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Some functional properties of iconic storage in retarded and nonretarded subjects

FLORRIE M. PENNINGTON and MARY A. LUSZCZ
University of Alabama, University, Alabama 35486

Four experiments, which examine some functional properties of iconic storage in mildly retarded subjects, are reported. Experiments I and III demonstrated that retardates report about three items, or one item less than normal subjects, after a single brief tachistoscopic exposure and that this span of attention was independent of size of array. Both normal and retarded groups reported more items correctly when arrays were arranged on two lines. Experiment II determined that exposure durations up to 250 msec did not influence the number of items reported by either group. Experiment IV compared the form of decay for both groups by cuing report of each of seven positions at five poststimulus delays. The presence of the typical W-shaped curve for both groups at all delays permitted the inference that items in iconic storage decay together rather than individually. Although quantitative differences existed between groups, in no case did intelligence interact with the manipulated variables. The results were discussed in relation to control processes and structural features within an information processing model of memory.

In recent years, research on retardation has reflected the widespread influence of information processing models of memory. Theorizing has focused on consistent evidence of a short-term memory (STM) deficit (Belmont & Butterfield, 1969; Ellis, 1970). Ellis revised and extended his earlier stimulus trace theory, suggesting that the poor STM performance of retardates reflects inadequate rehearsal strategies. Brown (1974) has argued that the STM deficiency can be viewed as one example of a general pattern of inadequate strategies for organizing, maintaining, and attending to relevant materials. Memory tasks not dependent upon the use of strategies may not be developmentally sensitive. Within the Atkinson and Shiffrin (1968) model, these strategies would be considered control processes, as opposed to the structural features of the various memory stores. When trained or instructed to do so, retardates rehearse in many circumstances (Kellas, Ashcraft, & Johnson, 1973). Thus control processes may be alterable through training, or "remediable" (Brown, 1974). However, there may be an upper limit to rehearsal capacity which is structurally determined and developmentally related. For retardates, this limit appears to be about three (Brown, 1974; Ellis, 1970; Spitz, 1973). Structural features refer to aspects of the system which cannot be varied or changed, because of some developmentally related limitation. Thus, structural differences may reflect invariances which would serve to define retardation.

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Requests for reprints should be addressed to Florrie M. Pennington, Department of Psychology, Box 6302, University, Alabama 35486.

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From a broader point of view, however, these defects interact with other related processes. Perceptual and encoding processes cannot be divorced from memorial ones (Norman & Rumelhart, 1970). The storage and retrieval of an item is directly related to the amount of perceptual processing of that item. Craik (1973) considers the memory trace to be one product of the level or depth of perceptual processing on a continuum from the transient products of physical feature analysis to the longer lasting results of more complex semantic processing. Within this framework, STM rehearsal is viewed as an attempt to maintain and prolong perceptual experience by the deliberate recycling of information at one level of analysis. Rehearsal strategies in STM involve operations which are logically preceded by perceptual encoding and readout from sensory storage (Neisser, 1967; Sperling, 1960). Information must be feature analyzed, identified, and read out into STM from the sensory register before rehearsal can be effective. The retardate's STM difficulty may be due to strategic inadequacies, lower sensory storage capacity, failure to encode, or slower readout rate from sensory storage to STM. A comprehensive theory of memory in retardates must be concerned with the relationship of these perceptual prerequisities to other aspects of memory.

Except for the work of Spitz (1973) and his associates, these earlier analyses of visual information have received little attention in retardates. The iconic or sensory storage register consists initially of a more or less photographic image of the stimulus which fades rapidly over a period of several hundred milliseconds. During this brief time, information can be read from the icon just as if the stimulus were still present. The readout is limited by the rapid fading and is apparently relatively automatic and independent of practice or strategies. Turvey (1967) concluded that the store for sensory data awaiting recognition is operationally different from the STM, since repetition was not an influential variable in the Sperling paradigm. Wickelgren and Whitman (1970) found no evidence of association between adjacent items exposed tachistoscopically. Thus, fewer qualitative differences in normal-retardate performance might be expected on this type of task than on other memory tasks demanding active strategies. On the other hand, structural features, such as the capacity of the sensory register, might differ quantitatively.

