 66-13,709

NEUFELDT, Aldred Homer, 1940-
SHORT-TERM MEMORY IN THE MENTALLY RETARDED: AN APPLICATION OF THE DICHOTIC LISTENING TECHNIQUE.

University of Hawaii, Ph.D., 1966
Psychology, experimental

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSPHY IN PSYCHOLOGY

January, 1966

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ACKNOWLEDGEMENT

The writer gratefully acknowledges the assistance of the following principals and their schools, staff, and students without whose cooperation this research could not have been carried out: Mrs. Kaliko B. Chun, Kauluwela Elementary School; Mr. Wayne King, Hawaii Baptist Academy; Mr. Archie Jackson, Liluokalani Elementary School; Mr. R.H. Shibasaki, Linekona School for Retarded; and, Mr. Fred S. Takebayashi, Nuuanu Elementary School. Special mention must also be made of Mr. Jerry Cochrane, Director of Special Education, Department of Education, Honolulu, Hawaii, whose interest paved the way.

SHORT-TERM MEMORY IN THE MENTALLY RETARDED: AN APPLICATION OF THE DICHOTIC LISTENING TECHNIQUE

by

Aldred Homer Neufeldt

ABSTRACT

A series of experiments was conducted to investigate short-term memory in mental retardates with the dichotic listening technique as initiated by Broadbent (1958). The primary purpose of these experiments was to discern whether or not short-term memory capacity and/or strategy of encoding information could account for some of the differences between retardates and normals.

Four groups of 15 Ss each were used for the three major experiments. The groups included: two groups of retardates, one organic (group O) and one cultural-familial (group F) in nature, matched in mental age and digit-span with a group of normal controls (group NMA). The fourth group, matched in chronological age with the two mentally retarded groups, served as a second normal control (group NCA).

In the first experiment dichotic series of 2, 3, 4 and 5 pairs of numbers were presented to the Ss at the rate of one pair every half-second. This experiment demonstrated that the effective short-term memory capacity of both retarded groups is much less than that of a comparable chronological-age control, but does not differ greatly from group

NMA. The evidence also indicated that the retardates were subject to a faster rate of information decay in that part of immediate memory which has been termed S-system by Broadbent.

The second experiment held the length of dichotic series constant at 3 pairs of numbers, but varied the rate of presentation as follows: 1 pair per quarter-second, 1 pair per half-second, 1 pair per second, and 1 pair per 2 seconds. This experiment demonstrated a marked degree of flexibility by the normals (both NMA and NCA) in their adaptation of different strategies of recall to the various rates of informational input. Such flexibility was not found in the retardates.

Experiment III similarly tested the immediate recall of series 3 pairs in length, but held the rate of presentation constant at 1 pair per half-second. In this experiment, however, each pair of items presented together consisted of a letter of the alphabet and a digit, and the side on which the letter was presented varied haphazardly from pair to pair. For the retarded Ss (both groups O and F) recall was more successful when S was instructed to recall the items of one type and then the items of the other type than when instructed to report the items heard on one side and then those heard on the other. Normal Ss (NCA and NMA) recalled equally well in both conditions.

In conclusion, the evidence indicated that short-term memory capacity was indeed an important difference between retardates and group NCA. This deficit in apparent capacity, however, was probably enhanced by the retardates' lack of flexibility in the search for and use of appropriate recall strategies, and their manifestation of difficulty with ambiguous types of strategies. Though capacity was essentially the same for groups O, F and NMA, the two retarded groups also fell below NMA Ss in their ability to adopt a flexible mode of behavior, and to utilize more ambiguous strategies. The differences between groups NMA and NCA, on the other hand, were indicative of the degree to which both memoric capacity and ability to make use of useful strategies develops in normal individuals over time.

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"Memory has never enjoyed even a small fraction of the interdisciplinary interest that has been expressed in symposia, discoveries, and methodological innovations during the last five years (Melton, 1963, p. 1)." This statement of a prominent psychologist, who has spent the greater part of his life investigating learning behavior, can be taken as a sound indication of the prominence that a psychology of memory is coming to have. The studies presented in this dissertation deal with short-term memory in particular[1], primarily as related to the conceptions of D.E. Broadbent (1958), one of the major theorists in this area of interest.

It is almost axiomatic that one of the best ways to learn about a system of which little is known is to study that system at its points of breakdown. Applying this principle to the topic at hand it soon becomes apparent that one of the most promising loci of investigating short-term memory would be the mentally retarded. The question as to why the mentally retarded are retarded can be looked at from two points of view -- either theirs is a problem of information

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[1]Short-term memory can be distinguished from long-term memory as that memory lasting but a few seconds or minutes as compared to days and weeks. A common example of short-term memory in action is in the retention of a telephone number. We remember it from the time we look it up until it has been dialed, but seldom longer provided, of course, we do not have to focus our attention on something else in between.

retrieval, or one of information acquisition. If one holds that it is one of retrieval this suggests that the retarded can encode[2] information as well as normals, but are not able to evoke that information again -- essentially an untestable hypothesis. The second proposal, that the problem is one of acquisition, suggests that the retarded are not able to encode as much as normals, or at least are not able to retain such information long enough for it to be permanently stored -- a problem of short-term memory and hence potentially testable. The experiments presented, then, deal with the mentally retarded, and have been designed to elucidate some of the concepts of immediate memory (discussed further below).

Historical perspective

As is indicated above, the study of memory historically has played but a minor role in the scientific realm of psychology. Following Ebbinghaus (1885), human learning became a topic of increasing interest. Memory, though recognized to be the reciprocal of learning, was relegated to a minor position in terms of interest and consideration. If the well known

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[2]The term "encoding" is used here to refer to the taking in of information by the organism. Osgood (1957) would refer to such a process as "decoding". In view of the literary definition of its prefix, however, it is felt that the term "encoding" has the more proper connotation. This usage of "encoding" agrees closely with that of James Deese (1958, p. 247).

review of human learning by McGeoch and Irion (1952) can be taken as an index of functional opinion with regard to the relative importance of memory to learning, then one can get some idea of this tendency, as the topic of retention and forgetting is dealt with in one chapter. To be sure this chapter does indicate that some interest in the problems of retention were in evidence, but the greater implication seems to be that one could study learning behavior without taking into account human memory, its mechanism and function. The recent focus of attention on memory, however, would seem to be a reversal of that trend; a manifestation of the fundamental importance of memory to any theory of learning.

Melton (1963) observes that perhaps the most vigorous force directing attention within psychology to the need for a general theory of memory is the spate of theorizing and research on immediate or short-term memory. The cogency with which Miller (1956) and Broadbent (1958) have presented its case now has even the traditionally cautious functionalist (cf. Melton, 1963) considering this facet of the study of memory and learning. The contrast of the quantity and kind of research since 1956 with the preceeding thirty years is striking indeed. During those years most research on short-term memory was concerned with the memory span as a capacity variable, and no more. Furthermore, research of this nature—more often was considered under the rubric of <u>Attention</u> than as an integral component of memory, as can be noted in Woodworth and Schlosberg's <u>Experimental Psychology</u> (1954).

The functional approach to learning considered memory primarily in terms of associations formed over repeated trials. Single trial situations were seldom considered and hence had no part of the association-interference theories of learning and forgetting as developed by such functionalists as McGeoch and Irion (1952), Underwood (1957), and Postman (1963). The vast majority of research carried out in this field of human learning (primarily serial-verbal in nature) dwelt on the notion that learning, retention, and subsequent forgetting could be considered as a single process. One learned by forming associations. One remembered those associations left intact. One forgot, not because of a spontaneous loss of these associations, but rather because of a masking or interference by previous or subsequent learning (proactive and retroactive inhibition respectively). No recourse to neurophysiology was intended and no such recourse felt to be needed.

The recent interest in memory, however, has broken with the functional tradition on almost all counts. While accepting their conclusions with regard to associations and interference as important, many psychologists have not only not refrained from utilizing physiological constructs, but have often deliberately postulated some, leading in turn to supportive research in such related fields as biochemistry and neurophysiology. D.O. Hebb's (1949) concepts of cell assemblies and phase sequences can be taken as a prime case-in-point. Research carried out by Duncan (1949), Deutsch

(1962), and Gerard (1963), among others, have in turn tended to support Hebb's notions of a dual-process memory system -- an initial period of reverberation followed by some relatively permanent structural change.[3] A neurophysiological basis for discriminating between short-term and long-term memory would thus seem to be available.

Independent of the physiological and biochemical search for the engram and more relevant to the topic of this dissertation, however, has been the psychological theorizing of Miller (1956) and Broadbent (1958). The rise of psychological information theory (cf. Berlyne, 1957) presented a major development with which to explore behavior. Viewing the organism in terms of information (stimulus) flow quickly led to consideration of the organism in terms of memoric capacity. In this fashion short-term memory has come to be taken of major importance in human information-processing. Information, whatever the source, upon entering the organism (in the case of exteroceptor stimulation) presumably enters a short-term memory system. Such information may either be lost here due to spontaneous decay or to interference from other incoming stimuli, or both (which, or both is a theoretical issue still very much alive), or it may be transferred

[3]As early as 1900 Müller and Pilzecker postulated a perseverative theory of memory suggesting that the retentive process should be thought of in two parts, much as does Hebb's theory (1949). This theory, however, was never considered very seriously by the functionalists (cf. McGeoch and Irion, 1952).

to some permanent storage locus (long-term memory). The import of short-term memory to any consideration of learning thus immediately becomes apparent in that a short-term memory system can control what and how much information the organism encodes.

Short-term memory. Those theorists, such as Osgood (1953; 1957), Broadbent (1958), and Miller, Galanter, and Pribram (1960), who consider learning and performance in terms of short-term memory would picture a learning situation something as follows. The organism is faced with a task which is to be learned. During the learning process the organism is bombarded with large amounts of information in a short period of time. Now, presumably, that organism which is able to store the most relevant information long enough for it to be transferred to the long-term memory system learns most. The learning problem thus becomes one of immediate storage capacity. Two factors which might affect an organism's effective storage capacity become apparent: (1) organisms may differ in inherent short-term storage capacity; and, (2) organisms may differ in strategy of encoding the available information, some strategies being more optimal than others (cf. Bruner, 1957; Neufeldt, 1963).

Particularly germane to the question of capacity and strategy is the problem of individual and group differences, as these should be readily amenable to interpretation in terms of short-term memory. Consider differences between fast and slow learners, between normals and mentally retarded, or merely the effect of increasing age on learning performance in normal individuals. These are all problems potentially interpretable in terms of short-term memory, yet traditional measures, such as the digit-span, reveal little or no differences between such overtly distinguishable groups. The immediate storage capacity of these various groups appear to be very much the same, a point rather well made by Miller (1956). The major point espoused by Miller is not, though, that the memory span of different individuals differ little, but that better or poorer use can be made of the span one has. A relatively efficient strategy of encoding or recoding information, for instance, can increase the apparent memory span, storing more information than a relatively inefficient or poor strategy can. Considerable evidence in support of the importance of encoding strategies is available (cf. Neufeldt, 1963).

Besides the importance of strategies on increasing the apparent capacity of short-term memory, however, it is also possible that inherent differences of capacity do exist, though not measured by the traditional tests of memory span. Consider the effect of increasing age on learning performance in normal people as a case-in-point. Conventional means of measuring short-term memory (digit-span) have shown very little falling off with increasing age as compared with other learning tasks (Gilbert, 1941; Bromily, 1958). This suggests that digit-span is not a very sensitive measure of short-term memory, a doubt reinforced by Inglis' (1957) demonstration that the usual kind of digit-span items do not even differentiate between elderly patients with and without gross memory disorder. A tool with greater powers of discrimination is obviously needed. Of considerable potential utility in this regard is a modified memory span technique presented by Broadbent (1954) and termed "dichotic listening". Using the dichotic listening task Inglis and Sanderson (1961) found evidence suggesting that such a memory breakdown occurs in the patients' short-term storage-system (S-system, considered below). That is, they were able to retain only that information which could <u>immediately</u> be attended to; other superfluous information, which normal patients can store for a short period, was lost. Caird and Inglis (1961) confirmed these results and extended them to the case in which the ear and eye were together presented with different digits. Inglis and Caird (1963) have furthermore shown significant changes in short-term memory capacity over ages 11 to 70 using the dichotic listening technique, again a life-span where known differences in learning behavior are observable but not readily measurable with used short-term memory measurement (e.g., digit-span) techniques.

It would thus appear that some overtly different groups of individuals differ in short-term memory capacity (as measured by dichotic listening), though conventional means of measurement fail to distinguish such differences. The problem of whether or not these results are generalizable to other groups who differ in learning ability, such as fast vs.

slow learners, or normals vs. mentally retarded, remains to be tested. As a measure of short-term storage capacity the dichotic listening technique would seem to be a highly sensitive method of getting at such differences. Two questions of some importance arise: First, can this dichotic task also be used as an index of encoding strategy? If it can tap strategy as well as capacity, then we have, indeed, a useful device. Second, can this technique tell us anything about the structure of short-term memory? To answer questions of this nature we must consider the theorizing of Broadbent in some detail.

The Broadbent model. Broadbent's Perception and Communication (1958) has played a key role in the rapid development of interest in short-term memory. Much of the experimental data marshalled by Broadbent in support of his approach has been derived from the dichotic listening technique already mentioned. In a typical dichotic listening experiment a subject listens to two sequences of digits presented in such a way that one number arrives at the left ear at the same time that a different number arrives at the right; for example, the left hears 637 while the right hears 194 in such a fashion as the left hears "6", the right hears "1", etc. Broadbent (1954) discovered that if such pairs of digits are presented in rapid succession -- i.e., at the rate of two pairs a second -- the subject, when required to identify the material heard in a free recall manner, will tend to report first all of the digits presented to one ear and then the digits presented to the other (either 637194 or 194637 for the above example). He also found that when the subject is required to report the first pair of digits (e.g., 61) first, then the second pair, and then the third (in the case where three pairs of digits have been presented), recall is less successful than when the subject is permitted to give the digits heard in one ear and then those heard in the other. The first finding recently has been confirmed by Bryden (1962); the second, with slight modification, by Moray (1960). It is thus evidently easier to report the digits ear by ear than to report them pair by pair so long as rate of presentation is fairly rapid. On the other hand, when the material is presented slowly, it is more common for the subjects to give the material in the order of arrival (Broadbent, 1954; Bryden, 1962).

