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# *RECOGNITION MEMORY IN OLDER ADULTS: ADJUSTMENT TO CHANGING CONTINGENCIES*

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Four older and 4 younger men were given extended exposure to a continuous-recognition memory procedure. Experimental variables included the type of stimulus (alphanumeric strings, words, or sentences), the intervals separating repeated items, gains and losses for correct and incorrect recognitions, and the extent of practice with the memory task. Signal detection analyses indicated that the older men generally were less accurate (sensitivity), particularly when the stimuli were strings, but that age differences decreased with practice. Under conditions in which the payoff matrix was neutral, the older and younger men showed equivalent rates of hits and false alarms (bias). Alteration of the matrix to require more liberal or more conservative patterns of recognition responding led to corresponding changes for men of both ages. Adjustments by the older men, however, were not as close to the bias values called for by the new matrices.

*Key words:* remembering, continuous-recognition memory, signal detection theory, sensitivity, bias, practice effects, key press, old and young adults

A well-known finding in the psychology of aging is that advancing age is accompanied by progressive failures of memory; various descriptions, discussions, and theories of this phenomenon may be found in the literature on aging (e.g., Kausler, 1982; Poon, 1985). The single-subject research methods of the experimental analysis of behavior (Sidman, 1960) have the potential for clarifying such changes in human operant performances, and, perhaps, for suggesting remedial procedures (cf. Skinner & Vaughan, 1983). But even a cursory survey of the literature on this topic will reveal that information about age and memory is more likely to come from experiments in which the conclusions rely heavily on statistical comparisons of the average performances of groups of old and young individuals. A necessary aspect of group statistical experiments is that each age group include a sufficient number of individuals to offset divergent performances by any particular member. However, the need for large samples works against close experimental control and makes it impractical to observe any given individual for very long.

Sidman (1960) and others have discussed the limitations of group statistical methods. We noted in this regard that the problems become particularly apparent when older adults are the subjects of study (Baron & Menich, 1985; Baron & Perone, 1982; Perone & Baron, 1982). There is reason to believe that variability increases with age. For this reason, conclusions based on group averages may not apply to all members of the group (Kausler, 1982). In addition, older adults may be unfamilar with laboratory procedures and may be prone to respond defensively when their performances are evaluated.[1] Consequently, deficits may be more indicative of transitory reactions than of a true loss of capability. These considerations point to the value of single-subject methods for the study of aging. The analysis of human performances as steady states focuses attention on the range of individual performances that contributes to the group average. In addition, observations over a series of sessions are more likely to give the older individual time to adapt to novel procedures.

Concerning memory in particular, the continuous-recognition paradigm (Shepard & Teghtsoonian, 1961) has features that make it compatible with a single-subject analysis. The subject in a continuous-recognition memory experiment views a series of stimuli (e.g.,

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[1] Hulicka, I. M. (1978). *Cognitive functioning in late adulthood.* Master lecture series on the psychology of aging. Washington, DC: American Psychological Association.

words) presented one at a time. He or she responds to each item in terms of whether it was encountered previously; that is, the subject emits a recognition response ("old") or a nonrecognition response ("new"). With this method, data from each subject can be used to generate entire retention functions by arranging the series with appropriate intervals between repeated stimuli. In addition, the results lend themselves to signal detection analyses (Green & Swets, 1966) in which the previously presented items are considered signals that appear against the background of the noise of the new items (Murdock, 1982). The distinction, within signal detection theory, between response sensitivity (the ability to recognize previously encountered stimuli) and response bias (tendencies to emit or withhold the recognition response) is of special importance for the study of aging. According to some writers (e.g., Botwinick, 1984; Okun, 1976), deficits on tests of memory may reflect not only fundamental limitations of memory but also a reluctance to report that an item has appeared previously, perhaps because of a history of aversive consequences when stimuli are falsely reported.

The experiment reported below was designed to clarify the results of some recent experiments on aging that used continuous-recognition procedures. Poon and Fozard (1980) found that a group of older subjects manifested lower sensitivity scores than a young adult control group (results were based on a single session, however). In addition, errors by older individuals were biased in a conservative direction; that is, the subjects were less likely to respond "old" to a new item. On the assumption that inexperience may have contributed to the age differences, we extended the Poon and Fozard procedure to include observations over a series of sessions (Le Breck & Baron, 1987). With practice, the older adults improved substantially in their ability to recognize previously presented items, although age differences were not reduced (the equivalently trained young adults showed equal gains). Concerning bias, the results were contrary to those of Poon and Fozard in that age differences were not observed at any point.

These results are encouraging for the view that memory deficits in the elderly can be remediated, but they do not provide good support for the hypothesis that recognition deficits in older adults are exaggerated by a reluctance to emit recognition responses. Subsequent consideration of age–performance interactions suggested that the performances of older adults may be more a function of reduced plasticity of behavior than conservative patterns of responding (Baron, Myerson, & Hale, 1988). In the case of recognition memory, for example, old and young individuals may react in similar ways to a given set of payoff contingencies, but older persons may be slower to adjust when the contingencies are changed. In the previous research, recognition was studied exclusively under neutral payoff contingencies, that is, under conditions in which penalties for false alarms ("old" to a new item) and misses ("new" to an old item) were balanced and remained constant throughout the procedure. This led us to undertake the present, more extended, single-subject investigation in which the payoff matrices for correct and incorrect recognitions were varied.