The present report describes four experiments designed to examine the functional properties of the visual sensory register in retardates: its capacity, readout, and decay. In particular, the studies sought to determine how much information can be reported by retardates after a single brief exposure (span of attention) and whether this limit is independent of size and arrangement of array (Experiments I and III), and whether this limitation is dependent upon exposure duration (Experiment II). The *form* of decay as a function of item position and delay of poststimulus cue was examined in Experiment IV.

NM

JLZ

DFM
RCQ

DCMS

LPMT
RJFK

XVNKH

NGRJLZQ

Figure 1. Types and arrangements of stimulus arrays.

EXPERIMENT I

The purpose of Experiment I was to determine the number of items reported by retardates under conditions similar to those of Sperling (1960), who determined that the span of attention was independent of number and spatial arrangement of items in arrays presented tachistoscopically.

Method

Subjects. Six students enrolled in the introductory psychology course at the University of Alabama and six midly retarded persons from a rehabilitation center in Tuscaloosa were employed for Experiments I, II, and IV. The mean age was 19.7 (SD .80 years) for normal subjects and 19.4 (SD 1.7 years) for retarded subjects. Mean IQ for retarded persons was 70.3 (SD 1.7, range 65-79) on the WAIS or Stanford-Binet. All subjects participated in two experimental sessions lasting approximately 75 min each. Retardates were paid for both sessions; normals received class credit for the first session and were paid for the second. All subjects had normal or corrected to normal vision and were able to identify correctly the letters used as stimuli.

Apparatus. A three-channel (Model T-3B-1, Gerbrands) tachistoscope with a 300 series timer was used to present stimuli and control temporal parameters. Viewing was binocular at a distance of 30 in. Throughout presentation, a centered fixation cross was dimly illuminated at approximately .29 fL. Stimuli were presented at an illumination of 1 fL.

Stimuli. The stimuli consisted of arrays of upper case consonants (excluding Y) arranged so that 2, 3, 4, 5, or 7 letters appeared on one line and 6 or 8 letters appeared on two lines. Figure 1 illustrates the seven types of arrays used. Forty different arrays of each size were printed with Para-tipe (folio medium, 24 pt., No. 11424) on 4 by 6 in. cards, centered vertically and horizontally around the fixation point. Each letter subtended a visual angle of 28.6 sec vertically and 21.7 sec horizontally. Depending on the number and arrangement of letters, arrays subtended 28.6 sec to 1 deg 40 sec vertically and 1 deg 26 sec to 6 deg 11 sec horizontally. Letters were chosen randomly without replacement for each array.

Procedure. Each subject was seated comfortably at the tachistoscope and allowed to dark adapt while the experimenter read instructions. The first session consisted largely of practice trials on each array size at a progression of diminishing exposure durations of 500, 250, 150, 100, and 50 msec. Practice trial data were recorded and the procedure was identical to that of subsequent test trials. During testing, all arrays were exposed for 50 msec. Each subject viewed blocks of 40 matrices of each array size beginning with two and progressing to eight letters. A trial began when the experimenter called Ready! and the fixation cross appeared. Two seconds later the array was presented, followed by a dimly lit field. Immediately after offset of the stimulus array, subject reported all the letters verbally. The experimenter recorded responses. Procedure for the second session was the same, with an abbreviated practice session.

Results

The mean number of letters correct at each array size for normal and retarded groups is shown in Figure 2.