Broadbent (1958) has proposed a model in terms of sensory "channels" to account for these findings. He argues that the material arriving at one ear (channel) is attended to and perceived as it arrives, while the material arriving at the other ear is held in short-term storage. Once the subject has perceived all the material on the first channel, he can attend to the material from the second, provided that the memory traces in the short-term storage system have not decayed. The subject is unable to switch attention from ear to ear (channel to channel) fast enough to assimilate all the incoming information when a rapid rate of presentation is used, and so "listens" (attends) to one ear while a "filter mechanism" of some sort shunts the information coming into the other channel into storage; thus, the subject reports all the numbers from the one ear first. If the rate of presentation is slowed down, the subject has enough time to shift attention channel to channel, and so can report the material in the order of arrival. Bryden (1962, 1964) has considered these various modes of recall in terms of strategy of recall.

The exact nature of the "filter mechanism" is left unspecified by Broadbent, and a consideration of its nature and locus has resulted in some disagreements (cf. Moray, 1960; and Emmerich, Goldenbaum, Hayden, Hoffman, and Treffts, 1965). There is, however, fairly good agreement that the short-term memory system must contain at least two parts: (1) a limited capacity channel which attends to information as soon as it is received (termed perceptual, or P-system); and, (2) a storage area which can store, for short periods of time, such superfluous information as can not immediately be carried by the P-system (termed S-system). The dichotic listening studies of Broadbent (1954, etc.), of Broadbent and Gregory (1961), Moray (1960), and Bryden (1962, 1964) support these concepts as outlined.

It might occur to the reader at this point that some factor other than short-term memory, such as cortical dominance, may be the causal factor behind the tendency to report the digits by ear -- one ear produces more activity on the opposite side of the cortex than the other ear does, and vice versa. This peculiar form of immediate memory might therefore be due to the division of the cortex into two hemispheres, thus failing to apply when other senses are used for delivering the information. The most telling experiment against this argument has been presented by Broadbent (1956) and replicated by Caird and Inglis (1961). These experiments were similar to the dichotic listening experiment already mentioned, but instead of using two ears they used an eye and ear simultaneously. In both studies the results were found to be similar to the binaural type of experiment. In the Broadbent study it is particularly striking that half the individuals studied reproduced the auditory information first and then the visual second, and _vice versa_, so that the effect cannot be due to some persistent auditory after-effect absent from other senses. Since the eye-ear presentation netted results similar to those received from the dichotic situation, this tends to confirm the notion that the phenomena here under consideration are due to some central rather than peripheral sensory mechanism.

The dichotic technique, as we have already seen, is an excellent indicator of memory capacity, both of the S- and P-systems. Broadbent's discussion of order of recall, however, would have it that the structure of short-term memory is what determines whether a person recalls the digits by ear or in temporal order. That is to say, the switching mechanism is what determines the subject's order of recall, and as was noted earlier, considerable disagreement with Broadbent has arisen over this claim. In view of the evidence a better approach, it seems, would be to accept short-term memory as a two-part system, but to view, along with Yntema and Trask (1963), the subject's recall performance more in terms of a search process; and, with Bryden (1962), the order of recall as a strategy. The fact that even at fast rates of presentation intrusions from the second ear do occur in recall of the first, and *vice versa* (what Bryden would term "attempted ear order"), would indicate that the two channels are not totally separable as suggested by Broadbent. However, the ear order of recall may well be the best *strategy* of recall that the subject can adopt.

Statement of purpose

From the studies of Broadbent (1954, etc.), Inglis and his co-workers (1960, 1961), and Bryden (1962, 1964) the utility of the dichotic listening technique in studying short-term memory would seem widespread. It is capable of picking up differences where conventional techniques fail, and if differences are present, as in the case of senile vs. intact *S*s, can pick up these differences with a very small *N*. The results appear to be generalizable to channels of input other than ear alone (cf. Broadbent, 1957; Caird and Inglis, 1961). Research using this technique has led to renewed interest in attention and also to the postulation of a theoretical structure of short-term memory (Broadbent, 1958) that has generated a considerable amount of research. Finally, as a technique, it is amenable not only to the discovery of differences in memory capacity, but also to the identification of strategies used in encoding information (Bryden, 1962; 1964), a problem most other techniques used in the investigation of short-term memory find difficult to handle.

Whether or not differences in storage capacity and/or strategy of information coding will account for group differences, such as those between normals and retardates, remains to be seen. The hypothesis of this paper is, however, that these two concepts should go a long way towards the explanation of such differences as do exist. As was indicated at the out-set of this chapter, the problems of mental retardation should make a good proving-ground for such an hypothesis.

N.R. Ellis (1963) has pointed out that really very little is known about the short-term memory of mentally retarded -- either in terms of strategy or capacity. On a gross level distinctions can be made between the organic and cultural-familial retardates, for instance (cf. Robinson and Robinson, 1965). When, however, attempts have been made to test such differences with such short-term techniques as delayed recall, relatively few have been found (cf. Weatherwax and Benoit, 1957; and Osborn, 1960). It has furthermore been observed that retardates as a whole do about as well on laboratory tasks under some circumstances as do normal subjects.

For example, Shapiro and Johnson (1964) have found that mentally retarded do quite well on laboratory learning tasks so long as learning trials are distributed and extraneous "noise" in the learning system is minimal. Laboratory tasks of this nature depend, of course, heavily on short-term memory. In a task such as mentioned above the amount of information to be handled by the subject is limited, it can be handled successively, and most of it is relevant. In a scholastic setting, however, the information available to the individual is almost infinite, and only some of it is relevant to the task of learning. Differences in learning in such a case could be thought of in terms of coding strategy -- retardates use less optimal strategies than do normals, such as attempting to encode all the information available, or not discriminating between relevant and irrelevant information, and so forth. If this is the case, such differences should become evident with the dichotic listening task where two different sources of information are present, both of which are highly demanding of attention, and where the information is presented too rapidly to be handled successively. In such a situation normals (at least those above chronological age 11, as demonstrated by Inglis and Caird, 1963) tend to report all the information received by one ear before reporting that of the other. How retardates respond in such a situation is not known and remains for the following experiments to discern. One might suspect, however, that if theirs is a problem of encoding strategy, as suggested above, retardates might well be found attempting to encode all the information of both ears simultaneously by shifting attention from one channel of input to the other. Because of the rapidity of presentation (1 pair per half second), though, such a strategy would tend to result in a net loss of such information to recall.

Hermelin and O'Connor (1964) have shown that, though the digit span of retardates and normals differ little, a faster rate of decay of short-term memory occurs in the retarded than in normal subjects. Where does this difference lie? Is it primarily due to decay in the S-system as with the senile (see above), or is there also a difference in capacity of the P-system? The experiments which follow have been designed to measure both differences in strategy of attention and recall, and in short-term storage capacity between normal and mentally retarded subjects.

Pilot Investigation

As a preliminary step in testing the hypotheses outlined above, and to ensure that the dichotic listening technique would be applicable to the mentally retarded, a pilot study was carried out.

Method

Subjects

Three groups of subjects (<u>Ss</u>) matched in mental age were used -- two mentally retarded and one normal control. The mentally retarded Ss, obtained from Linekona School for Retarded Children, were grouped into those who were retarded due to organic causes, as determined by medical report (group O), and those presumably retarded for cultural-familial reasons; at least with no known organic cause (group F). Normal Ss (group N) were obtained from the University Elementary School. Subjects in these groups ranged in mental age from 8 years 3 months to 11 years 6 months, with the mean IQ for each group, as measured by the Wechsler Intelligence Scale for children (WISC), as follows: 70.8 for group O; 68.8 for group F; and, 110.8 for group N. No S showed any impairment of hearing.

Procedure

The apparatus used to administer the binaural stimuli consisted of a Sony two-channel tape-recorder (Model 464CS) played into a pair of Sharpe headphones (Model HA-10). Different sets of digits, taken from Inglis and Caird (1963), were recorded on each channel as shown in Appendix A(i). Each series was recorded so that two numbers, one from each channel, were simultaneously heard by S. The digit pairs within each series were recorded at the rate of 1 pair every one-half second. Care was taken to control the numbers on each channel for timing and intensity. The headphones covering the Ss' ears were equipped so that each ear received only the digits from one of the two channels.

Each S, on first arriving, was seated at a table opposite the experimenter (E). The S was briefly introduced to the use of the headphones, and then given series A, B, and C (see Appendix A(ii), instructions 1 and 2). This procedure provided a practice series allowing S time to become used to the experimental situation, and ensuring that group differences were not due to differences in sensory acuity. When S was fully acquainted with the procedure, the test series was begun with in the order shown. The longest series presented to Ss of this study, however, was the 4-pair series shown on Appendix A (i). Ss were informed of each change in series length (see instruction 3). E recorded S's output on mimeographed score-sheets for later scoring.

Responses were scored following the procedure used by Broadbent (1954, etc.), and Inglis and Sanderson (1961). The first digit repeated by S determined in each case which channel was taken to be the half-span recalled first. The score obtained was the average number of correct responses for each half-set of digits, taking each digit's position in the series into account.

Results and Discussion

Figure 1 illustrates that using the dichotic listening technique group differences in short-term memory are distinguishable. Most striking to cursory examination is that for all groups the digit half-span recalled first is

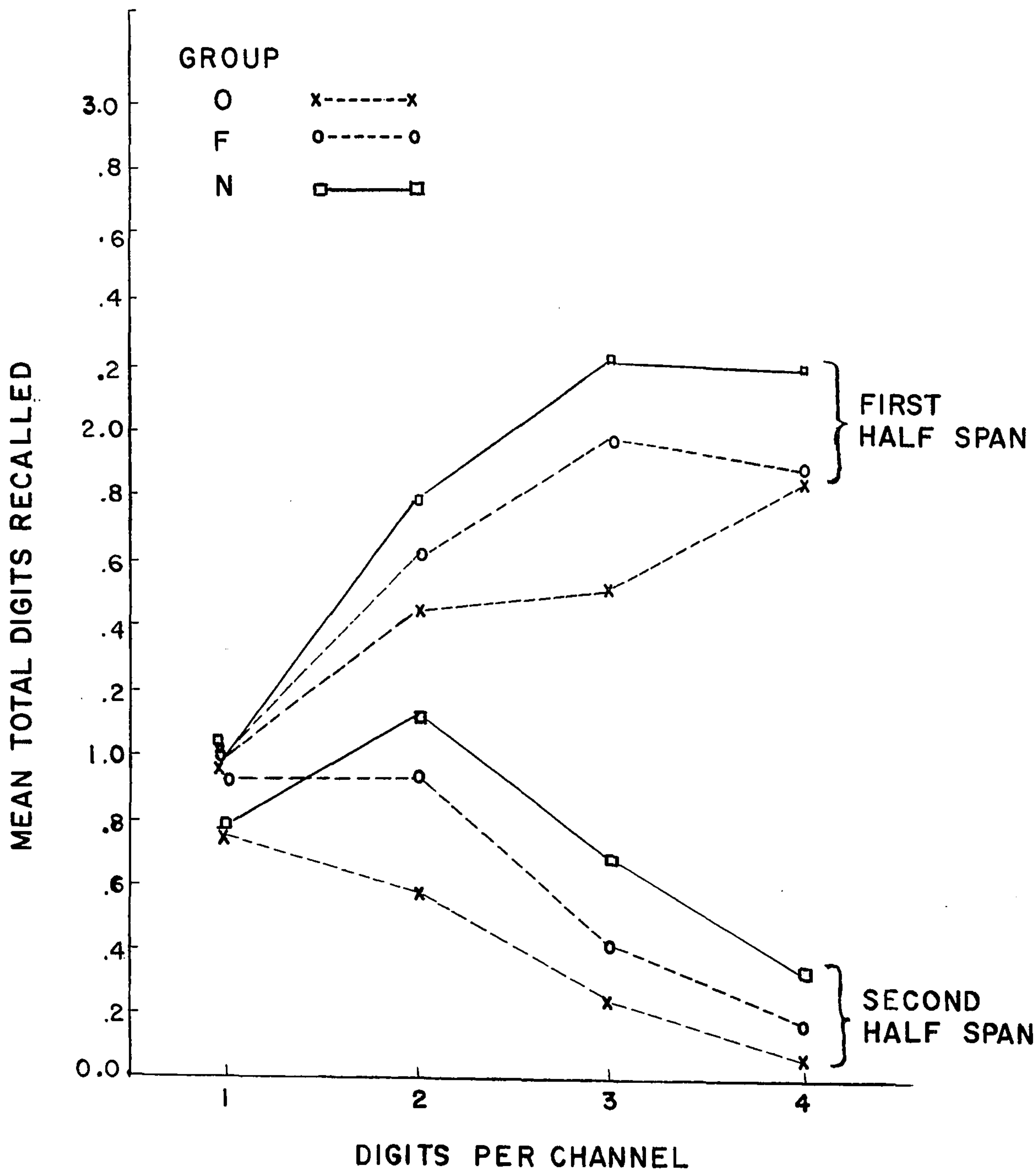

Figure 1. Mean number of digits recalled per trial for series varying in length.

much superior than that recalled second. This result agrees with those obtained by Broadbent (1954), and Inglis and Sanderson (1961), and concurs with the P- and S-model advanced by Broadbent (1958). The dichotic technique thus appears to be suitable for more detailed study of group differences between retardates and normals.