## METHOD

### *Subjects*

Four older (62 to 75 years) and 4 younger (18 to 26 years) men volunteered to serve in an extended laboratory experiment (about 40 hr) in which payment would depend on performance. The older men were selected with the goal of minimizing variables extraneous to age. Thus, they all reported good health, scored at least within the normal range on a brief test of intelligence, and were taking courses at the university (either as undergraduates or as participants in programs for older adults). Two 50-min sessions per day were scheduled. Payment included money that could be earned based on responding (up to $3.00 per session) plus an additional bonus of $2.00 per session for completing the experiment.

### *Apparatus*

A sound-attenuating booth, 1.8 m square, contained a chair and a table. Mounted on the table was a 31-cm video monitor and a response console (28 by 25 by 7 cm). Six keys were inset on the top sloping surface of the console, of which only two were used. The operative keys, labeled "new" and "old," were 15 cm apart. A speaker on the wall behind the table delivered auditory stimuli. When the man was seated before the table, the monitor was approximately 50 cm away at eye level and the response keys were within easy reach. Experimental conditions were controlled by a microcomputer located in an adjacent room.

### *Procedure*

A series of verbal stimuli (items), each of which appeared twice, was displayed on the screen of the monitor. The items were presented at the rate of 10 per minute. Each item appeared for 4 s and was separated from the succeeding item by a 2-s interval. During the 4-s period, the man was required to respond on one or the other of the two keys depending on whether the item was new (first presentation) or old (second presentation). It was necessary to press a key in response to every item; a warning tone sounded 2 s after onset of the stimulus, and there was a monetary penalty for not responding.

Immediately after the response, a message appeared on the screen indicating the key that had been pressed (new or old), whether the response was correct or incorrect, and the number of credits that had been earned. Each credit was worth 8 cents; depending on condition, subjects could gain or lose from one to nine credits as a consequence of each response (see Table 1). If a response was not made to an item, 10 credits were lost. At the end of the session, the number of credits (gains minus losses) and the monetary equivalent were displayed on the screen. Actual payment was withheld until all scheduled sessions had been completed.

Printed instructions explained the essential features of the procedure: (a) "Each item will appear briefly, so you will have to pay careful attention." (b) "Concentrate on the stimulus and try to remember it." (c) "Your job is to decide whether the stimulus has appeared before or whether it is new." (d) "Press the NEW key if the stimulus is new and the OLD key if the stimulus has appeared before." (e) "You will have 4 seconds to make your response. If you have not responded within 2 seconds, a tone will be presented to warn you that the time is almost up."

The items were arranged so that paired items (the first and second presentations) were separated by varying numbers of intervening items: either 0, 1, 2, 4, 8, 16, 32, or 64 items. Each series contained a total of 120 pairs, of which 80 were actually used in the data analyses (10 pairs for each separation interval); the remaining 40 pairs served as fillers. The entire series required 24 min for completion. Two series were presented during a session; they were separated by a brief rest period during which the man remained in the booth. The items were selected from a large pool, and each series was unique. The order was determined randomly with the restriction that the series contain the appropriate separations.

Table 1

Payoff matrices for the neutral, recognition, and nonrecognition bias conditions. Cell entries indicate the number of credits gained and lost for the responses "old" and "new."

| Stimulus | Response | | | | | |
|---|---|---|---|---|---|---|
| | Old | New | Old | New | Old | New |
| Old | +5 | −5 | +9 | −9 | +1 | −1 |
| New | −5 | +5 | −1 | +1 | −9 | +9 |

In addition to the separation intervals, experimental variables included the verbal content of the items and the characteristics of the payoff matrix. Three types of items were used, with entire sessions (two series) devoted exclusively to each type. The item could be a four-character alphanumeric string (e.g., "R42H"), a common word (e.g., "migrate"), or a brief sentence of the sort found in a newspaper headline (e.g., "Mayor Fires Police Chief"). For the first 12 sessions of the experiment, each block of three sessions contained one session with each item type. The next 12 sessions exclusively used the alphanumeric strings. The final 12 sessions again rotated the three types.

As shown in Table 1, three payoff conditions were studied. Under the neutral condition, rewards and penalties for recognition and nonrecognition responses (old or new) were balanced. Under the recognition-bias condition the schedule favored recognition responses. Finally, under the nonrecognition-bias condition the schedule favored nonrecognition responses. The neutral payoff condition was in effect for the first 12 sessions and was followed by six sessions with the recognition-bias condition and six sessions with the nonrecognition-bias condition. The neutral condition was reinstated during the final 12 sessions of the experiment.

## RESULTS

The data analyses focused on the performances of individual men. Inferential statistics were used as needed to clarify between-subject differences (age), as well as interactions between the age variable and the three experimental variables (type of stimulus, separation interval, and payoff matrix).

A comprehensive summary of each man's hit and false alarm rates may be found in Appendices A and B. Values are based on performances during the last two sessions under each condition (40 observations per condition; in a few cases the number was less because a response was not made within the time limit). Signal detection analyses of these data followed the procedures of earlier studies of age and recognition memory (Le Breck & Baron, 1987; Poon & Fozard, 1980) and used the nonparametric methods described by Grier (1971) and Hodos (1970) to derive measures of recognition sensitivity (*A*′) and percentage bias. As pointed out by Grier, nonparametric analyses avoid specific assumptions about underlying distributions (his computing formulas are given in Appendix C). Other treatments of signal detection performances are available, including those based on the generalized matching law (Davison & Tustin, 1978; White & McKenzie, 1982). The present approach has the advantage of allowing direct comparisons with previous results from the literature on aging.