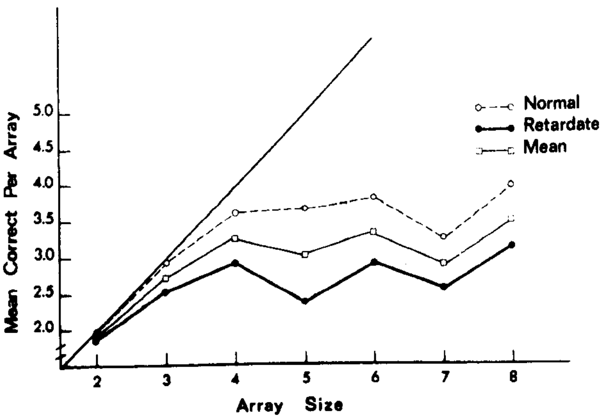

Figure 2. Mean letters correct per array as a function of array size and intelligence (Experiment I).

Data from Array Sizes 2 and 3 were excluded from analysis because of pronounced ceiling effects for both groups. Overall conditions, the mean number of letters correct per array was 3.7 (SD .21, range 3.4 to 4.0) for normals and 2.8 (SD .32, range 2.4 to 3.1) for retardates, $F(1,10) = 23.7$, $p < .001$. Unexpectedly, the effect of array size was reliable, $F(4,40) = 6.6$, $p < .001$. A Newman-Keuls test and Fisher's least significant differences (lsd) revealed that performance was not significantly different for 7-, 5-, and 4-item arrays, but was higher for 6- and 8-item arrays than for 7.

Performance of the retarded group closely paralleled that of normal subjects, although at a lower level. The effect of array size seems to arise largely from decreased correct responses at Array Sizes 5 and 7 for retardates, and of 7 for normals. It was observed that for 6- and 8-item arrays many subjects reported one line of the array or the other, thus reducing the functional stimulus to 3 or 4 letters. It thus appears that the arrangement of letters affected the number reported. Experiment III explored this phenomenon.

Intrusions, defined as report of a letter not in the array, were rare for both groups. For example, the retarded group reported a mean of 3.55 letters for the 8-item arrays, of which a mean of 3.12, or 88%, were correct. In the same condition, normal subjects reported a mean of 4.24 letters, of which 4.0 or 94% were correct. Performance was comparable for other array sizes. Over all conditions, the percentage of reported letters which were correct was 87 for retardates and 97 for normals. It appears, then, that neither group used the strategy of guessing randomly.

EXPERIMENT II

Experiment II sought to determine, for retarded individuals, whether exposure duration is an important variable in determining how many letters subject can report correctly.

Method

Subjects and Apparatus. The same subjects and identical equipment were used as in Experiment I.

Stimuli. Eighty six-letter stimulus arrays were prepared as in Experiment I. Each array was arranged on two lines. They were randomly divided into four blocks of 20 arrays each.

Procedure. All subjects viewed blocks of 20 trials at exposure durations of 15, 50, 150, and 500 msec. Order of presentation of blocks and exposure durations was counterbalanced between subjects.

Results

Mean letters correct per array over all exposure times were 3.4 (SD .58, range 2.7 to 4.0) for retarded subjects and 4.3 (SD .71, range 3.6 to 5.3) for normal subjects, $F(1,10) = 51.6$, $p < .001$. The effect of exposure duration was reliable, $F(3,30) = 16.5$, $p < .001$. A least significant differences test revealed that this effect was due to higher performance by both groups in the 500 msec condition.

EXPERIMENT III

Since the arrangement of letters in arrays seemed to affect performance in Experiment I, the following study was conducted to explore this phenomenon. Six and eight item arrays arranged in one or two lines were used as stimuli. An additional variable, random or blocked presentation of arrays, was also manipulated.

Method

Subjects. The subjects were eight undergraduate students enrolled in the introductory psychology course at the University of Alabama ($\bar{X}$ age 20, SD 1.7 years, range 18.3 to 23.4) and eight midly retarded persons enrolled at a rehabilitation center in Tuscaloosa ($\bar{X}$ age 19.5, SD 4.52, range 15.8 to 30.1; $\bar{X}$ IQ 67.4, SD 10.5, range 46 to 79 on WAIS or Stanford-Binet). All subjects had normal or corrected to normal vision and could identify the stimulus letters.

Stimuli. Four sets of 40 stimulus arrays were prepared by combining orthogonally two sizes (6 or 8 letters) and two arrangements (1 or 2 lines) of letters, making a total of 160 arrays. The letters contained in each of the arrangements of a given array size were identical and their sequence remained constant.