A Lindquist Type I (Lindquist, 1953) analysis of variance for between group effects did not reach significance ($F = 1.79$, $.1 < p < .2$), but was suggestive that with better control these groups would in fact differ significantly. One obvious artifact affecting these results was that no attempt had been made to match the groups on the ordinary digit-span. Furthermore, Inglis and Caird (1963) have shown a significant effect of chronological age (CA) on immediate memory. Since the retardates were older (mean CA of group O = 14 yrs. 6 mo.) and hence had more experience than the normals (mean CA = 7 yrs. 11 mo.), this may have in effect narrowed such group differences as in fact are present. In view of such confounding effects of CA on performance Denny (1964) has suggested that two normal control groups be used -- a mental age and a chronological age control. Further research should, then, not only match the groups on digit-span, but also use the dual control suggested by Denny.

Experiment I

The pilot study presented evidence in support of the notion that both strategy and storage capacity play an important part in differences between normal and mentally retarded Ss. The purpose of the present experiment was to extend and refine that evidence by: (1) studying the problem in more detail; and, (2) improving on its experimental design by (a) using a dual control as suggested by Denny (1964), and (b) matching the experimental and control groups on digit-span.

Method

Subjects

Four groups -- two mentally retarded and two normal -- of 15 Ss each were used. On the basis of medical evidence available in files on each S, 15 clearly organic retardates (9 males and 6 females) were selected, ranging in WISC IQ from 53 to 79. Fifteen familial retardates were then selected, matched in mental age (MA) and digit-span, one for each group O subject. Subjects were matched in MA, but E kept the IQ and hence the CA of the matchings quite close as well. Plus or minus 3 months MA was considered an adequate match (see Table 1 for a summary of matching data). The retarded Ss were obtained from special classes in Kauluwela, Liluokalani, and Nuuanu Elementary Schools, and from Linekona School.

Table 1

Summary of data on which groups were matched

Group	Mean CA	Mean MA	Mean IQ**	Mean digit-span
O	13-06*	9-3	69.13	4.53
F	13-01	9-3	71.13	4.67
NMA	8-10	9-3	105.27	4.73
NCA	13-06		106.86	5.60

* to be read 13 years 6 months

** the IQ scores for groups O and F are derived from the WISC, but the estimates of IQ for groups NMA and NCA are based on group tests given in the schools

The normal control groups were matched as follows: Each of 15 Ss of the first group (NMA) was matched in MA and digit-span with one of the O-group Ss following the same procedure used in the organic-familial matching above. It should be noted that the only intelligence ratings available for these Ss were from the California Test for Mental Maturity (CTMM) regularly administered to local elementary school children. It was felt, however, that though not perfect, this rating was adequate as an estimation of normalcy for the MA control group. Each S of the second control group (NCA) was similarly matched with one of the O-group Ss, but in terms of CA rather than MA, keeping their IQ range within the normal range of plus or minus 1 standard deviation from the test mean. Although attempted, it was found that as close a match on digit-span as found in the previous 3 groups was not to be obtained here, so that in fact the digit-span of NCA is superior to all other groups (e.g., comparing NCA with NMA, $t = 3.36$, $p<.05$). The matching procedure is discussed further, below.

The younger normal Ss were obtained from Liluokalani Elementary School, and the older Ss from Hawaii Baptist Academy.

Procedure

The apparatus, procedure and instructions were the same as those used in the pilot study except as follows: (a) the items from the WISC digit-span forward were recorded and administered via the headphones to all Ss, for matching purposes, before proceeding with the instructions of the experiment proper. Plus or minus one digit was allowed as acceptable for matching the digit-span of individual Ss in groups F and NMA with those of Ss in group O, (b) whereas the 1-pair series contributed little to the study of group differences, this material was dropped from presentation and the 5-pair series shown in Appendix A (i) was added; and, (c) the test series were presented in a partially counterbalanced order -- half the Ss in each group receiving the 2-pair material first (the order shown in Appendix A (i), the other half first receiving the 5-pair material (reverse order).

Scoring. Two scoring procedures were utilized: (1) ear order -- the procedure described and used in the pilot study. This procedure was used as the best estimate of P- and S-system capacities, following Broadbent (1954), Broadbent and Gregory (1961), and the Inglis studies (1961, 1963), and also as a measure of the degree to which the ear-order strategy of recall was in use (cf. Introduction, pp. 9-10, above); (2)any other logical order. This second procedure allowed for the use of other strategies of recall, such as the "temporal" and "attempted ear order" described by Bryden (1962) (cf. Introduction, pp. 12-13, above) and scored as correct all responses following the order of the digits presented in some logical sequence. Consider for example that a S has heard 653 on his left ear, and 924 simultaneously on his right. A normal S might respond

924653. A response of this nature would be scored as 3 correct for the first half-span recalled and 3 for the second half-span for both scoring procedures. Suppose, however, that a response is 624953, then the ear order method of scoring would provide values of 1 and 1 for each half-span, as the first number given is taken as the indicator for the half-span first recalled. It can readily be seen, however, that this S actually reported all six digits correctly, but rather than following the ear order he switched from ear to ear. The second scoring procedure would, then, record this latter response as 3 and 3.

Results and Discussion

Figure 2 presents the mean number of items recalled by each group for each series length as determined by the two scoring procedures. Figure 3 more clearly reveals the overall group differences by combining the data from both half-spans recalled. These same data are presented in Figure 4 as a proportion of the total number of items presented that were correctly recalled. It is readily apparent from the three Figures that group NCA is much superior to any of the other three groups, with NMA falling above, but clustering with groups F and O, in that order. From these Figures the differences between Scoring I and Scoring II are also readily apparent. As Scoring II contains all the information of Scoring I, plus any additional information retained by strategies of recall other than "ear order", the results of the second scoring are always above those of the

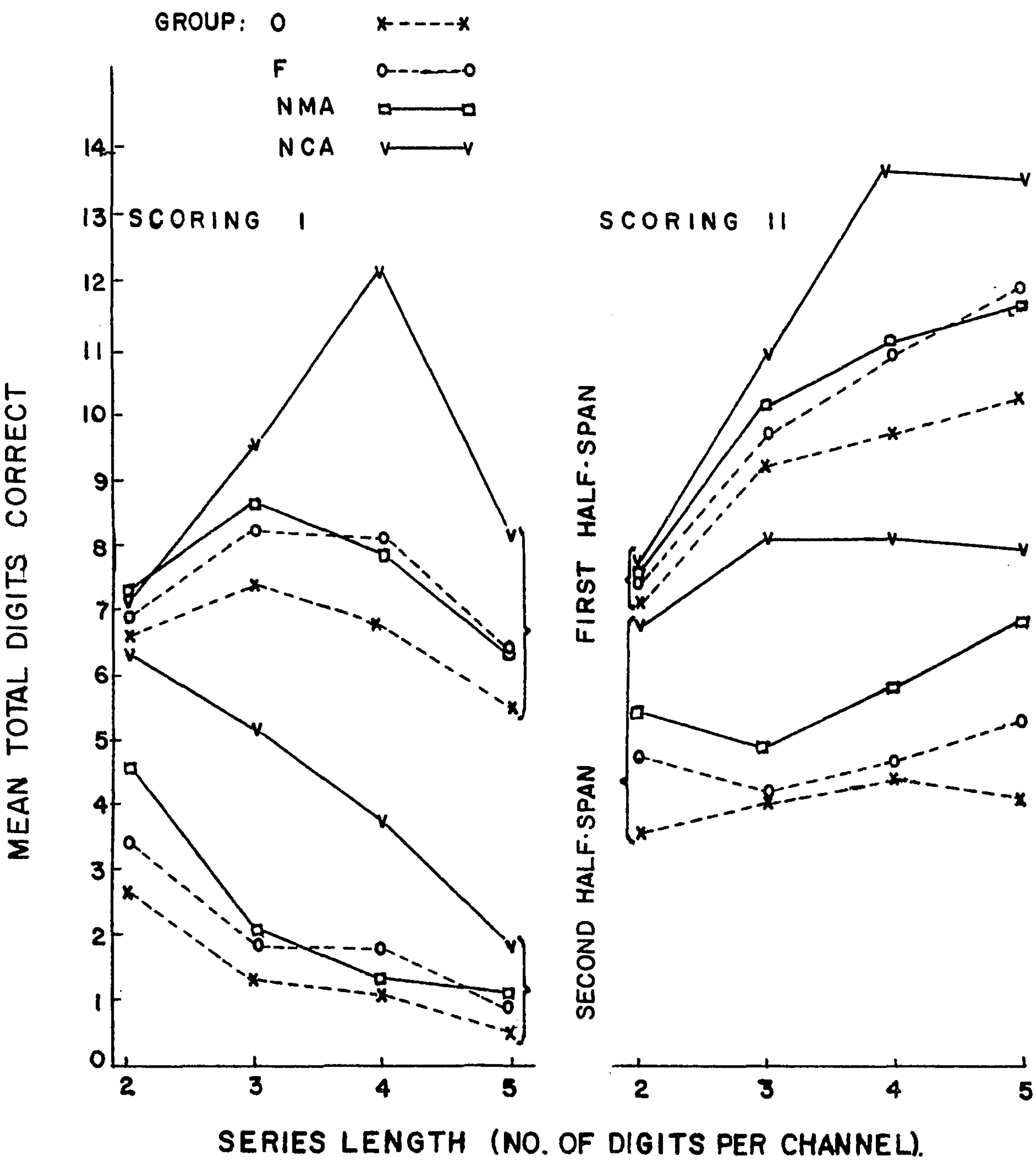

Figure 2. Amount recalled from series varying in length, summing across the trials of each series length.

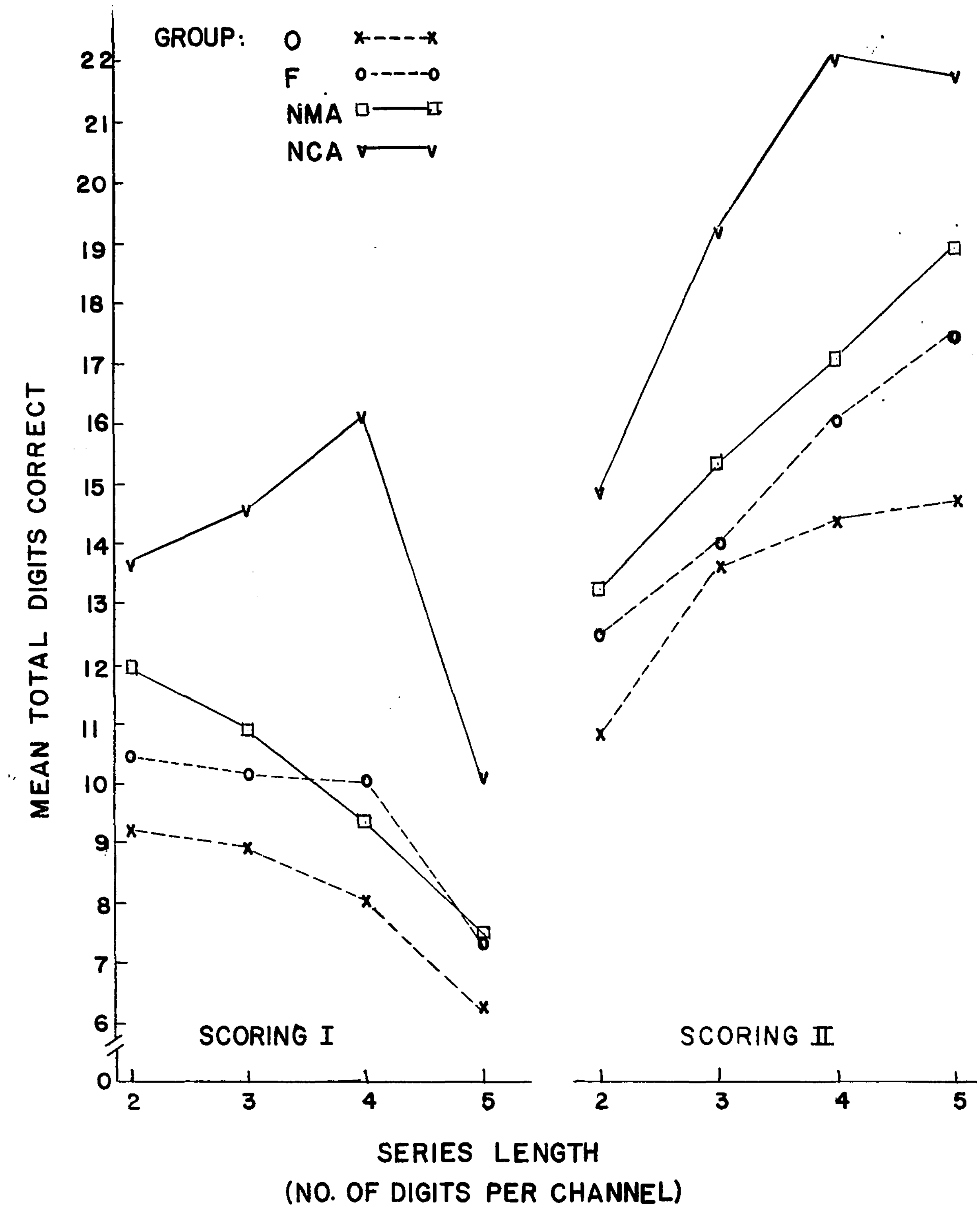

Figure 3. Total amount recalled in both half-spans from series varying in length, summing across the trials of each series length.