### *Sensitivity*

The sensitivity measure of the signal detection analysis indexes the individual's ability to recognize previously encountered stimuli. Figure 1 and Table 2 summarize results from the neutral payoff condition during the last six sessions of the initial series (Sessions 7 through 12) when the men were relatively inexperienced and the last six sessions of the terminal series (Sessions 31 through 36). Figure 1 shows the changes that occurred as the separation interval was increased from 0 to 64 items. This analysis is limited to responses to the alphanumeric strings, the condition with the highest degree of recognition failures. The results in

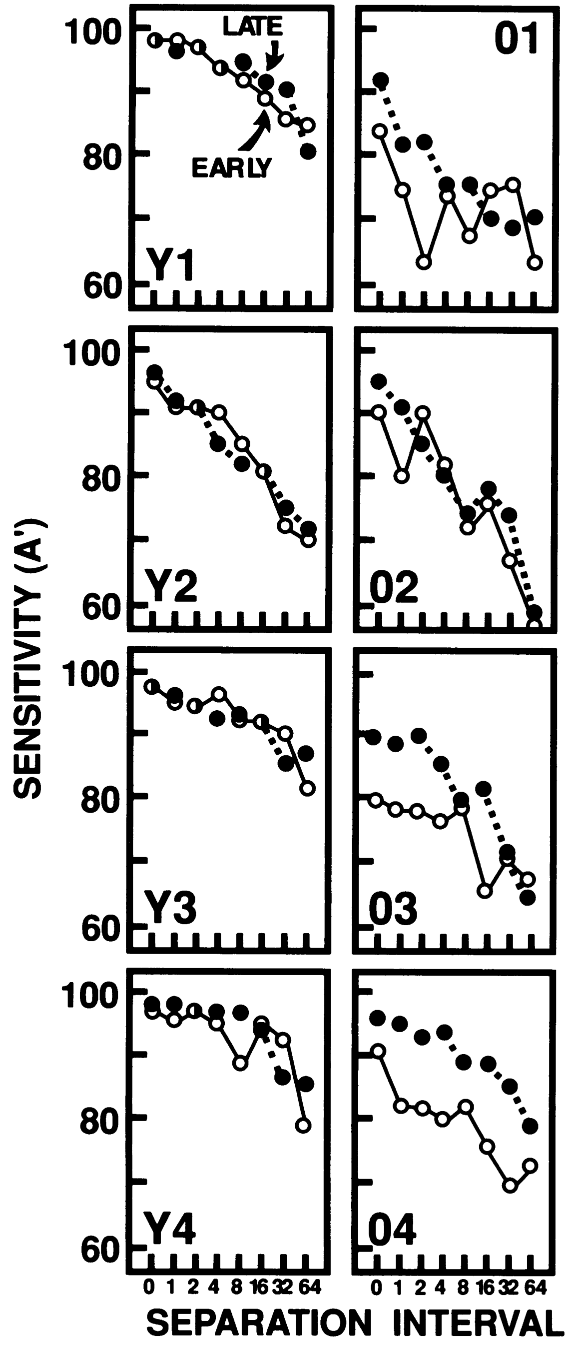

Fig. 1. Recognition sensitivity functions for each subject during the initial and terminal sessions. The stimuli were alphanumeric strings.

Table 2

Sensitivity scores for young and old adults as a function of stimuli (strings, words, sentences) and interval length (short vs. long). Values are on a scale from 100.0 to 0.0 in which maximal sensitivity equals 100.0 and chance performance equals 50.0.

| | | Initial sessions | | | | | | Terminal sessions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Strings | | Words | | Sentences | | Strings | | Words | | Sentences | |
| Age | Subject | Short | Long | Short | Long | Short | Long | Short | Long | Short | Long | Short | Long |
| Young | 1 | 97.7 | 86.7 | 99.0 | 98.3 | 98.3 | 95.7 | 97.0 | 88.0 | 99.0 | 95.7 | 98.7 | 97.0 |
| | 2 | 92.3 | 74.3 | 97.3 | 89.0 | 97.7 | 94.3 | 93.3 | 76.0 | 97.3 | 84.3 | 97.0 | 83.7 |
| | 3 | 96.3 | 88.7 | 98.3 | 93.3 | 98.0 | 93.0 | 96.7 | 88.7 | 99.0 | 98.3 | 98.0 | 92.3 |
| | 4 | 96.3 | 88.7 | 98.0 | 95.7 | 98.3 | 95.0 | 97.7 | 88.7 | 99.0 | 94.3 | 98.7 | 93.0 |
| | *M* | 95.7 | 84.6 | 98.2 | 94.1 | 98.1 | 94.5 | 96.2 | 85.4 | 98.6 | 93.2 | 98.1 | 91.5 |
| Old | 1 | 74.3 | 71.7 | 97.7 | 96.3 | 97.0 | 95.0 | 85.7 | 70.3 | 98.7 | 97.3 | 97.7 | 96.3 |
| | 2 | 86.7 | 66.3 | 97.7 | 91.7 | 95.0 | 86.7 | 90.3 | 70.0 | 98.7 | 92.3 | 98.3 | 94.0 |
| | 3 | 79.3 | 68.3 | 94.7 | 91.3 | 96.7 | 94.0 | 89.7 | 73.0 | 96.7 | 92.0 | 97.0 | 93.3 |
| | 4 | 85.0 | 73.0 | 98.0 | 95.3 | 99.0 | 95.0 | 94.7 | 84.3 | 99.0 | 97.0 | 98.3 | 94.7 |
| | *M* | 81.3 | 69.8 | 97.0 | 93.7 | 96.9 | 92.7 | 90.1 | 74.4 | 98.3 | 94.7 | 97.8 | 94.6 |