Apparatus and Procedure. Apparatus was the same as in previous experiments. Beginning with 500 msec exposure time and decreasing to 50 msec, subjects viewed practice arrays not included in the experimental trials. Test stimuli were exposed for 50 msec, and subject reported as many letters as possible immediately after offset of the array. Presentation was blocked (according to size and arrangement) with order counterbalanced across subjects, or random, with all subjects receiving the same randomized order of the 160 arrays. Normal and retarded subjects participated in each of these conditions. All subjects viewed 160 trials of the different stimulus arrays.

Results

Over all conditions, normal subjects reported a mean of 3.7 letters per array and retarded subjects a mean of 2.4 letters, $F(1,12) = 11.6$, $p < .01$. The effects of order and number of letters did not reach significance, nor did any interactions. Both groups, however, reported significantly more letters on arrays arranged in two lines than on one line, $F(1,12) = 27.9$, $p < .01$. Thus, the effect of arrangement on two lines was to increase performance. There was no systematic relation between IQ and performance for the retarded group.

Discussion

Taken together, the results of Experiments I, II, and III suggest that the sensory storage performance and early perceptual analyses of retarded individuals are closely parallel to those of normal subjects, though at a slightly lower level. In no case did intelligence interact with the manipulated variables. Table 1 summarizes the findings of the three studies. Overall, retarded subjects consistently reported about one letter less than normals. In each experiment, a comparable condition (two-line, 6-

Table 1
Mean Letters Correct Per Array as a Function of Intelligence and Conditions in Experiments I, II, and III

Condition	Experi-ment	Intelligence Normal	Retar-date	Diffe-rence
	I	3.7	2.8	-.9
Overall	II	4.3	3.4	-.9
	III	3.7	2.4	-1.3
	Mean	3.9	2.9	-1.0
	I	3.9	2.9	-1.0
Selected*	II	4.0	2.9	-1.1
	III	3.9	2.6	-1.3
	Mean	3.9	2.8	-1.1

**Six- and eight-letter arrays on two lines, exposed at 50 msec.*

and 8-letter arrays exposed for 50 msec) was examined. The means of these conditions also differ by about one letter. Size of array was not a relevant variable, but both retarded and normal subjects performed better on arrays arranged in two lines. Both groups tended to report one line or the other, suggesting that, in the Sperling paradigm, normal and retarded subjects perform similarly. This effect may have been due to the proximity of the items. At 250 msec and below, the effect of exposure duration was not reliable, which is consistent with Sperling's (1960) findings.

These findings are not consistent with a specific deficit conceptualization of retardation. Rather, they invite a description of the retarded person as an information processor whose sensory storage analyses are essentially similar to those of nonretarded persons, but at a slightly lower level. Performance differed quantitatively but not qualitatively. If perceptual processing is relatively independent of plans or strategies under the control of subject, then this result could be expected in light of Brown's (1974) suggestion that the retarded individual's difficulty is with the use of strategies. The perceptual processing performance of both groups would be limited by the structural or invariant features of the sensory register. The results of the reported studies are consistent with that position. It appears that the span of immediate memory for mildly retarded individuals is about three items or one item less than that of normal subjects.

EXPERIMENT IV

The experiments reported thus far established that the retarded person's immediate span of memory is slightly lower than that of normal subjects, but left unanswered the question of whether the limitation is due to lower sensory register capacity or to inability to readout more letters before decay. Sperling's (1960) subjects insisted that they had seen more than could be reported. Through the use of partial report procedures and poststimulus cues, he found that information in excess of the immediate memory span was available to subjects before decay. The assumption was that the probability of correct report of any item at any moment is indicative of the percentage of items in the total stimulus array available in the sensory register at that moment. Using 4 by 3 matrices of 12 letters, he deduced that most subjects had available about 9.1 items initially, and that the number of items decreased up to 250 msec after stimulus offset. Averbach and Coriell (1961) used a visual poststimulus cue (bar marker) to instruct subjects which of a 2 by 8 matrix of letters to report. Their results were in essential agreement with Sperling's.