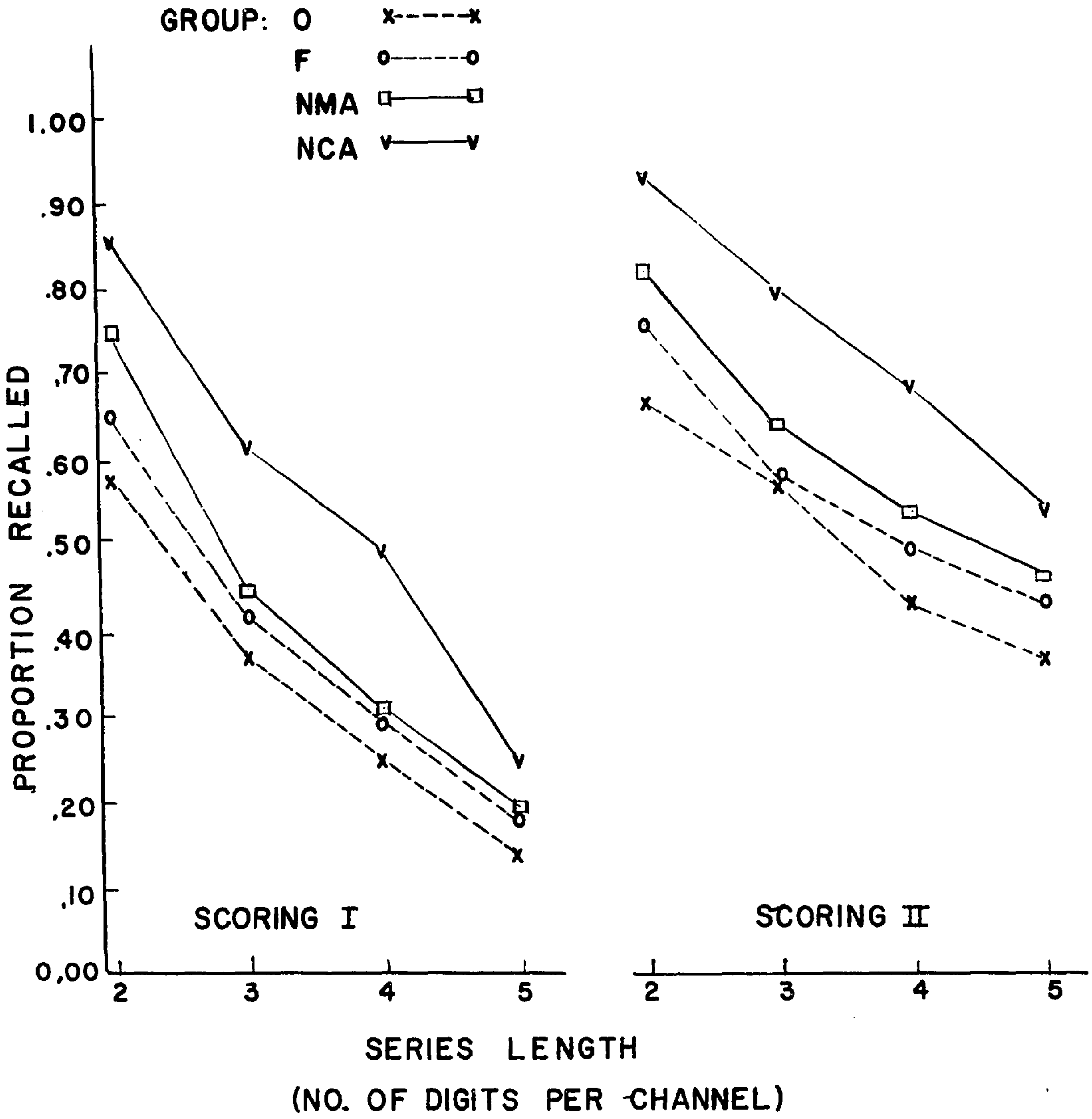

Figure 4. Proportion of items recalled as a function of series length.

first (compare Scoring I and Scoring II on Figures 2, 3, and 4).

After subjecting the original proportions to the standard arcsin transformation (cf. Snedecor, 1956) in order to secure homogeneity of variance, three Lindquist (1953) Type VI analyses of variance were computed for each scoring of the data. These analyses are summarized in Tables 2 and 3. A contrast of Tables 2 and 3 reveals little difference in discriminability by the two scoring procedures used. In both cases the three main effects of Group, Series Length and Half-span were highly significant on all analyses, with Length x Half-span the only interaction consistently so.

Consider these results in detail. The overall group effect shows the normal Ss (both NCA and NMA) to be superior to retardates. Such differences must be considered in the light of the Group x Half-span, Group x Series Length, and the Group x Half-span x Length interactions. The Group x Half-span interaction is of particular interest here because group differences are expected to occur on both halves of information presented. The degree to which the main Group effect is influenced by Half-span and Series Length directly tests the questions about the P- and S-systems as advanced in the introduction. It can be noted that the Group x Half-span interaction is not significant. This suggests that the main Group effect is to be interpreted in terms of differences in both the P- and S-systems.

The hypothesis with regard to the Group x Length

Table 2

SUMMARY OF ANALYSES OF VARIANCE,

FIRST SCORING OF EXPERIMENT I

Source of Variation	df	MS (O x F x NMA)	F (O x F x NMA)	MS (O x F x NCA)	F (O x F x NCA)	df (NMA x NCA)	MS (NMA x NCA)	F (NMA x NCA)
Between Ss								
Groups (G)	2	16.36	3.25*	106.63	13.60***	1	75.40	10.19**
Error(b)	42	5.06		78.38		28	7.40	
Within Ss								
Series								
Length (L)	3	233.32	131.94***	238.92	161.34***	3	230.59	89.92***
G x L	6	2.90	1.64	3.76	2.54*	3	3.11	1.20
(L x S)w	126	1.77		1.48		84	2.60	
Half-span (H)	1	884.84	204.26***	811.21	156.42***	1	473.66	538.19***
G x H	2	.41	n.s.	3.51	n.s.	1	2.40	2.72
(H x S)w	42	4.33		5.18		28	.88	
L x H	3	11.03	4.52**	8.43	3.09*	3	12.01	5.50**
G x L x H	6	.95	n.s.	7.42	2.72*	3	5.68	2.60
(L x H x S)w	126	2.44		2.73		84	2.18	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 3

SUMMARY OF ANALYSES OF VARIANCE,

SECOND SCORING OF EXPERIMENT I

Groups Analysed	O x F x NMA			O x F x NCA		NMA x NCA		
Source of Variation	df	MS	F	MS	F	df	MS	F
Between Ss								
Groups (G)	2	19.81	3.69*	105.84	16.64***	1	60.98	15.40***
Error(b)	42	5.37		6.36		28	3.96	
Within Ss								
Series Length (L)	3	120.51	114.08***	129.78	108.53***	3	107.20	87.83***
G x L	6	1.31	1.24	2.29	1.92	3	2.10	1.72
(L x S)w	126	1.06		1.20		84	1.22	
Half-span (H)	1	589.68	122.78***	520.70	107.75***	1	235.19	125.18***
G x H	2	2.75	n.s.	9.73	2.01	1	3.22	1.71
(H x S)w	42	4.80		4.83		28	1.88	
L x H	3	6.98	3.70*	61.66	31.33***	3	3.26	2.17
G x L x H	6	.75	n.s.	4.17	2.17*	3	4.24	2.82*
(L x H x S)w	126	1.89		1.97		84	1.50	

* p<.05
** p<.01
*** p<.001

interaction was that group differences should be minimal on the shorter series and increasingly in evidence as series length increased. This interaction, as well as the Group x Length x Half-span triple interaction was found to be significant on the O x F x NCA analysis. The changes representing these interactions can be illustrated as in Figure 5. Using the critical difference technique of determining significant group differences (Lindquist, 1953, pp. 271-272), the above prediction was found to be generally true in the first half-span attended to; that is, no group differences were found on the short series, but the groups did differ significantly on the longer series (see Table 4). In Broadbent's (1958) terms, it would appear the P-system (measured by the first half-span) of all groups can adequately handle a relatively small amount of information. However, whereas the NCA Ss are able to increase the load of the P-system (up to a point) with increased input of information, the P-capacity of retardates appears to remain about the same (see Figure 2) across input conditions.

In the second half-span (second ear attended to) the above prediction did not hold true. In fact, just the reverse was the case. Group NCA had significantly better recall than group O or F on the shorter series, but such differences diminished to virtually none at the longest (Table 4). It seems, then, that storage capacity of retardates is either uniformly poor in encoding, or else

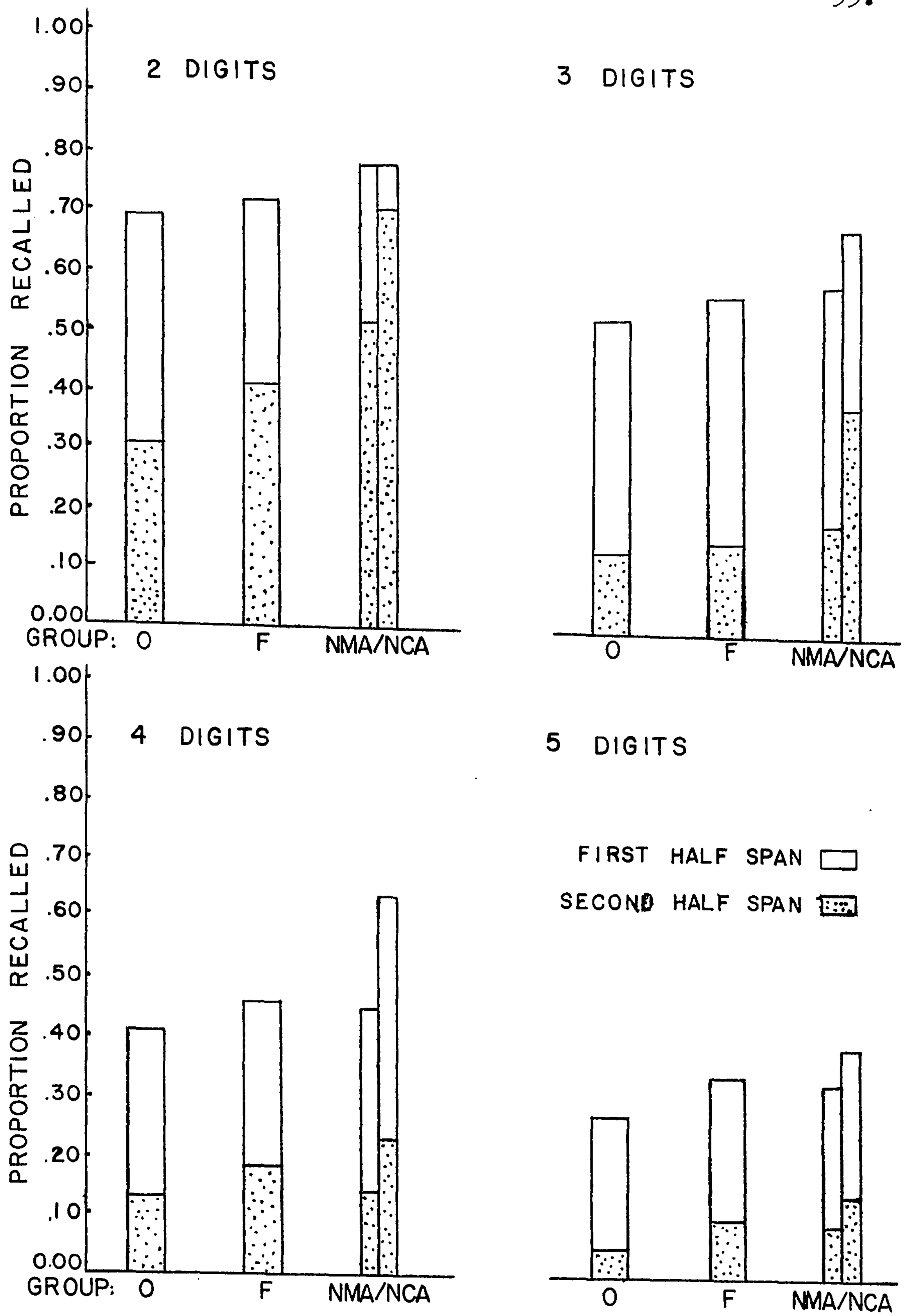

Figure 5. Group differences in each half-span as a function of series varying in length.

Table 4

SIGNIFICANT MEAN GROUP DIFFERENCES FOR BOTH HALF-SPANS, FIRST SCORING OF EXPERIMENT I

Groups Compared	Series length in digits per ear 2	3	4	5	Critical* Difference for $p<.05$
1st half-span					
O vs. F	n.s.	n.s.	n.s.	n.s.	10.76
O vs. NCA	n.s.	16.91	23.63	10.93	"
F vs. NCA	n.s.	11.39	18.32	n.s.	"
2nd half-span					
O vs. F	n.s.	n.s.	n.s.	n.s.	14.07
O vs. NCA	39.83	25.32	n.s.	n.s.	"
F vs. NCA	29.21	23.32	n.s.	n.s.	"
O vs. NMA**	21.65				

* The critical differences on this table were calculated from the Mean Square within cells obtained from Lindquist Type I analyses carried out separately for each half-span of data (cf., Lindquist, 1953, pp. 271-2). Appendix B summarizes these analyses.