Table 2, by comparison, show effects for all three types of items (alphanumeric strings, words, and sentences), with findings grouped in terms of interval size, that is, the three shortest intervals (zero, one, and two items) versus the three longest intervals (16, 32, and 64 items). The values for the short and long intervals were derived by averaging the sensitivity measures for the individual intervals.

Concerning the stability of the men's performances, scheduling considerations required that they be given equal exposure to the conditions. The duration of the observations was sufficient, however, to yield reliable values. For the conditions summarized in Table 2, the sensitivity score usually did not vary by more than 5% from performances during the previous six sessions under the same condition (this was the case for 91% of the comparisons), and in no case did the change exceed 20%.

Table 2 displays some effects common to all 8 men, as well as some specifically associated with age. For men of both ages, sensitivity was controlled by the verbal content of the items: Values were consistently higher for the words and the sentences than for the less meaningful strings. Sensitivity also was controlled by the size of the separation interval: Values increased as the separation interval was reduced (compare short vs. long). Overall, sensitivity was lower for the older men, most notably during initial performances with the strings. But sensitivity increased with practice, and age differences diminished as the experiment progressed. The recognition functions in Figure 1 show in greater detail the pattern of change in sensitivity across the entire range of intervals. For all of the men, sensitivity was highest when the intervals were short and values declined as a linear function of the logarithm of the separation interval.

To confirm the statistical reliability of the age-related differences, the values in Table 2 were entered into a repeated-measures analysis of variance with age as a between-subject variable and the significance level set at $p = .05$. In general, the outcomes of the statistical tests coincided with the differences apparent in the table. Thus, the magnitude of age differences was larger for strings than for words or sentences, Age × Stimulus, $F(2, 12) = 25.02$, $p < .001$, and the overall degree of improvement was greater for the older than the younger men, Age × Practice, $F(1, 6) = 22.41$, $p < .01$. As is apparent in individual performances, sensitivity changes as a function of separation interval were not related to age, Age × Interval, $F(1, 6) = 0.01$, $p =$ ns; other more complex interactions involving age also were absent. The statistical analysis also verified the general (age-independent) effects mentioned above: Practice, $F(1, 6) = 13.86$, $p < .01$; Separation Interval, $F(1, 6) = 36.37$, $p < .001$; Stimulus, $F(2, 12) = 93.12$, $p < .001$; as well as the tendency for interval and practice effects to be largest under the string condition: Prac-

Table 3

Bias scores for young and old adults as a function of stimuli (strings, words, sentences) and interval length (short vs. long). Values are on a scale from −100% to +100% in which performances biased toward recognition responses are indexed by negative values and performances biased toward nonrecognition responses by positive values.

| | | Initial sessions | | | | | |
|---|---|---|---|---|---|---|---|
| | | Strings | | Words | | Sentences | |
| Age | Subject | Short | Long | Short | Long | Short | Long |
| Young | 1 | −78.7 | 67.3 | −99.9 | −46.7 | −61.3 | 52.0 |
| | 2 | −21.0 | 46.0 | −64.0 | 64.0 | −87.7 | 35.3 |
| | 3 | −32.0 | 54.7 | −63.3 | 60.7 | −74.7 | 50.7 |
| | 4 | −85.7 | 4.3 | −99.9 | −0.7 | −66.7 | −40.0 |
| | *M* | −54.3 | 43.1 | −81.8 | 19.3 | −72.6 | 24.5 |
| Old | 1 | −36.0 | −23.7 | −90.3 | −53.3 | −99.9 | −51.7 |
| | 2 | 1.7 | 28.7 | −62.7 | 58.7 | −60.7 | 28.3 |
| | 3 | −51.3 | −17.3 | −76.3 | −17.0 | −55.0 | −12.3 |
| | 4 | −47.7 | 5.3 | −99.9 | −10.7 | −99.9 | 33.3 |
| | *M* | −33.3 | −1.8 | −82.3 | −5.6 | −78.9 | −0.6 |

tice × Stimulus, $F(2, 12) = 5.50$, $p < .05$; Interval × Stimulus, $F(2, 12) = 56.41$, $p < .001$.

### *Bias*

The bias measure indexes the individual's tendencies to respond "old" or "new" to the items. Values for the nonparametric analysis are on a scale from −100% to +100% in which performances biased toward recognition responses (i.e., a disproportionate number of false alarms: "old" to new items) are associated with negative values and performances biased toward nonrecognition responses (i.e., a disproportionate number of misses: "new" to old items) are associated with positive ones. Table 3 is organized along the lines of Table 2; that is, data are from the initial and terminal phases under the neutral payoff condition with all three types of stimulus material. The data in Figure 2 are limited to the conditions with the alphanumeric strings and compare performances under the neutral condition (initial and terminal phases) with those when the payoff matrix was biased toward either liberal or conservative recognition patterns (middle 12 sessions).