The purpose of Experiment IV was, first, to investigate through partial report procedures the capacity of the sensory register for retarded persons. A second purpose was to describe the *form* of the decay as a function of time and position, for both normal and retarded subjects. Whether the items in an array decay individually or together is not known (Atkinson & Shiffrin, 1968). Sperling (1960) reported idiosyncratic orders of readout and accuracy, but did not examine position accuracies for various delays. Harcum (1957, 1967) observed that errors at different positions in linear patterns did not conform to gradients of retinal sensitivity. The greater number of errors near the center may have resulted from mutual interference of the items. Across delays, Averbach and Coriell (1961) found that center and end items were reported more accurately than those between. This W-shaped curve has been observed by other investigators (Merikle, Lowe, & Coltheart, 1971; Townsend, 1973). If the shape of this curve remains constant across delays, then the items can be inferred to decay together, but if the curve changes as a function of time, then the items may decay individually. An examination of the relation between position accuracy and poststimulus delay would permit inferences about the form of decay of the visual image. To test these assumptions required the cuing of partial report of each position in stimulus arrays at various poststimulus delays. The experimental conditions were therefore defined by the factorial combination of the positions (1-7) of seven letter arrays with five (00, 15, 50, 150, 500 msec) cue delays.

Method

Subjects and Apparatus. All 12 subjects had previously participated in Experiments I and II. Equipment and illumination of stimuli were the same.

Stimuli. One hundred and forty 7-letter arrays were prepared as in previous experiments. Each array subtended a visual angle of 28.6 sec vertically and 6 deg 11 sec horizontally around the central fixation point. In addition, seven poststimulus cues consisting of bar markers (made with the letter I of the Para-tipe) were prepared. One cue corresponded to each of the positions in the array, and was centered .125 in. above the position. The stimuli were divided into five blocks of 28 arrays each.

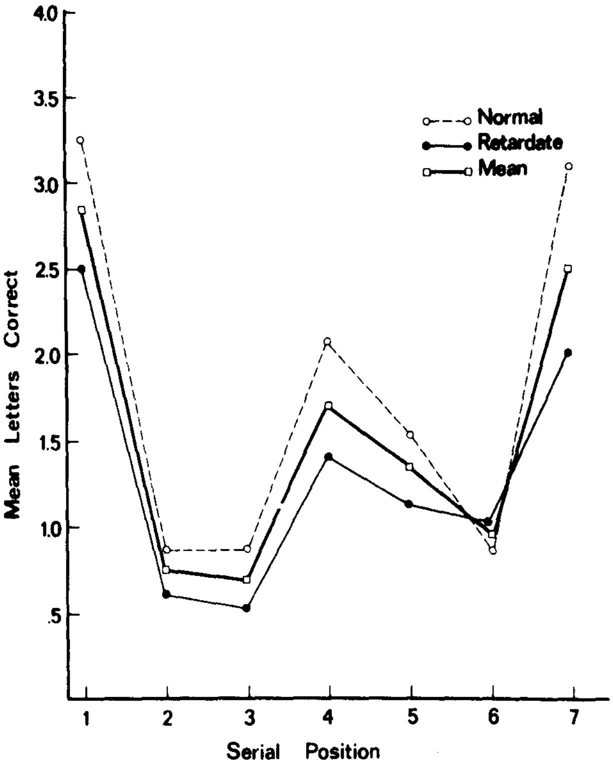

Figure 3. Mean letters correct (out of four trials) as a function of serial position and intelligence (Experiment IV).

Design. Normal and retarded subjects were each tested 140 times. Each subject viewed blocks of 28 trials at each delay of poststimulus cue (00, 15, 50, 150, 500 msec). Within a block, each position of the 7-item array was randomly cued four times. Treatments were counterbalanced across subjects.