** All other comparisons of O x F, O x NMA, or F x NMA were not significant.

subject to rapid decay, the latter being Broadbent's hypothesis. If we agree with Broadbent (1958), and Broadbent and Gregory (1961) that the first scoring procedure used here is the only valid measure of the S-system, and for the sake of parsimony that the same process occurs in both normals and retardates, then decay would seem to be the correct answer. In the pilot study (Figure 1, above) it was noticed that the S-system of retardates operates about as well as that of normals at the very-short series (1 digit per ear). With longer series, even as short as 2 digits per ear, as in this study, recall from the S-system falls off and remains low. Similarly, though the short-term storage capacity of normals is relatively good at the shorter series (as noted above), as the normal S has to attend to an increasingly longer series with his P-system, the information in the S-system is increasingly subject to decay. Such stimulus decay seems, though, to occur somewhat more slowly in the chronological-age control than in the mentally retarded so that a lack of difference is found between NCA and the retarded groups only at the 5-digit series.

Earlier it was noted that the main Group effect of the O x F x NMA comparison was significant. This significance was found in both Table 2 and Table 3, above. The suggestion thus was that group NMA was superior to one or both of the mentally retarded groups. A more detailed analysis of Scoring I with the same three groups, but considering the data from each half-span separately (cf. Appendix B, and also Table 4), found that the P-system (first half-span) of group NMA, though approaching it at points, never differs significantly from that of either group F or group O. The S-system of group NMA, however, is superior, but only to group O and this on the shortest series alone. A similar analysis of Scoring II presented the same results. Taken in the light of the O x F x NCA comparison above these results suggest that the capacity of the P-system of groups O, F and NMA are very similar. Furthermore, these normals of comparable mental age seem to have the same problem of short-term storage decay that the mentally retarded do (this might be taken as supportive evidence for the utility of the concept of "mental age"). The fact that group NMA is significantly superior to group O on the shortest of the series may well indicate that the information decay process in the S-system of these normals is somewhat slower than in the retardates, but not quite as slow as that of group NCA.

Consider next the two main factors of Half-span recalled, and Series Length. All previous evidence (i.e., Broadbent, 1954; Inglis and Sanderson, 1961; Dodwell, 1964) suggested that gross and significant differences would be found between the two half-spans; that is to say, the first channel attended to should be much more accurately recalled than the second. The results of this experiment corroborate such previous research and thus are supportive of Broadbent's theory in this respect. The significant Series

Length effect is similarly not of particular interest, except again in-so-far as to corroborate previous evidence; namely, that an increase in length of series nets a decrease in percentage of items correctly recalled.

Experiment II

Earlier it was noted that normal Ss will generally use an "ear order" of recall in the dichotic situation, with an occasional lapse to some other recall order. This statement holds true primarily for rates of presentation as rapid as 1 pair per half second. Broadbent (1954) and Bryden (1962) have, however, also shown that at slower rates of presentation, such as 1 pair per 2 seconds, one of the other recall strategies, primarily recall by temporal order, will more frequently be used; that is, the numbers will tend to be recalled in their order of arrival. As was noted in the introduction, although Broadbent (1958) accounted for this phenomenon in terms of a "switching mechanism", it was felt that this change in recall might better be thought of in terms of recall strategy. At slow rates of presentation S can most readily recall the information in the temporal order; whereas, at faster rates of presentation it becomes optimal for the normal S to focus attention on all the information presented in one channel first before switching, thus avoiding wastage of time spent in switching and concomittant loss of information.

Evidence from both the pilot study and from Experiment

I showed that even at the fastest rate of presentation mentioned above, retardates frequently will use some order of recall other than the ear order. That is, they tend to alternate their attention between the two input channels rather than to limit their attention as the normals (particularly group NCA) do. This experiment was designed, then, to investigate whether the retardates can be induced to use the more efficient ear order of recall by using a rate of presentation faster than that previously used.

Method

Subjects

Dodwell (1964), in a carefully controlled series of studies, found practice effects on this type of task to be virtually non-existent; thus the same Ss were used in this experiment as in Experiment I.

Procedure

The equipment used in this experiment was the same as that used previously.

Appendix C presents the 24 3-pair series of numbers which were prepared using numbers from 1 to 10. Each series consisted of six different numbers. Six series were recorded at each of the following rates: 1 pair per 2 seconds, 1 pair per second, 1 pair per half second, and 1 pair per quarter second. The four conditions were presented in a partially counterbalanced order, half of the Ss in each group beginning with the slow rate of presentation, and half with the fast rate.

Scoring. The same two scoring procedures as used in Experiment I were used in this study. However, as the second scoring method is an estimate of overall correct output, an additional measure was obtained in this study -- a difference measure between the two scoring procedures. It was noted in Experiment I, above, that when the ear order of report was used predominantly, the difference between the two scoring procedures was minimal. When, however, some other strategy of recall is utilized by the S, then the difference in scores obtained by the two procedures increases. The relative usage of the ear-order of recall as compared with other strategies, can thus readily be determined. For normal Ss this Difference score should be low at the fast rates of presentation and increase at the slower speeds. This would follow from the evidence presented by Broadbent (1954) and Bryden (1962) which shows that normals tend to use the "ear-order" of recall at fast rates of presentation, but switch to a temporal-order of recall at slower rates (see pp. 9-10, above).

Results and Discussion

As was indicated above, the clue as to whether or not retardates can be induced to use the more effective ear-order of recall lies in the Difference scores. Figure 6 presents the Difference scores graphically. The prediction that these scores should be low at the fast rates of

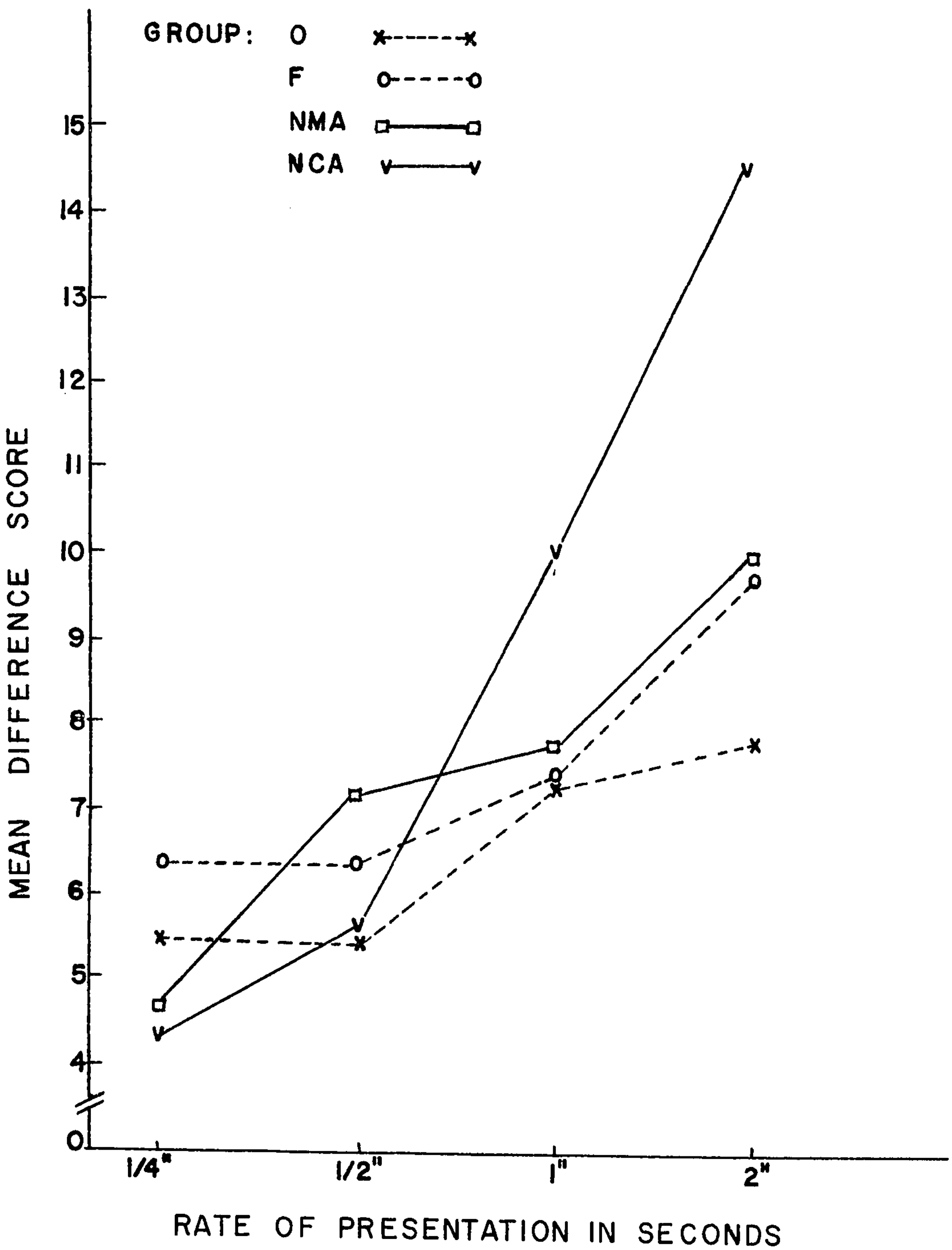

Figure 6. Group differences in the use of recall strategies as a function of rate of series presentation, calculated by taking the difference between the two scoring procedures used.

presentation and large on the slower speeds was tested by a Lindquist Type 1 analysis of variance, summarized in Table 5. The significant main effect of Presentation Speed indicates that the Groups do indeed change their recall strategy with shift in presentation speed, and a glance at the graph indicates that the shift is in the predicted direction.

The significant Group x Presentation Speed interaction at two of the three tested levels, however, suggests that some groups are more affected by the change in speed than others. Most noteworthy is group NCA, as can be seen in Figure 6. This group most closely follows the prediction as outlined, showing a very marked shift. In other words, at high speed of presentation this group uses the ear-order almost exclusively (as measured by Scoring I), but as the speed of presentation is slowed, group NCA comes to depend largely on other strategies of recall. Group NMA, though not as markedly, is also strongly affected by presentation speed. A Treatments x Subjects analysis of variance on the NMA data alone revealed the effect of Speed as highly significant ($F = 6.78$; $df = 3$, $p < .001$).

Of the two groups of retardates only group F changes strategy to a significant degree. A Treatments x Subjects analysis of variance obtained $F = 3.20$; $df = 3, 42$; $p < .05$. The treatment differences, however, were significant only at the extreme graphic points ($\underline{t} = 2.18$, $df = 14$, $p < .05$). Group O, on the other hand, was only mildly effected by the

Table 5

SUMMARY OF ANALYSES OF VARIANCE OF DIFFERENCE

SCORES, EXPERIMENT II

Groups Analysed		O x F x NCA		O x F x NMA		NMA x NCA		
Source of Variation	df	MS	F	MS	F	df	MS	F
Between Ss								
Groups (G)	2	75.09	1.16	18.20	n.s.	1	53.34	1.19
Error(b)	42	64.90		55.90		28	44.81	
Within Ss								
Presentation Speed (Sp)	3	282.12	26.59***	116.84	11.29***	3	354.89	31.43***
G x Sp	6	60.45	5.70***	9.66	n.s.	3	59.60	5.28***
(Sp x S)w	126	10.61		10.35		84	11.29	

*** $p < .001$

change in speed (t-test between lowest and highest graphic point nets $t = 2.09$, $df. = 14$, $p < .1$).

From these results, then, we can conclude that normal Ss tend to be quite flexible in their use of recall strategy. The attempt at inducing the retarded to use the more optimal ear-order of recall can be regarded as a modest success only. Far more impressive is the rigidity in the behavior manifested by these two groups. Retardates generally, and particularly those of group O, tend to show very little inclination toward changing their pattern of recall, even when it is strategic to do so.

Experiments III a & b

The Broadbent (1958) attention hypothesis suggests that when dichotic information is received at a fast pace the best strategy that S can adopt -- indeed, is almost forced to adopt by the hypothetical switching mechanism -- is to "fix his attention on one ear" and perceive the digits presented to that ear at the time they are presented. The S holds the stimuli presented to the other ear in the S-system and goes back to perceive them later. The digits are, so to speak, lined up in the P-system in the order in which they are perceived, and so are most easily recalled in that order. If they were to be recalled in any other order -- for example pair by pair -- then they must be rearranged, which is difficult just as it is difficult to rearrange an ordinary list of digits and say them backwards.

Yntema and Trask (1963), however, have suggested that recall performance entails more of a search process. They assume, in opposition to Broadbent, that both members of a pair are perceived and stored in memory at the time of presentation. The processor (the S) then adopts a search plan (a term taken from Miller, Galanter, and Pribram, 1960), with certain search plans being more readily executed than others. It is, for instance, easier for the search to go forward in terms of presentation order than to go sideways (as in the recall of individual pairs) or backwards. Following this line of reasoning Yntema and Trask suggest that the items are most easily retrieved ear by ear because they have no other characteristic that so neatly divides them into two groups within which the processor may proceed in temporal order. If, however, another prominent set of characteristics or tags were made available to S, the search process should just as readily follow this order as the ear order. Consider the following example:

Left ear	Right ear
0	good
room	2
5	coil

Each pair contains both a digit and a word; and the pairs are presented to S at 1 per half-second. According to Broadbent's (1958) attention hypothesis S should most readily recall the information from one ear and then the other. Recalling words and then digits should be difficult, from

Broadbent's point of view. According to the search hypothesis, however, the S should just as readily, or perhaps more readily, recall the items by type of information as by ear order; perhaps more readily because each item is unambiguously tagged as a word or a digit, but there may at times be a little uncertainty about the side on which it is heard. Evidence found by Yntema and Trask (1963), as well as by Gray and Wedderburn (1960), and Bryden (1962, 1964) tend to support this latter line of reasoning.

This experiment was designed to test whether the mentally retarded could adopt a given strategy of recall (search process) as readily as normals. Previous experiments (cf. Yntema and Trask, 1963; Gray and Wedderburn, 1960) used familiar words, or word phrases. It was felt, however, that Ss used in this experiment would be more equally familiar with letters of the alphabet than words. With this in mind ten letters, A, E, I, O, U, Y, L, M, R, X, were chosen. It can be noted that except for "I" and "Y" none of the letters rhyme with another, and that they all are spoken as a single syllable as the digits are. A short study was carried out to ensure the equivalence of these materials. This is described as Experiment III a, below.