Table 3 indicates that all 8 men responded in similar ways to the different stimulus- and separation-interval conditions. The words evoked more liberal recognition patterns than did the strings or the sentences, and responding was more conservative for the longer than the shorter intervals. Unlike the findings for sensitivity (Table 2), the analysis of bias in Table 3 does not indicate systematic differences associated with age. Another difference is the absence of consistent changes from the initial to the terminal phase. In general, these conclusions were supported by the statistical analysis. Age differences (including all interactions involving age) were not significant, and the only reliable effects were those associated with the retention interval, $F(1, 6) = 110.13$, $p < .001$. (Stimulus type just missed an acceptable level of significance, $F(2, 12) = 3.54$, $p = .06$.)

As may be seen in Figure 2, the men's performances varied according to the payoff matrix: 7 of 8 (the exception was Subject O4) showed more liberal recognition patterns when the matrix was biased in that direction and more conservative patterns when the conservative payoff was in effect, and adopted intermediate levels of performance when the payoff matrix was balanced. The previously mentioned effects of the separation interval also may be seen in Figure 2. The men tended to be more conservative when a stimulus was repeated after a long interval than a short one. Also apparent is that the pattern of bias values differed as a function of age. Although the older and younger men were similar in the direction of effects, the arrangement of the matrix exerted a lesser degree of control over the performances of the older ones. As may be seen in the figure, the values of the older men tended

Table 3 (*Continued*)

| | | Terminal sessions | | | | | |
|---|---|---|---|---|---|---|---|
| | | Strings | | Words | | Sentences | |
| Age | Subject | Short | Long | Short | Long | Short | Long |
| Young | 1 | −72.3 | 52.7 | −73.3 | 62.3 | −80.7 | −23.0 |
| | 2 | 33.3 | 69.0 | 44.7 | 85.3 | 43.3 | 87.7 |
| | 3 | −65.3 | 49.3 | −73.0 | −21.0 | −99.9 | 45.0 |
| | 4 | −88.7 | 61.2 | −99.9 | 59.7 | −27.7 | 81.7 |
| | *M* | −48.3 | 58.0 | −50.4 | 46.6 | −41.3 | 47.9 |
| Old | 1 | −37.3 | 17.0 | −84.7 | −23.3 | −77.3 | −39.7 |
| | 2 | −13.0 | 39.0 | −83.7 | 57.0 | −61.3 | 69.3 |
| | 3 | −73.7 | 4.3 | −64.7 | 12.7 | −1.7 | 60.7 |
| | 4 | −76.7 | 32.7 | −99.9 | −1.7 | −45.0 | 80.0 |
| | *M* | −50.2 | 23.3 | −83.3 | 11.2 | −46.3 | 42.6 |

to fall in the midrange of the bias scale, whereas those of the younger men were more likely to correspond with the extreme values called for by the payoff matrix.

Statistical analysis of the values depicted in Figure 2 coincided with impressions from the graph. Although age was not a significant main effect, the less extreme scores of the older men were reflected in an age-related interaction, Age × Payoff Matrix, $F(3, 18) = 5.78$, $p < .01$. The analysis also confirmed the main effects of variations in the payoff matrix, $F(1, 3) = 27.80$, $p < .001$, and the separation interval, $F(1, 6) = 49.54$, $p < .001$. A less clear finding was that response patterns of men of both ages varied as a joint function of the two variables, Separation Interval × Payoff Matrix, $F(3, 18) = 3.74$, $p < .05$. As shown in the figure, the majority of the men showed larger differences between the liberal and conservative conditions when the intervals were short than when they were long, but a number of exceptions also can be seen.

## DISCUSSION

Before considering the results, comment is in order concerning the experimental design. If nothing else, inclusion of the subject's age as a variable in human operant research provides a way of testing the generality of the findings across individuals; this is a type of systematic replication (Sidman, 1960). Thus, similar results from human subjects with markedly different personal characteristics (so-called "individual differences" such as age, gender, or social history) provide increased confidence in the relationships that emerge. The approach is not unlike the strategy used in comparative psychology, in which operant conditioning variables across a range of different species are investigated. There is a further link between developmental and comparative approaches. The constraints that phylogenetic differences can place on the conditioning process have engendered considerable theoretical discussion. By comparison, very little has been said about constraints that may depend on the organism's developmental level. The nature and extent of developmental constraints are not well understood, largely because experiments on human operant performances usually have studied children and young adults—individuals in an age range that is characterized by a progression toward enhanced behavioral capabilities. The study of operant conditioning during the remaining course of human development, particularly those later stages during which capabilities decline, remains an unexplored area (Baron et al., 1988).