Procedure. Each subject dark adapted while the experimenter read instructions. Fourteen practice trials preceded the experimental ones. A trial began when the experimenter called Ready! and a dimly lit fixation cross appeared. Two seconds later the stimulus array was exposed for 100 msec. After the appropriate delay interval, a bar marker appeared for 100 msec over one of the array positions, and subjects reported verbally the letter from that position.

Results and Discussion

For each subject, correct responses (out of four trials) were tabulated by serial position and delay. The mean correct was 1.8 letters for normal and 1.32 for retarded subjects, $F(1,10) = 8.70$, $p < .05$. Figure 3 shows the mean letters recalled as a function of serial position, $F(6,60) = 27.1$, $p < .001$. The close correspondence of the typical W-shaped curves for both groups underscores the lack of interaction between intelligence and serial position. A least significant differences (lsd) test revealed that Positions 1 and 7 were reported more reliably than all others, and that recall at Position 4 was reliably higher than all others except 1 and 7. The lack of interaction between serial position and delay was revealed by the presence of the W-shaped curve at all delay intervals. This result suggests that the various positions of the iconic image fade together at the same rate.

Figure 4 shows that the performance of both groups declined as a function of delay of poststimulus cue, $F(4,40) = 3.11$, $p < .05$. Performance at 00, 15, and 50 msec was reliably higher than at 150 and 500 msec, (lsd .05 = .35). Again, performance of retarded subjects closely paralleled that of normals, indicating no interaction between delay and intelligence. The results fall somewhere between those of Averbach and Coriell (1961), who found marked decline of recall with delay, and those of Mayzner, Abrevaya, Frey, Kaufman, and Schoenberg (1964) who found no decrease with delay.

When the partial report is treated as a random sample of the letters subject has available at a particular moment, then the total number of letters available can be calculated from the percentage correct at various delays. On this basis, retarded subjects had 2.29 letters available at 00 msec delay, 2.75 letters at 50 msec, and 1.91 letters at 500 msec. Normal subjects had 3.42 letters available initially, 3.58 letters at 50 msec, and 3.04 letters at 500 msec. Since subjects were required to report only one cued letter on each trial, the probability of guessing correctly was 1/20 or .05. These figures are in substantial agreement with the whole report of 7-letter arrays in Experiment I (2.6 letters for retarded and 3.28 letters for normal subjects). Partial report procedures in the study did not demonstrate for either

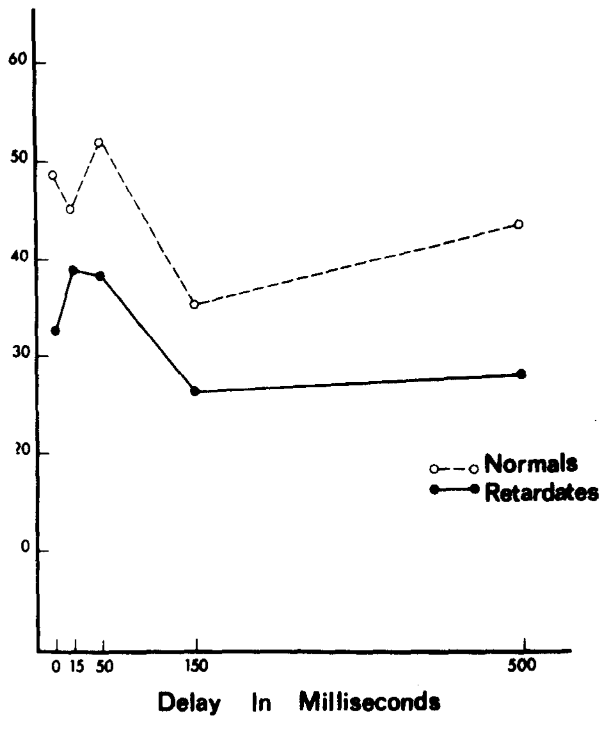

Figure 4. Percent correct responses as a function of delay of poststimulus cue in msec and intelligence.

group that more letters were available than could be reported before decay.

