goldiamond's (1966) example of functional classes, the implied "responses" are "stepping on the brake pedal" and "stepping on the gas pedal." Because the depression of foot peddles to stop and go are topographically the same, the location of the depressed pedal determines whether the response is correct. In the current experiment, if differential response training produced conditional relations between the sample stimuli and the locations (as stimuli, L1 and L2) of the differential responses, then subsequent arbitrary matching trials tested for the combined properties of symmetry and transitivity for equivalence classes A1, B1, C1, D1, G1, L1 and A2, B2, C2, D2, G2, L2. In this analysis, the functional stimulus classes satisfy the prerequisites for stimulus equivalence classes.

If the matching of functional class members is dependent upon the inclusion of the common response location as a member of an equivalence class, then there may be no difference between the stimulus control of matching performances for functional and stimulus equivalence classes. If so, methods for training the prerequisites for equivalence class formation in infrahuman organisms may more nearly parallel those traditionally used with humans than previously thought.

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Biological and Behavioral Selection: Similar Subprocesses?

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Theories of both biological evolution and operant conditioning suggest that variations are selected by environmental consequences (Donahoe, 1991). Skinner (1981) and Glenn (1991) have discussed analogies between natural selection and the selection of behavior through consequences. Glenn (1991) has suggested that the behavioral subprocesses of reinforcement and extinction are analogous to the selection and extinction of organisms which meet or fail to meet the requirements of a stable environment. An examination of the natural selection subprocesses that select against organisms reveals possible analogies with the behavioral subprocesses of punishment and extinction.

The subprocesses of natural selection and the selection of behavior by consequences appear to operate at analogous levels. Both the species and the operant are classes which evolve as they interact with stable aspects of the environment. A species is a class of individual organisms (phenotypes) just as the operant is a class of individual responses. Further, an organism's phenotype is largely determined by its genetic composition just as the topography of a single response is largely determined by neurophysiological events. However, the genetic and neural levels are probably not the levels at which the selection processes occur. Natural selection and selection by consequences appear to work at the levels of the phenotype and individual response as they are in physical contact with the environment. However, genes, and possibly neurophysiological responses, are replicated in subsequent generations, or responses.

Just as reinforcers select those responses which meet the contingencies in operation, the natural environment selects those phenotypes which meet the minimum requirements of the stable contingencies of survival. The genetic composition of the organism which meets the environmental requirements is replicated in its progeny with some degree of variability caused by the meiotic process in diploid organisms and random mutation. As new phenotypes possessing a selective advantage over other phenotypes interact with the environment, an increase in the population of the mutated genes is observed in the gene pool. A similar process occurs when reinforced responses are increased along some physical dimension during response acquisition.

Essentially the opposite effect is observed when a particular phenotype fails to meet the contingencies of survival, or a particular response meets a punishment contingency. For example, organisms born with blood cells requiring oxygenation will not live to reproductive maturity if oxygen collecting organs such as lungs or gills are not present. As this phenotype fails to meet the contingency of survival, the unfit genotype will be quickly removed from the gene pool. Similarly, pun-

ished responses rapidly decrease in rate. The rapidity of decreases in both selection processes is mitigated by parametric variables (e.g., intensity of the punishing stimulus or degree to which the phenotype is at odds with the contingencies of survival).

A second method by which genes are decreased in relative proportion in the gene pool is analogous to the behavioral subprocess of extinction. Just as previously reinforced responses that are no longer reinforced gradually decrease in rate, so too do previously selected genes which lose their selective advantage. A familiar example illustrates this process. In a malaria-rich environment organisms possessing the heterozygous genotype SA are malaria resistant because a small percentage of their red blood-cells are sickle shaped. Organisms possessing either homozygous genotype AA or SS are at a selective disadvantage given that the former possess no malaria resistance and the latter most often die of anemia. Nonetheless, the three genotypes are continually represented in the gene pool because both the S and A genes are represented in the advantaged heterozygote. Eradicating malaria causes the S allele to lose its advantageous status and the genotype is observed in gradually decreasing proportions in the gene pool (see Sober, 1984, pp. 40-42 for Darwinian fitness equations). Changing the environment in a manner which causes a genotype to lose its selective advantage is similar in process and effect to extinction.