One of our objectives was to determine the feasibility of studying memory in human subjects from a single-subject standpoint (perhaps it goes without saying that Ebbinghaus' pioneer studies of memory, more than 100 years ago, used just this approach). The present results were encouraging. In particular, the individual sensitivity functions for the alphanumeric strings showed orderly declines as the separation interval was increased (see Figure 1), and a similar pattern of differences resulted

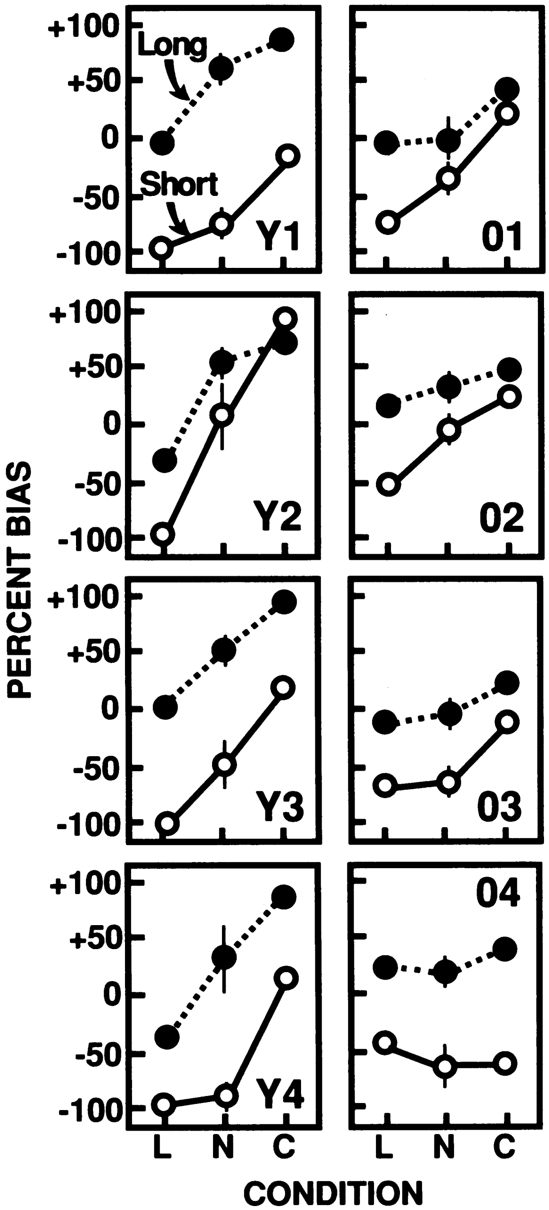

Fig. 2. Percentage bias for each subject under liberal (L), neutral (N), and conservative (C) payoff matrix conditions. Values are plotted separately for the short and long recognition intervals; the values for the neutral condition are the mean of performances during the initial and terminal phases, as indicated by the range bars.

for the words and strings (see Table 2). The regularity of these changes compares quite well to those seen in reports of averaged data for groups of old and young subjects (Poon & Fozard, 1980). Another consistent finding across individuals was that levels of recognition sensitivity were lower for the alphanumeric strings than for the more meaningful words and sentences. Differences in these measures increased in magnitude as the separation interval became longer (see Table 2). Finally, the results provided evidence that practice with the task led to improved recognition sensitivity, particularly in the case of the older men. Although this effect was well supported by the statistical analysis (both the main effect of practice and the Practice × Age interaction were statistically significant), the single-subject data (see Figure 1 and Table 2) indicted a fair amount of variation depending on the particular condition and subject. The smaller changes for the words and sentences than for the strings may have been a consequence of the initially high levels of performances with the more meaningful material (a ceiling effect). Similarly, the largest improvements were shown by men who manifested relatively poor performances at the start (e.g., Subjects O1, O3, and O4).

Practice with the memory task not only improved the accuracy of the older men's performances but also reduced the age differences seen at the start of the experiment. This finding, together with previous results (Baron & Mattila, 1989; Perone & Baron, 1983), suggests the importance of disuse as a factor contributing to age-related deficits (Thorndike, Bregman, Tilton, & Woodyard, 1928). The conventional wisdom about memory in older individuals is that deficits reflect irreversible changes in the workings of the central nervous system. For this reason, it should be difficult, if not impossible, to improve performances. The disuse hypothesis, by comparison, raises the possibility that deficits also may reflect insufficient current exposure to the relevant contingencies; in the present study, the contingencies involved in the prompt recognition of previously encountered stimuli. Through appropriate training, it should be possible to restore lost abilities. Therefore, the gains seen in the present study provide a more optimistic view of memory in the older adult than is usually advocated. But it also bears emphasis that the procedures did not bring the older subjects to the level of the young adult controls. More intensive training procedures might have the consequence of further reducing the difference. Alternatively, the deficient performances seen at the end of the experiment may be indicative of irreversible limitations in the memory functions of the elderly.

The present procedures and results make it apparent that identification of the variables that contribute to age-related deficits is not an easy matter. We attempted to arrange the procedures in ways that deemphasized factors that may be correlated with age but actually are secondary to the basic aging process (Kausler, 1982). The possible roles of inexperience and test anxiety were addressed by conducting observations when the subjects were well acclimated to the laboratory procedures. Health status was taken into account by selecting older men who were in relatively good health and who were maintaining an active lifestyle. Finally, an effort was made to match the educational backgrounds of the older and younger subjects by studying older men who were enrolled in programs at the university. Therefore, it seems reasonable to conclude that age deficits in memory were observed independently of these secondary factors. Nevertheless, such a conclusion must be adopted with caution in light of the inherent limitations of cross-sectional research designs as a tool for studying aging (i.e., procedures in which performances of older adults are compared to those of young adult controls). As emphasized by Willis (1985), such designs include a critical assumption that may not always be met—that the older subjects *when they were young* actually were capable of the performances seen in the contemporary young adult controls. If this assumption were violated in the present study (in the absence of longitudinal data, there is no obvious way to determine whether it was), the results may have underestimated the extent to which practice restored the performances of the older adults to their own earlier levels.