Experiment III a

Ten mentally retarded Ss, of the familial-cultural variety, naive with regard to the dichotic listening task, were obtained from Linekona School. Retarded rather than normal Ss were used as it was felt that of the two the retarded Ss should find the letters and numbers least equivalent.

Appendix D presents 16 3-pair series of which 8 contain only letters and 8 only digits. The order of these series was randomly arranged and recorded on the stereo tape in the same manner as in the previous experiments. The pairs within a series were presented at the rate of 1 pair per half-second. The instructions used for the practice series were the same as those used in Experiment I (see Appendix A (ii)).

Results

As in previous experiments, both scoring techniques were used here. For Scoring I the Mean Total number of items recalled was: numbers = 24.8, letters = 20.7; the t of the difference = .47, df = 9, and thus not significant. For Scoring II: numbers = 32.6, letters = 29.3; t = .19, df = 9, and similarly not significant. It thus seems that though the recall of numbers is slightly better than that of letters, this difference is minimal and at a chance level.

Experiment b

The four groups of Ss used in the previous experiments were used in this experiment as well, with the exception of two Ss from group O who, with their matches in the other groups, were dropped because of inability to maintain attention. Thus, there were 13 Ss in each subject group.

Equipment was the same as that used previously. The dichotic series each consisted of 3 pairs, a pair being a letter of the alphabet presented to one ear and a digit presented simultaneously to the other (see Appendix E). The digits were three different digits (from one to ten), and the letters any three of those used in Experiment III a. The pairs of a series were recorded at half-second intervals and are presented in Appendix E.

At the beginning of the session E repeated the ten letters to the S, indicating that they were the vowels plus four consonants. The Ss then repeated the letters back to E. S was then informed that this experiment, like the previous one, would always have six items, but always contain three numbers and three letters. The letters heard would always be three of those S had just learned. S was also instructed to try to say exactly six items after every series, guessing when he could not remember.

Three conditions were used. In the Pairs condition the Ss were instructed to report the first pair of items, then the second pair, and then the third. In this condition E always illustrated what was wanted by presenting S with an example, and then indicating which items belonged together. This continued until S understood what was required of him. In the Sides condition half of the Ss in each group were instructed to give the items on the left in temporal order and then the items on the right in temporal order; with the other half left and right were reversed. In the Types condition half were instructed to give the digits in temporal order and then the letters in temporal order; with the other half digits and letters were reversed.

Each S made 12 trials under each condition. The 12 trials were made in a block and were preceded by 3 or (for the first block) 5 practice trials made under the same condition. Order of conditions was balanced across Ss within a group. The 12 lists in a block included 3 of each of the 4 possible kinds -- i.e., no crossings (the digits all on one side and letters on the other), a crossing after the first pair, a crossing after the second pair, and two crossings.

Results and Discussion

An item was counted as correctly recalled only if it was reported in the correct position. Figures 7 and 8 show the results. Lindquist Type I analyses of variance were computed and found the main effect of recall strategy to be highly significant (see Table 6). A further Treatments x Subjects analysis of variance was also calculated for the data within each subject group to test for the relative effects of the three strategies on each group. These analyses similarly found the effect of strategy to be highly significant. Table 7 summarizes significant *t*-test results as calculated by the critical difference technique from that data. Most noteworthy is that recall is much less

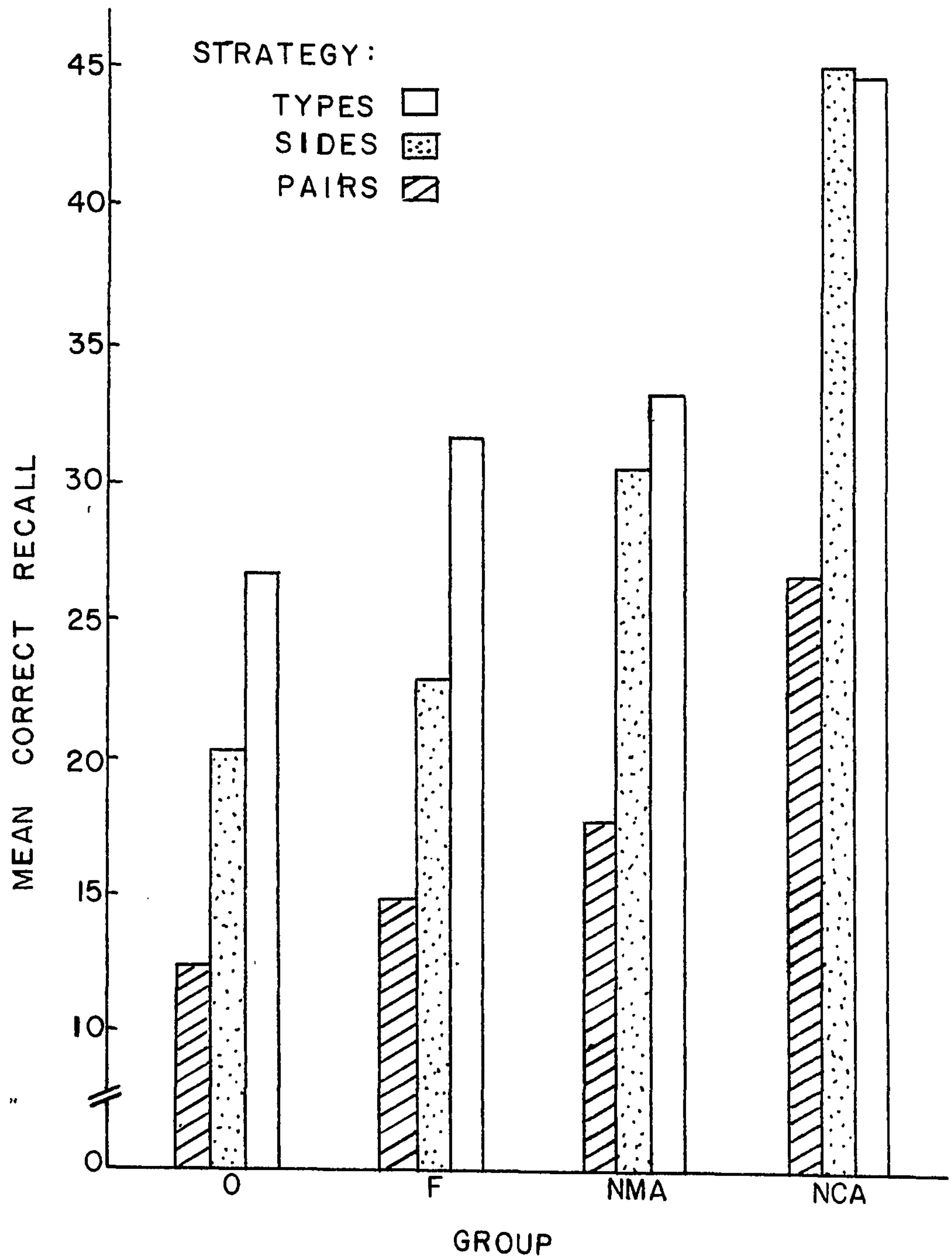

Figure 7. Differences in recall as a function of strategy, for each subject group.

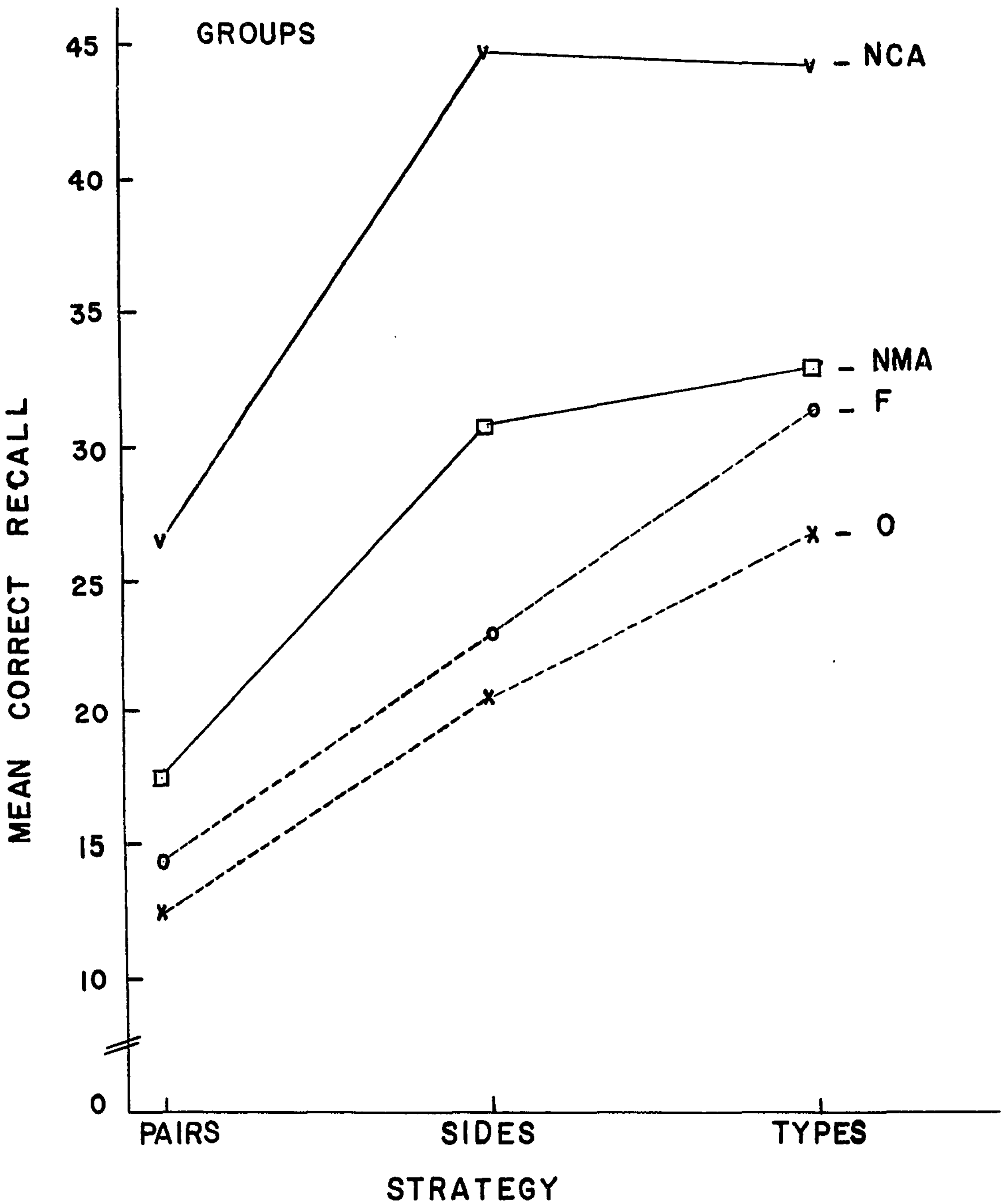

Figure 8. The same data as in Figure 7, but plotted to more clearly show group differences for each strategy of recall.

Table 6

LINDQUIST TYPE I ANALYSES OF VARIANCE, EXPERIMENT III b

Groups Analyzed		O x F x NMA		O x F x NCA		NMA x NCA		
Source of Variation	df	MS	F	MS	F	df	MS	F
Between Ss								
Groups (G)	2	441	1.39	3428	8.01**	1	2269	4.42*
Error(b)	42	317		428		28	513	
Within Ss								
Strategy	2	2117	40.71***	2449	42.96***	2	2017	51.72***
G x Strat.	4	36	n.s.	113	1.98	2	44	1.10
(Strat. x S)w	84	52		57		56	39	

* p<.05

** p<.01

*** p<.001

Table 7

STRATEGY DIFFERENCES WITHIN GROUPS

Strategies Compared	Pairs vs. Sides	Pairs vs. Types	Sides vs. Types	Critical Difference for $p < .05$
Group				
O	8.16	14.31	n.s.	7.35
F	8.54	16.08	8.54	5.42
NMA	13.07	15.53	n.s.	4.12
NCA	18.62	18.23	n.s.	2.42

accurate when S is instructed to report by simultaneous pairs then when he is instructed to report the items heard on one side and then those heard on the other. This difference was found to be highly significant for all groups.

The crucial comparison with regard to the attention hypothesis is between recall by types of material and recall by sides of the head. Under the attention hypothesis recall by sides of the head should be more accurate. The results obtained here, however, are in agreement with those of Yntema and Trask (1963) who did not find such a difference. In fact, as can readily be seen in Figure 7, recall by Types is highly superior in both the retardate groups, while somewhat better but showing no appreciable difference in the normals. This finding supports Yntema's and Trask's conception of the search hypothesis.

It is to be noted, however, that Yntema and Trask found Types of material to be superior in recall to the Sides condition, while no such difference was found in the normal Ss tested herein. This difference may well lie in the type of material used for recall. Yntema and Trask utilized words and digits, while this study used letters and digits. As words, of course, are generally high in meaning as compared with letters or digits, it may well be that this difference provided the additional cues to make recall by Types better than that of Sides. Experiment III a of this paper, however, found that, if anything, recalling letters is slightly more difficult than digits. The failure to find the Types strategy easier than the Sides strategy by the normal Ss in this experiment then suggests that the cues for materials used here are no more distinctive than those indicating which side of the head the items are heard on.

Although normal Ss did not distinguish between the Types and Sides conditions the retardates did, finding recall by Types to be easier than recall by Sides. This result might indicate that the Sides condition is somewhat ambiguous -- the S is not always able to distinguish which stimulus item comes from which side. From the evidence obtained here it would seem that the mentally retarded are not able to cope with such ambiguity as are the normals.