An analysis of the types of errors made by subjects is presented in Figure 5. An intrusion was defined as report of any letter not in the array presented. If subjects were guessing randomly, the proportion of intrusions should be about .65, since 7/20 letters were presented in each array, and the proportion correct would be about 1/20 or .05. The proportion of intrusions was .264 for retarded subjects and .088 for normals, $t(10) = 5.32$, $p < .01$. Although the retarded group responded randomly more often, they still performed well above chance.

Townsend (1973) considered three types of spatial information required of the subject in the Averbach and Coriell paradigm: the location of a letter relative to the letter display, the location of a bar marker relative to the bar marker display, and the relative position of the bar marker to the letter display. Her subjects had less difficulty identifying *what* letters had been in the display (Experiment II) and *where* the bar marker had been (Experiment III) than performing both tasks at once (Experiment I). She concluded that the decay function may be due to the task requirements as well as to the fading icon. The present experiment also required both location and identification of bar marker and letter. If subjects had difficulty connnecting bar and letter location, then the letters adjacent to the probed position might have a higher probability of report, due to the proximity of these letters to the cued position. To examine this notion, incorrect responses consisting of another letter from within the presented array were tabulated in terms of absolute number of positions removed from the cued letter. Figure 5 shows that, given a response was not correct (0 positions removed), the letter reported was more likely to be the letter one position removed from the cued one than any other letter in the array. The phenomenon was present at all delays. These results tend to confirm Townsend's suggestion that loss of information may be influenced by subject's ability to connect a particular bar location to a particular letter location. If the bar marker had masked the cued letter, then there would have been more responses at one position removed than correct ones, which was not the case.

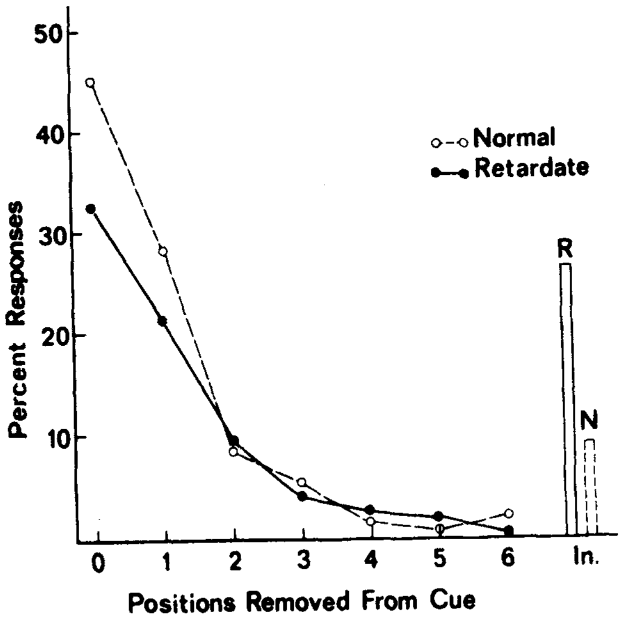

Figure 5. Percent responses as a function of intelligence and positions removed from cue. Zero positions removed represents a correct response. Numbers 1-6 represent responses within the array removed the respective number of positions. In. = intrusions.

Under several conditions in the present studies, educable retardates were able to read out about three letters from iconic storage, supporting with a different experimental procedure the "magical number three" of Spitz (1973, p. 153). The data confirm his studies of digit span, and are congruent with the finding of no retardate deficit in the duration of the icon, but suggest that its capacity may be slightly lower.Results in substantial agreement have been reported by Ellis (1970) using an immediate memory probe task, and by Brown (1974) with keeping track performance. It is interesting to note that both these authors found better performance in terminal positions where rehearsal strategies have no substantial effect. In light of the different experimental paradigms, the consistency of these findings is remarkable.

The experiments reported support the notion that when strategic behaviors are not essential to the execution of a memory task, the performance of retarded subjects is similar to, but slightly lower than, that of normals. The functional properties of the sensory register appear relatively independent of processes under the control of the subject. The studies reported have shown a quantitative but not a qualitative difference in the perceptual processing of visual information.

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