Given the apparently analogous selection subprocesses of operant conditioning and natural selection, researchers in both fields may find it fruitful to direct their research efforts in directions the other discipline has found informative. For example, biologists have learned much by understanding the variables effecting genetic variability and mutations. Operant researchers may likewise find the origins of response variability a useful area of investigation.

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Precurrent Operants: A Preliminary Analysis

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One consequence of behavior can be to affect the conditions controlling another operant behavior. To distinguish between these two behaviors we call the former "precurrent" and the latter "current." A defining, and possibly important, feature of precurrent behavior is that it does not directly produce the reinforcer; rather, reinforcement is mediated through another (current) behavior of that same organism.

Skinner has made use of the concept of precurrent behavior in his interpretative analyses of human conduct. Initially, he wrote in terms of a "controlling response" altering variables so as to change the probability of a "controlled response" (1953, p. 231). In later works the term "precurrent behavior" was emphasized which "changes either our environment or ourselves in such a way that 'consummatory' behavior occurs" (1968, p. 121), "makes subsequent behavior more effective" (1968, p. 124), and "furthers the reinforcement of subsequent behavior" (1969, p. 137). The focus of his discussions have concerned the case in which precurrent behavior changes the situation so that the current behavior can occur (1968, p. 132). For example, when asked "Who is that behind you?", the precurrent behaviors of turning and looking "generate a discriminative stimulus in order to emit a particular name" (Skinner, 1969, p. 142). There is, however, another way that precurrent behavior can "make subsequent behavior more effective": it may increase the probability (or magnitude) of reinforcement for the current behavior. While Skinner does not discuss precurrent behavior in this context, he does not ignore this type of contingency. Consider the "autoclitic." According to Skinner, "the autoclitic component acts upon the listener to strengthen his [the listener's] reaction to the response which it accompanies" (1957, p. 326). Thus, autoclitics are verbal precurrent behaviors that alter the reinforcer component of other verbal operants.

A preliminary experimental analysis was concerned with the conditioning and maintenance of precurrent behavior that functions to enhance the reinforcement probability for current behavior. Subjects responded on a computer mouse that contained two keys. Pressing the right-key was reinforced according to a probability schedule ($p = .02$ or a minor deviation thereof). Depending on the condition, pressing the left-key either had no scheduled consequence (the precurrent contingency was absent) or increased the reinforcement probability ($p = .08$) for right-key responding for 15 s (the standard precurrent contingency was present). Generally, with no precurrent contingency, left-key responding quickly dropped to near zero levels; with the precurrent contingency present, left-key responding maintained at enhanced levels. Initial exposure to the precurrent contingency resulted in the acquisition of left-key responding for four of eight subjects. For the other four

subjects, a special conditioning procedure was required, which included either: (1) increasing the degree to which a left-key response raised the reinforcement probability for right-key responding, or (2) decreasing the reinforcement probability for right-key responding to zero unless a left-key response had occurred within the previous 15 s. Both procedures produced enhanced levels of left-key responding which eventually maintained when the standard precurrent contingency was reintroduced. For four subjects, a changeover delay (COD) was later imposed onto the precurrent contingency, and in two cases the COD reduced left-key responding to near zero levels. Right-key responding generally occurred at a high stable rate within sessions, between sessions, and between conditions. Efficiency (i.e., the proportion of right-key responses in a session emitted under the enhanced probability state) rarely approached maximal levels and generally did not improve with extended exposure to the precurrent contingency. The accuracy of post-session verbal reports varied both between- and within-subjects, and also generally showed little improvement with the continued presence of the precurrent contingency.