Of primary interest to this study was the comparison between mentally retarded and normals with regard to their relative ability to handle the various recall strategies. In the overall analyses of variance (Table 6) it was noted that significant group differences occur only when group NCA was involved. This effect can be demonstrated by arranging the results as in Figure 8. Table 8, furthermore, demonstrates that group NCA is superior to all groups on all strategies. In other words, the NCA Ss were able to utilize even the worst of these strategies (the Pairs condition) reasonably well. Indeed, as can be seen on Figure 8, their poorest performance on the Pairs condition is about as good as the best performance of the mentally retarded in the Types condition. This again is indicative

Table 8

SIGNIFICANT MEAN GROUP DIFFERENCES

FOR EACH STRATEGY

Strategy: / Groups Compared	Pairs	Sides	Types	Critical Difference for $p<.05$
O vs. NMA		10.07		8.51
O vs. NCA	14.00	24.46	17.92	9.60
F vs. NCA	11.92	22.00	13.07	"
NMA vs. NCA		14.39	11.54	10.04

of the flexibility with which the NCA Ss can adopt a given strategy as well as utilize their large P- and S- capacities.

Both the retarded groups, however, do reasonably well as compared with Group NMA on the Types condition. A result of this nature is probably best interpreted as indicative that both short-term memory capacity and strategy of recall, and the ability to use such strategies is closely linked to an individual's mental age (rather than to CA or to IQ), thus also supporting the concept of mental age. On the other hand, it should be noted that even though no significant differences exist between group NMA and the two retarded groups, except between O and NMA on the Sides condition, groups O and F do fall below the NMA performance on all levels. This might suggest that even when matched in terms of mental age the retarded Ss are not as readily able to utilize these various strategies.

Discussion

The conjecture of a number of psychologists has been that perhaps the key to learning lies in the understanding of short-term memory, since it seems reasonable to believe that if information cannot pass from short-term memory into permanent storage, learning has not occurred. The experiments in this dissertation have dealt with the problem of short-term memory, and have been aimed at investigating it at its point of breakdown. For this reason, mentally retarded subjects were chosen for study. It was felt that perhaps a fair amount of the difference between retarded and normal individuals lay in their capacity for and/or strategies used in encoding information into their memory systems.

The dichotic listening technique, and the theoretical conceptions advanced by Broadbent (1958), seemed ideally suited for testing with retardates. As was noted in the introduction, the order of the S's recall as well as the output from each half-set of digits heard is of potential interest for a consideration of the effective capacity of the P- (perceptual) and S- (storage) systems of these groups -- the first half-set recalled being indicative of P-capacity, and the second half-set of S-capacity.

Let us consider the results of the first experiment in terms of capacity.

The first experiment presented both the retarded groups (O and F) as well as the two control normal groups (NMA and NCA) with dichotic series varying in length from two digits per channel to five per channel. It has already been noted that in the overall comparison of retardates with normals (both NMA and NCA), the respective analyses of variance revealed an over-all main group effect. This overall effect can be broken down for consideration in terms of the P- and S-systems.

First of all, the P-system of group NCA, as measured by the first half-set of digits recalled in the Scoring I, was decidedly superior to that of both retarded groups, as well as to group NMA. As was predicted, this superiority increased with length of the series to be attended to and recalled. At the shortest series length no difference was to be found, but with succeeding series the difference between these groups tended to increase. One could conclude from this that whereas relatively small amounts of information can be utilized by the retardates, their P-system can not handle the larger amounts of information. The effective capacity of this system is, then, fairly small for them as compared with normal Ss of their same chronological age.

When comparing the P-capacity of these retardates with the mental age control, though, very little difference is found between the groups. The capacity in this system seems about the same for organics, cultural-familial retardates, and normal controls of the same mental age. An examination of the data as plotted in Figure 2 (p. 26, above) showed that the mean recall for this first half-span of Group O was consistently below that of NMA, but that groups F and NMA are almost indistinguishable. Although the differences between groups O and NMA were not statistically significant, the results do suggest that the functional P-system of the O group tends to fall below that of NMA. The difference that is in evidence might thus well be due to their relatively greater difficulty of maintaining their attention for more than brief periods of time, though this is but post-experimental conjecture on the part of E. Suffice it to say that the groups did not differ in this respect. Such lack of difference in both the O and especially the F Ss suggests that the utility of using a concept of "mental age" is indeed meaningful.

What, then, of the S-system? It was in this auxilliary storage area that Inglis and Sanderson (1961) found differences between elderly patients with and without memory disorder when such obvious differences could not be distinguished by other short-term memory techniques. It is likewise the system in which Inglis and Caird (1963) later found differences in age groups ranging from 11 through 60 when the groups compared were matched on the digit-span.

This study similarly found gross differences in the S-system of the mentally retarded, especially as compared with the chronological control. But, whereas the P-system of NCA was indistinguishable from that of the retarded in the short series and was superior at the long series (as was predicted), the relationship in the S-system was found to be just the reverse. That is to say, it was at the shortest series length of Experiment I that the greatest between-group differences occurred. If one can extrapolate evidence from the pilot study to the results of Experiment I, it would be more accurate to say that at the very shortest dichotic series (the 1-digit pair) the S-system of retardates functions about as well as, though perhaps slightly below, the level of NCA on the average. When, however, the dichotic series increases in length so that more information has to be stored in the S-system for longer periods of time, the total output (Figure 2, Scoring I) as well as the proportional recall falls drastically. As was mentioned in the Discussion section of Experiment I (above), this result is highly indicative of rapid storage decay taking place. Such evidence is in keeping with the stimulus-decay model of Broadbent (1958), and also tends to agree with that of Brown (1958). The recall output of group NCA, though dropping consistently, does not fall as rapidly as that of the retardates, and thus leads one to conclude that the rate of decay of the memory trace in their storage system is slower.

What, then, of normal children of like mental age? In the introduction of this paper (p. 15), it was noted that Hermelin and O'Connor (1964), using a delayed recall type of task, found a faster rate of decay in the short-term memory of imbeciles (ranging in IQ from 41 to 54) than a normal mental-age control group. The evidence in Experiment I suggests that this finding is a result of decay chiefly occurring in the S-system. Though the retarded Ss used in this experiment were considerably superior in intelligence (ranging in IQ from 53 to 79) to those used in the Hermelin and O'Connor study, a difference in decay rate was nevertheless in evidence. Group NMA's recall performance from the second half-span is significantly better than that of group O at the 2-digit series. Whereas most of the imbeciles used by Hermelin and O'Connor were likely of an organic nature, these results would seem to agree with theirs, and furthermore, to pin-point the decay to the S-system. The fact that such statistical significance is not carried over to the longer series of this study indicates that the decay rate of the S-system in normal Ss at this young chronological age is also fairly rapid, though not as rapid as that of the mentally retarded.

Thus far we have considered Experiment I only in terms of short-term memory capacity. In agreement with Broadbent and Gregory (1961) the above discussion was, for this purpose, limited to the data as presented by the first scoring procedure. Broadbent would argue that when "errors" occur (which, in some cases, are what this writer, Bryden (1962), and others would consider to be strategies of recall other than ear-order) one can not clearly tell how much of the report given can be attributed to the P-system and how much to the S-system. For this reason, Scoring I is considered by Broadbent to be the more adequate measure of the capacities of these systems. Comparing the statistical analyses of Scoring II with those of Scoring I suggests that the conclusions reached above are not far wrong. The relative relationships between the groups stay the same in both half-spans (compare Tables 2 and 3, above). However, greater informational output of Ss, as determined by Scoring II would seem to indicate that Scoring I slightly underestimates the capacities of the two systems. This underestimation would appear to be fairly constant for the four groups, as the difference between Scoring I and Scoring II seems to be about the same at all series lengths (compare Scoring I with Scoring II in Figures 2, 3 and 4).

What, then, about group differences in strategy of recall? Comparing groups O, F and NMA on Figure 2 again shows that initially these groups operate near capacity (in the P-system) for the first half-span of Scoring I. This would indicate that the ear-order of recall is in almost exclusive use at the short series (thus ensuring that the decay found in the S-system, as discussed above, is not just an artifact of the strategy utilized by the Ss). There is a slight increase in recall by use of the ear-order strategy through the 3-digit series and then a falling off as the series get longer. However, the total number of digits recalled continues to climb, using Scoring II, even in the longer series. This would seem to suggest a gradual shifting, by these groups, to strategies of recall other than ear-order, as series length increases.

While the above discussion is true for groups O, F and NMA, it is noteworthy that group NCA continues to utilize the ear-order technique to a large degree up to and including the dichotic series that is 4 digits in length. This group then suddenly drops the ear-order of recall in favor of other recall strategies. The total amount of information recalled in these two (4 vs. 5 digits) series lengths remains about the same (though, of course, the proportion of the number presented which are recalled continues to drop), but the amount recalled by the ear-order strategy showed a marked decline. Why this sudden change occurs is not easily answered. As noted above, this change from ear-order to alternate strategies occurs in group O, F and NMA, as well as NCA. However, in these groups, the shift was gradual and occurred earlier in the series. One might conjecture that as the short-term memory system becomes increasingly overloaded the Ss cease to use the system that served them best in the past and to grasp at any system available to them. It is, in other words, a shift from an active, organizing strategy of recall to a more-or-less passive one. One might almost think of this shift as something of a "panic" syndrome, though, of course, no overt panic was manifested by the Ss except the occasional remark to the effect that, "Boy, this is getting too hard". That the ear-order of recall is both a rational and strategic order of recall is indicated by the fact that as long as it is retained by the Ss (of all 4 groups), the climb in total number of items recalled remained fairly steep with increase in series length -- until that point where other recall strategies came into use. At this point the upward trend is flattened, or drops (see both Scoring I and II; on the first half-span in Figure 2 particularly). Although true for all four groups, this change is most evident for group NCA.

To summarize, the results of Experiment I have revealed that the effective storage capacity of the short-term memory of retardates is much smaller than that of normals of the same chronological age. This is true both with regard to the P- and the S-system. As compared with normals the same mental age, however, retardates are remarkably similar in P-system capacity, but differ somewhat (though not too much) in the S-system. The relative differences in P-capacity of groups O, F, and NMA, as compared with NCA, is probably largely a problem of encoding strategy used, although, as indicated below, an inherently smaller capacity cannot be ruled out. In terms of S-system capacity it would seem that there is a real difference between these groups in terms of speed with which information in this system will decay -- perhaps a maturational factor.

As was noted above, relatively less use was made of the ear-order of recall by groups O, F and NMA than by group NCA, except for the 2-digit series. The second experiment was conducted to see whether this situation could be altered by varying the rates of presentation of the stimulus material. The expectation, derived from evidence presented by Broadbent (1954) and Bryden (1962), was that at very rapid presentation rates (i.e., 1 digit per quarter second) the normal <u>S</u>s would use the ear-order of recall almost exclusively, but that at slow rates (i.e., 1 pair every 2 seconds) this particular strategy would be used very little. As Figure 6 (p. 40) shows, this effect did occur in both normal groups, though most markedly in group

NCA. The retardates, on the other hand, were characterized by a more fixed technique of recall, with group O manifesting this trait to a more marked degree than group F. Group O showed no statistical change in strategy from rate to rate. Group F did demonstrate a small but significant change when comparing Difference scores from the fastest with those of the slowest speeds of presentation, thus placing it intermediate in position between groups O and NMA. What this evidence tells us is not so much that normals will change their strategy of recall with changes in rate at which information is presented; rather, that normals are flexible enough, when handling information, to search for and utilize better strategies when their previous ones have broken down. The fact that group NMA does not manifest as marked a shift as that of NCA suggests that this procedure is a matter of learning and practice, although, perhaps, a minimal short-term memory capacity must first be available. The two retarded groups tend to exhibit a very limited amount of such flexibility, suggesting that they tend to assume one strategy and "hang on to it", regardless of whether or not it is strategic to do so.

Experiment III was similarly carried out to study strategy of recall in retardates, but was designed to test the ease with which they could adopt a given strategy, as well as being a test of the search hypothesis of Yntema and Trask (1963) as opposed to Broadbent's (1958) attention hypothesis. According to the search hypothesis it should be no more difficult, and perhaps may be easier to recall dichotic information in terms of types of information heard (i.e., digits and letters) than to recall the same information following the ear-order of recall. The results revealed that the retardates found it much easier to recall the information in terms of types of material rather than to recall all of the information heard in one ear before that heard in the other. The normals (both NCA and NMA), on the other hand, found these two strategies of recall to be about equal in effectiveness. Both of these results would be in keeping with the search hypothesis.

Mentally retarded Ss, though, find it easier to recall by Types than by Sides. One readily available explanation for this finding would be that for the retardates to recall the information in the Sides condition is too ambiguous. That is to say, in the dichotic situation, especially when the information is fed in *via* headphones, it is relatively easy to lose track of what information belongs to which ear. For the retardate to keep such information distinct seems to be a difficult strategy to follow. The Types condition, however, presents a recall situation in which the items to be distinguished are clearly tagged. Thus, it is this strategy that the retardates (both group O and group F) find easiest to handle. Normal Ss, on the other hand find the Sides condition no more difficult than that of Types of material. What is a difficult strategy for the retardates can be handled relatively well by both normal groups.