Clearly, the results did not provide support for the hypothesis that older adults are more conservative in reporting that a stimulus has previously been encountered (for similar results, see Baron & Le Breck, 1987; Le Breck & Baron, 1987). A role played by age was seen, however, when the contingencies of the payoff matrices were changed. Although the older men showed orderly transitions in the bias measure (see Figure 2), the extent of the adjustment tended to be less than for the younger men. Thus, for recognition memory at least, the essential age difference appears to be one of reduced sensitivity to changed contingencies (cf. Nevin, 1988; what has been sometimes called "rigidity" in the literature on aging) rather than conservative tendencies.

It remains an open question as to why older adults should be less flexible in their responses. Certainly, to do no more than label the behavior as "rigid" or "insensitive" is not much progress toward an answer. One approach is suggested by Ruch's (1934) classic finding that older adults, by comparison with younger ones, had more difficulty on a rotary pursuit task when the target was observed through a mirror rather than directly. Ruch reasoned that the older subjects' poor performance was not so much a matter of impaired learning ability as it was a consequence of their more extensive experience with unreversed environments—with advancing age, reversed images might be expected to induce progressively higher levels of interference (negative transfer). By the same token, one might speculate that old and young individuals have been exposed to similar environments from the standpoint of gains and losses for correct and incorrect recognitions. The more extensive history of the older person, however, serves as an impediment to changes in behavior when the contingencies are changed. Of course, other interpretations of the present results also are possible (e.g., that the central nervous system changes of old age impair basic mechanisms of reinforcement). Resolution of these interesting issues awaits further research.

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## APPENDIX A

Proportions of hits (at each separation interval) and false alarms during initial and terminal sessions.

| Sub-ject | Stimuli | Initial sessions 0 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | FA | Terminal sessions 0 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | FA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yng-1 | Strings | 1.00 | 1.00 | .95 | .88 | .80 | .70 | .60 | .58 | .08 | 1.00 | .95 | .98 | .88 | .90 | .83 | .78 | .48 | .09 |
|  | Words | 1.00 | 1.00 | 1.00 | .98 | .98 | 1.00 | 1.00 | .93 | .03 | 1.00 | .98 | .00 | 1.00 | .98 | .95 | .90 | .73 | .03 |
|  | Sentences | 1.00 | .98 | .98 | 1.00 | 1.00 | .92 | .93 | .78 | .04 | 1.00 | 1.00 | .98 | .98 | .95 | 1.00 | .97 | .83 | .04 |
| Yng-2 | Strings | .95 | .85 | .85 | .83 | .68 | .58 | .38 | .35 | .15 | .95 | .80 | .75 | .55 | .48 | .43 | .30 | .23 | .07 |
|  | Words | 1.00 | .95 | .98 | .98 | .95 | .85 | .65 | .55 | .07 | .93 | .95 | .93 | .80 | .83 | .67 | .40 | .35 | .03 |
|  | Sentences | 1.00 | 1.00 | .98 | .90 | .95 | .90 | .90 | .83 | .07 | .98 | .93 | .83 | .78 | .78 | .53 | .46 | .33 | .03 |
| Yng-3 | Strings | 1.00 | .93 | .90 | .98 | .85 | .85 | .78 | .50 | .08 | 1.00 | .98 | .93 | .85 | .90 | .85 | .65 | .68 | .10 |
|  | Words | .98 | .98 | 1.00 | .93 | .98 | .93 | .85 | .63 | .05 | 1.00 | .98 | 1.00 | .98 | .98 | .93 | 1.00 | .98 | .03 |
|  | Sentences | .98 | 1.00 | .98 | .95 | .97 | .88 | .88 | .70 | .07 | 1.00 | 1.00 | 1.00 | .95 | .93 | .90 | .87 | .65 | .07 |
| Yng-4 | Strings | 1.00 | .95 | 1.00 | .95 | .75 | .95 | .85 | .50 | .13 | 1.00 | 1.00 | .98 | .98 | .98 | .85 | .60 | .60 | .08 |
|  | Words | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | .90 | .80 | .06 | 1.00 | 1.00 | 1.00 | .98 | .93 | .95 | .90 | .63 | .03 |
|  | Sentences | 1.00 | 1.00 | .95 | .85 | .95 | 1.00 | 1.00 | .60 | .05 | 1.00 | .98 | .95 | .95 | 1.00 | .85 | .78 | .70 | .03 |
| Old-1 | Strings | .93 | .78 | .63 | .77 | .68 | .78 | .80 | .62 | .46 | .98 | .75 | .78 | .65 | .65 | .55 | .53 | .55 | .29 |
|  | Words | .98 | 1.00 | 1.00 | .98 | .98 | .98 | .98 | .93 | .09 | 1.00 | .98 | 1.00 | 1.00 | 1.00 | 1.00 | .90 | .95 | .06 |
|  | Sentences | 1.00 | 1.00 | 1.00 | .98 | 1.00 | 1.00 | .90 | .93 | .13 | 1.00 | .95 | 1.00 | .98 | .98 | 1.00 | .97 | .85 | .08 |
| Old-2 | Strings | .85 | .60 | .85 | .65 | .44 | .51 | .35 | .23 | .19 | .98 | .85 | .68 | .55 | .43 | .50 | .43 | .20 | .15 |
|  | Words | 1.00 | .98 | .95 | .95 | .82 | .88 | .77 | .67 | .07 | 1.00 | 1.00 | .97 | .93 | .98 | .93 | .83 | .58 | .05 |
|  | Sentences | .95 | .98 | .93 | .83 | .90 | .88 | .70 | .58 | .14 | .98 | .98 | 1.00 | 1.00 | .95 | .83 | .87 | .79 | .04 |
| Old-3 | Strings | .88 | .85 | .85 | .83 | .85 | .68 | .74 | .70 | .48 | .95 | .93 | .95 | .85 | .73 | .78 | .58 | .48 | .30 |
|  | Words | .98 | .98 | .95 | .93 | .98 | .93 | .85 | .83 | .16 | 1.00 | .95 | .95 | .95 | .98 | .90 | .92 | .68 | .10 |
|  | Sentences | 1.00 | .98 | .90 | 1.00 | .95 | 1.00 | .90 | .73 | .09 | 1.00 | .87 | .93 | .95 | .93 | .93 | .85 | .63 | .05 |
| Old-4 | Strings | .98 | .80 | .80 | .75 | .80 | .68 | .58 | .63 | .33 | 1.00 | .98 | .93 | .95 | .80 | .80 | .70 | .55 | .16 |
|  | Words | 1.00 | 1.00 | 1.00 | .95 | 1.00 | .95 | .90 | .90 | .09 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | .93 | .85 | .05 |
|  | Sentences | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | .95 | .90 | .78 | .06 | 1.00 | .93 | 1.00 | .98 | .95 | .90 | .87 | .68 | .03 |