Clearly, one behavior can affect the conditions controlling another operant behavior such that the second behavior is more likely to occur (see, e.g., Guevremont, Osnes, & Stokes, 1988; Zeigler, 1987) or more likely to be reinforced; that is, many behaviors serve a precurrent function. It is less clear what role, if any, precurrent contingencies play in the conditioning and maintenance of precurrent operants. In our preparation, a precurrent operant did not always develop and maintenance was sometimes fragile. Continued research into precurrent contingencies may discover commonalities between such seemingly diverse behaviors as stepping on the accelerator pedal before starting the car, qualifying statements with "I think. . ." being polite, and looking at someone when speaking.

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Human Manual and Vocal Responding Under Temporal Schedules of Reinforcement

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In operant theory, form or modality of the response is considered arbitrary (Skinner, 1935). Response forms are selected in part on the basis of experimental convenience (e.g., easily recorded and easily emitted by the animal). Support for the belief in the generic nature of operant responses is found in the wide generality of the effects observed across species. However, many studies with humans show discrepancies with the animal findings. For instance, cumulative records of animal fixed-interval (FI) performances show a pause followed by an accelerated rate of responding (Ferster & Skinner, 1957). In contrast, most cumulative records of human FI performances show a constant rate of responding throughout the interval (Lippman & Meyer, 1967).

These performance differences may result in part from the response modality chosen for study (e.g., Branch, 1991). For example, the most frequently employed human response, button pressing, may differ from commonly used nonhuman responses in terms of "typicality" for the subject or in terms of pre-experimental histories. Thus, a response modality that is both transducible and "typically-human" should be investigated to test the idea that observed differences between human and animal performances may stem from nonparallel testing procedures. For example, Gonzalez and Waller (1974) found that human handwriting was temporally patterned under FI schedules.

Two experiments were conducted. Each contained four conditions formed by combining two levels of the response (manual or vocal) with two levels of the feedback (verbal or nonverbal). In each condition, subjects either responded orally with the word "Ready" or pressed a hand-held noise-making device (a cricket) to obtain reinforcers. Feedback displayed on the monitor was either verbal (the words "Ready" or "Not Ready" printed on the computer screen) or nonverbal (the symbols "<<<>>>" or "**** ****"). In Experiment 1, responses were reinforced according to a FI 30-s schedule, and in Experiment 2, responses were reinforced according to a differential-reinforcement-of-low-rates (DRL) 5-s schedule.

In Experiments 1 and 2, no differences were found between manual and vocal responses, and feedback did not appear to enhance schedule control. The results of Experiment 1 showed that the response patterns of most subjects (22 of 28) under the FI schedule were characterized by high steady response rates and brief post-reinforcement pauses. The response patterns of the remaining subjects (6 of 28) were characterized by low response rates and long pauses. Reinforcement rates were negatively correlated with response efficiency (percentage of reinforced responses). The results of Experiment 2 showed that the response patterns of most subjects (24 of 28) were characterized by low response rates and long pauses. The response patterns of the remaining subjects (4 of 28) were characterized by high steady response rates and brief pauses. Reinforcement

rates were positively correlated with response efficiency—results that are consistent with animal DRL performances (Kramer & Rilling, 1971).

These results show that regardless of the response modality or type of feedback, most subjects responded in ways that maximized reinforcement rates under both temporal schedules of reinforcement. Therefore, variables other than response modality may be responsible for human-animal performance differences under FI schedules. The results of human responding under the DRL 5-s schedule used in Experiment 2 suggest that human-animal performance differences under FI schedules may be due to response-cost (Azrin, 1958).

Under FI schedules, the differences in human performance from that of animals may be a consequence of the minimal response cost for the subject, whereas under DRL schedules, human and animal performances are similar (despite numerous procedural differences) because response cost is an inherent feature of the schedule. One might argue that the DRL schedules possess a response-cost contingency (reinforcement delay) that generalizes across species, whereas FI schedules do not. Consequently, FI schedules can accommodate a wide variety of response patterns. This suggests that comparisons made between subjects' response patterns under schedule contingencies that accommodate a wide range of variability in response patterns should concentrate on the functional properties of responding (Zeiler, 1977).

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