In conclusion, one might query as to why the differences, discussed in the last few pages, occur. These results could presumably be due either to learned and/or innate factors. With group F, a good quess would be that many of these differences discussed above could be at least partly attributed to learning factors. Their group name of "cultural-familial" suggests this to be the case. Presumably, children coming from an inadequate cultural environment have not had the opportunity to learn the best of encoding strategies or have not had sufficient experience to allow them to evaluate the relative efficiency of the various strategies. If so, it may be that deliberate training in the use of relatively superior encoding strategies might at least minimize differences between a group such as this and their fellow age-mates. Such specific training would probably have to be begun fairly early, though probably early school-age (such as the NMA Ss here) might be adequate. The suggestion of early school-age is based on the observation that the NMA Ss used in this experiment were not too far advanced in their development of immediate memory as they seem to be after they reach about 10 or 11 years of age (cf. Inglis and Caird, 1963). The determination of what the more sophisticated encoding strategies for the scholastic situation might be must await considerable future research.

As has been seen above, group F is more like NMA than group O is. It would seem that group O suffers from some additional handicap. For them, one cannot be quite so certain that theirs is a problem of learning how adequately to encode information. Rather it might seem, again as their group name (organic) implies, that they may well be deficient in both P- and S-systems, and that training in strategies would have a lesser effect than with, say, the cultural-familial type of retardate. Whether or not this is the case also remains for future research, probably at least in part of a physiological nature. Some evidence for such an hypothesis has been advanced by Ellis (1963), who considers retardation to be largely due to stimulus-trace deficits, a position not altogether at odds with the one taken here.

The differences between group NMA and NCA are revealing as to how much change occurs between their two respective chronological ages, for in terms of IQ these two groups were essentially the same. Inglis and Caird (1963) found that the only difference between normals over the age of 11 was essentially in the S-system; and, such changes as were in evidence were so only as a trend over a considerable range of ages. Here, however, we found that normals changed a good deal with respect to the apparent capacities of both the S- and the P-systems, as well as in the ability to utilize the best strategies available, and furthermore, in their flexibility in doing so. There would seem to be both a maturational and a learning effect here. The differences between these two groups in terms of rate of memory storage decay, for instance, might well be maturational in nature, as perhaps is the ability to tolerate large amounts of information and still retain the best strategy. On the other hand such factors as flexibility in the change to more adequate encoding strategies, and the search for such strategies might well come about with practice and experience.

On the surface it seems somewhat surprising that the retardates in general, and group F in particular, did as well as they did as compared to Ss in the mental age control group. Casual experience with both normal and retarded children, of, say, mental age 9, would suggest quite marked differences in performance. The normal child appears to be more intelligent in general behavior (despite the equivalent mental age) and certainly more adaptable to diverse environmental situations. Perhaps, though, an answer to this is available in the results of this investigation. Experiment I showed that these groups (O, F and NMA) had essentially the same P-capacity and did not differ much in S-capacity. Experiments II and III, however, revealed that normal Ss are much more flexible in their use of strategies for information coding, and, furthermore, are able to tolerate strategies (such as the Sides condition, above) more ambiguous in nature. The results are, then, perhaps not so surprising after all. The matching of groups O and F with NMA in terms of mental age and digit-span suggests that, in terms of potential, these groups are about the same. Evidence from Experiment I corroborates that suggestion. A casual comparison of the overt behavior of these three groups, however, tells us that if their potential is the same, they certainly don't seem to be making the same use of it. Results obtained in Experiments II and III would tend to corroborate that observation. In terms of short-term memory, at least, these groups seem to have about the same potential, but their use of that potential does differ.

To summarize, this paper set out to investigate the short-term memory of mentally retarded -- particularly with respect to memoric capacity and encoding strategy. Consider each of these in turn.

Capacity. The first experiment showed that retardates differ from normals the same chronological age in both the P- and the S-system. The effective capacity of the P-system is considerably smaller in both groups of retardates, probably due to the inefficient use of strategies for encoding information. S-capacity is not only somewhat smaller in retardates than in group NCA, but also seems to be subject to faster loss of information (decay). However, retardates differ very little from the mental age control Ss. The P-system is virtually indistinguishable between these three groups, and particularly when comparing group F with NMA. Similarly, the groups do not differ markedly in S-capacity except for somewhat of a faster rate of information decay in this system for groups O and F as compared with NMA. In comparing the two normal groups one finds results similar to those between group NCA and groups O and F, though not quite as marked. The effective capacity of both the P-and S-systems of the older Ss (NCA) is considerably greater than that of the younger normals (NMA).

Encoding Strategy. The two scoring procedures used in Experiments I and II were utilized to delineate group differences in coding information. Experiment I found that although groups O, F, and NMA used the ear-order strategy of recall on short-series, there was a growing tendency not to as the amount of information to be handled increased. Group NCA, on the other hand, continued to use this same strategy successfully through much larger amounts of information, but then suddenly dropped it, apparently due to information overload. This change was explained in terms of a reversion from an active ordering of information to passive attempts at recall, and suggests that NCA Ss are able to tolerate a much greater information load than either the younger normal Ss, or the mentally retarded. Experiment II revealed normal Ss (this time both NCA and NMA) to be much more flexible in their use of strategies than the retarded Ss, giving up a strategy which was losing it's efficiency in order to search for and use a better one. Retarded Ss, on the other hand, showed very little such flexibility. Finally, Experiment III found that retardates were able to utilize a useful, unambiguous strategy of recall as well as NMA Ss. However, whereas the normals were able to use a more ambiguous, but still useful type of strategy equally well, mentally retarded Ss were not able to do so. Comparing groups O, F, and NMA with NCA again found NCA much superior. Their use of even the poorest recall strategy resulted in performance as good as the highest level reached by retardates on their best strategy.

In conclusion, the suggestion that retardates perform so poorly as compared with normals largely because of a limited short-term memory capacity and the inefficient use of encoding strategies would seem to have gained considerable supportive evidence. The experiments discussed above demonstrate not only that the effective capacity of mentally retarded is smaller than normals the same chronological age, but also that this limitation may be due, in large part at least, to a lack of flexibility, and hence inefficient strategy usage on the part of the retardate.

Summary

A series of experiments was conducted to investigate short-term memory in mental retardates. The primary purpose of these experiments was to discern whether or not short-term memory capacity and/or strategy of encoding information could account for some of the differences between retardates and normals. This investigation was carried out with the dichotic listening technique as initiated by Broadbent (1958).

Four groups of 15 _S_s each were used for the three major experiments. The groups were as follows: two groups of retardates, one organic (group O) and one cultural-familial (group F) in nature, matched in mental age and digit-span with a group of normal controls (group NMA). The fourth group, matched in chronological age with the two mentally retarded groups, served as a second normal control (group NCA).

In the first experiment dichotic series of 2, 3, 4 and 5 pairs of numbers were presented to the Ss at the rate of one pair every half-second. This experiment demonstrated that the effective short-term memory capacity of both retarded groups is much less than that of a comparable chronological-age control, but does not differ greatly from group NMA. The evidence also indicated that the retardates were subject to a faster rate of information decay in that part of immediate memory which has been termed S-system by Broadbent, and is tapped by the second half-set of digits recalled. Comparing the data from the two scoring procedures used, furthermore, suggested that as information-load increased with length of series, Ss tended to change in strategy from recalling the digits ear by ear (ear-order), to other types of strategies generally less efficient at the rate of presentation used here. Such a change occurred later in the series for group NCA, than for groups O, F or NMA, indicating a greater tolerance for a large information load. This shift appeared to be a change from an actively organizing to a passive type of recall strategy.

The second experiment held the length of dichotic series constant at 3 pairs of numbers, but varied the rate of presentation as follows: 1 pair per quarter-second, 1 pair per half-second, 1 pair per second, and 1 pair per 2 seconds. This experiment demonstrated a marked degree of flexibility by the normals (both NMA and NCA) in their adaptation of different strategies of recall to the various rates of informational input. Such flexibility was not found in the retardates. At rapid rates of presentation normal Ss tended to report the numbers from one ear followed by numbers from the other (as in Experiment I). As the rate slowed, the frequency and accuracy of this order of report decreased while the frequency and accuracy of reporting the material in other orders, such as the order the information arrived at the ears, increased. Such a shift was only partly in evidence in group F, and not at all in group O.

Experiment III similarly tested the immediate recall of series six items in length presented two at a time (one to each ear), but held the rate of presentation constant at 1 pair per half-second. In this experiment, however, each pair of items presented together consisted of a letter of the alphabet and a digit, and the side on which the letter was presented varied haphazardly from pair to pair. For the retarded Ss (both groups O and F) recall was more successful when S was instructed to recall the items of one type and then the items of the other type than when instructed to report the items heard on one side and then those heard on the other. Normal Ss (NCA and NMA) recalled equally well in both conditions. The conclusion was that, though normals could handle each type of recall strategy equally well, retardates had more difficulty with the greater inherent ambiguity involved in recalling information by sides of the head than by types of material.

In conclusion, the evidence indicated that short-term memory capacity was indeed an important difference between retardates and group NCA. This deficit in apparent capacity, however, was probably enhanced by the retardates' lack of flexibility in the search for and use of appropriate recall strategies, and their manifestation of difficulty with ambiguous types of strategies. Though capacity was essentially the same for groups O, F and NMA, the two retarded groups also fell below NMA Ss in their ability to adopt a flexible mode of behavior, and to utilize more ambiguous strategies. The differences between groups NMA and NCA, on the other hand, were indicative of the degree to which both memoric capacity and ability to make use of useful strategies develops in normal individuals over time.

APPENDIX A (i)

DIGITS USED FOR BINAURAL STIMULATION IN THE PILOT STUDY AND EXPERIMENT I

		Channel 1	Channel 2
Practice Series	A.	3	Blank
	B.	Blank	7
	C.	3	7
Test Series		5	8
		7	6
		4	1
		6	3
		39	72
		85	17
		38	59
		65	28
		592	174
		793	462
		479	836
		584	719
		5638	2941
		9754	8362
		6542	7918
		9356	4271
		81342	96571
		74682	31579
		57841	29356
		38671	15429

APPENDIX A (ii)

TAPED INSTRUCTIONS GIVEN EACH S

1. Each S is first told: "Now listen carefully. You are going to hear a number. I want you to tell me what number you hear." Practice series (the spoken digit 3 on channel 1) was then played. If S responded correctly, the procedure was repeated with series B (digit 7 on channel 2). If S failed to respond or gave the wrong number, the volume was increased until the correct response was made.

2. Each S was told: "Now you are going to hear two numbers together, one in each ear. Tell me what numbers you hear." The two channels then played the spoken digits 7 and 3 simultaneously (series C). If S responded with the correct digits (i.e., 73 or 37) then the test series were commenced with.

3. S was told: "Now you are going to hear N numbers, N/2 in each ear" (where N was 2, 4, 6, 8, or 10). "Tell me what numbers you hear." These instructions were repeated at the beginning of each series of a new length. Between each of the items within a series the Ss were asked, "Now what numbers do you hear?"

APPENDIX B

ANALYSES OF VARIANCE ON EACH HALF-SPAN OF DATA

EXPERIMENT I

Groups Analysed		First half-span: O x F x NCA		O x F x NMA	
Source of Variation	**df**	**MS**	**F**	**MS**	**F**
Between Ss					
Groups (G)	2	35.95	8.23**	6.03	1.46
Error(b)	42	4.36		4.13	
Within Ss					
Series Length (L)	3	127.65	81.64***	147.09	122.82***
L x G	6	1.99	1.28	.47	n.s.
(L x S)w	126	1.56		1.20	
		Second half-span			
Between Ss					
Groups (G)	2	74.19	8.57***	10.74	2.04
Error(b)	42	8.66		5.26	
Within Ss					
Series Length (L)	3	119.70	45.26***	97.27	32.31***
L x G	6	9.18	3.47**	3.38	1.12
(L x S)w	126	2.64		3.01	

** $p<.01$
*** $p<.001$

APPENDIX C

DIGITS USED FOR BINAURAL STIMULATION, EXPERIMENT II*

Channel 1	Channel 2
681	309**
732	016
931	824
072	956
324	965
980	157
319	685
857	291
271	059
792	085
597	286
436	592
128	346
794	610
380	621
472	953
251	746
719	683
382	605
584	236
956	742
985	703
569	470
851	347

* These series were recorded in two orders at speeds of 1 pair/quarter-sec., 1 pair/half-sec., 1 pair/sec., and 1 pair/2-sec., as follows: (1) recording the first set of 6 series a the fastest rate with succedding sets successively slower, and (2) in reverse order

** "O" was recorded as "ten"

APPENDIX D

MATERIAL PRESENTED TO SUBJECTS IN EXPERIMENT III a

	Channel 1	Channel 2
Practice Series:	3	blank
	blank	7
	3	7
	271	059
	oax	eir
Test Series	681	309
	xyu	Loi
	fir	aLe
	732	016
	931	824
	072	956
	efL	aou
	324	965
	oam	iur
	uxf	arL
	ufL	eri
	980	157
	319	685
	xLo	mea
	oru	efa
	857	291

APPENDIX E

MATERIAL PRESENTED TO SUBJECTS IN EXPERIMENT III b

	Channel 1	Channel 2
Practice series:	4um	al7
	oei	806
	85e	ui6
	3m9	o7r
	4y0	x3u
Test series:	034	Loi
	y8r	7i3
	96a	Ly4
	42u	ao8
	eyL	560
	9L8	e6i
	o8a	3m9
	o95	4iu
	ux0	72y
	lar	L69
	786	uyL
	0ry	e94
Practice series:	9a5	x24
	eL3	7ly
	0ma	i62
Test series:	al7	4um
	xLo	816
	8m9	L2a
	e0a	5y9
	xm5	83i
	4e3	i0x
	umL	968
	84o	ru2
	32i	ao7
	Lmr	502
	5xL	i74
	y27	9mx
Practice series:	7xl	a9r
	rm4	20e
	9yo	e65
Test series:	u8y	4r5
	6ex	i37
	6y4	r8a
	oax	832
	06L	ar9
	3y5	e2i

Test series cont'd

423	mrL
oi4	96r
6au	L05
m53	7xr
xeL	396
08o	ry4

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