## APPENDIX B

Proportion of hits (by separation interval) and false alarms under recognition bias and nonrecognition bias conditions.

| Subject | Recognition bias | | | | | | | | | Nonrecognition bias | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | FA | 0 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | FA |
| Yng-1 | 1.00 | 1.00 | .98 | .93 | .98 | .90 | .83 | .80 | .17 | 1.00 | .98 | .93 | .87 | .80 | .78 | .59 | .45 | .03 |
| Yng-2 | 1.00 | 1.00 | .98 | .95 | .93 | .85 | .78 | .80 | .38 | .80 | .48 | .38 | .30 | .13 | .18 | .10 | .03 | .01 |
| Yng-3 | 1.00 | 1.00 | 1.00 | .93 | .90 | .88 | .78 | .68 | .19 | 1.00 | .98 | .90 | .95 | .93 | .88 | .78 | .53 | .01 |
| Yng-4 | 1.00 | .98 | 1.00 | 1.00 | 1.00 | .98 | .88 | .93 | .12 | .98 | .98 | .93 | .85 | .83 | .68 | .38 | .30 | .03 |
| Old-1 | .98 | .93 | .90 | .83 | .73 | .80 | .58 | .63 | .36 | .90 | .40 | .50 | .23 | .35 | .30 | .23 | .25 | .13 |
| Old-2 | 1.00 | .88 | .78 | .70 | .70 | .58 | .68 | .55 | .27 | .90 | .83 | .64 | .51 | .43 | .33 | .26 | .20 | .11 |
| Old-3 | .93 | .85 | .95 | .75 | .65 | .77 | .70 | .59 | .38 | .85 | .75 | .75 | .59 | .55 | .60 | .58 | .45 | .25 |
| Old-4 | .98 | .88 | .75 | .75 | .85 | .68 | .45 | .55 | .24 | 1.00 | .90 | .93 | .93 | .80 | .63 | .70 | .60 | .17 |

## APPENDIX C

Following Grier's (1971) derivations, the nonparametric index of sensitivity (A′) is computed using the formula (Grier, Formula 2)

$$A' = \tfrac{1}{2} + \frac{(\mathrm{H} - \mathrm{FA})(1 + \mathrm{H} - \mathrm{FA})}{4\mathrm{H}(1 - \mathrm{FA})}$$

where H is the probability of a hit (i.e., "old" to a previously presented stimulus) and FA the probability of a false alarm (i.e., "new" to a previously presented stimulus).

Computation of the nonparametric index of bias (percentage bias or $B'_{\mathrm{H}}$) requires different formulas depending on whether the point is to the left or right of the negative diagonal of the signal detection space. For points to the left of the diagonal, $B'_{\mathrm{H}}$ is computed using the formula (Grier, Formula 7)

$$B'_{\mathrm{H}} = 1 - \frac{\mathrm{FA}(1 - \mathrm{FA})}{\mathrm{H}(1 - \mathrm{H})}$$

and $B'_{\mathrm{H}}$ can vary from 0.00 to +1.00. For points to the right of the negative diagonal, the formula (Grier, Formula 8) is

$$B'_{\mathrm{H}} = \frac{\mathrm{H}(1 - \mathrm{H})}{\mathrm{FA}(1 - \mathrm{FA})} - 1$$

and $B'_{\mathrm{H}}$ can vary from 0.00 to −1.00.