MENTAL RETARDATION AND THE DEVELOPMENT OF RECOGNITION MEMORY

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SUMMARY

One well established characteristic of mild mental retardation is a short-term memory deficit. This area remained largely unexplored until the advent of the information processing approach to research. This thesis investigates the Sternberg memory scanning model of recognition memory, an information processing approach which is based upon the 'additive factor method' of analysing reaction time (RT) into a number of separate mental operations. It was considered that this method had the potential for defining a short-term memory deficit in terms of impairment located within a particular mental operation or within some combination of these operations.

Sternberg has proposed that the time between the presentation of a stimulus or probe item and a response as to whether or not that item belongs to a previously memorized set (the 'positive set') is occupied by a series of four mental operations, or stages. Firstly, the probe item is encoded - i.e. transformed into a stable form. Secondly, the positive set is scanned, during which a serial, exhaustive comparison of the probe with the items in memory is executed. Each item is compared with the probe, regardless of whether a match has been found or not. The third stage consists of determining which response is appropriate, and the final stage involves actual execution of the response. In a typical paradigm, the number of items in the positive set is varied. The angle of the slope of the item recognition function relating RT to the number of items in the positive set is assumed to represent the speed of memory scanning, while the zero intercept of this function is held to represent the total time taken for the other three operations. Thus, when the memory scanning stage is independent from other stages, the slopes and zero intercepts of item recognition functions obtained from within a group of subjects should not be correlated.

The average item recognition function for normal adults is generally characterized by a slope of 30-40 msecs/item and a zero intercept of around 400 msecs. Evidence in the literature suggested that a steeper slope to the group item recognition function, whereby subjects are assumed to be scanning memory at a slower rate than normal, may indicate some permanent impairment in memory processing. Steeper than normal slopes and higher zero intercepts have been found for aphasic persons, brain damaged alcoholics and retarded persons, while normal children and schizophrenic persons have been found to respond with similar slopes and higher zero intercepts when compared with normal adults. However, a review of the literature established that these results were open to dispute. There is evidence, for example, that normal children can produce steeper slopes than normal adults, suggesting that the slower scanning assumed to occur in the performance of retarded persons may be due to a developmental lag. In addition, considerable individual differences have been found in the pattern of results from aphasic and schizophrenic persons. Furthermore, studies of the performance of mildly retarded subjects have failed to establish a typical pattern of performance when compared with either chronological age or mental age controls. On these grounds, a careful study of factors affecting the retarded memory performance was warranted.

Experiment 1 considered the relation of retarded adults' performance to that of chronological age and mental age controls, when material to be remembered was presented in a fixed set procedure, during which subjects were repeatedly tested on the same well learned positive set, and a varied set procedure during which they were only tested on a positive set once before having to learn a new set. In previous studies, the performance of normal adults has appeared similar under these two procedures, the slope values of the item recognition functions being about the same. This finding was replicated in Experiment 1. However, retarded adults in this experiment performed differently under the two procedures. There was also a gradation of slopes from less steep values for nonretarded adults to increasingly steep values for nonretarded children and for retarded adults. Although it seemed possible that a relatively high error rate in the retarded group may have biassed the analysis of correct mean RT towards a significant difference between groups, Experiment 2 replicated the results of Experiment 1 even though error rates were lower, so that this explanation was not admissible. In these two experiments, the performance of both nonretarded children and retarded adults appeared to be qualitatively different to that of nonretarded adults, and significant negative correlations between slopes and zero intercepts for item recognition functions suggested that among children and retarded subjects the memory scanning operation was not independent from other operations.

It was hypothesized that differential sensitivity to practice may have biased results from Experiments 1 and 2 by inflating group differences. Following a review of evidence that retarded subjects and nonretarded children can improve RT and recall memory performance with practice, Experiment 3 investigated the effects of practice on the performance of retarded adults and their nonretarded controls, once again using the two procedures of fixed and varied sets. While practice had little effect on the performance of nonretarded adults, both the slopes and the zero intercepts for item recognition functions obtained for nonretarded children and retarded adults decreased over seven sessions of practice especially under the varied set procedure. Thus, earlier studies in which normal children have been found to produce steeper item recognition functions than normal adults may not have controlled adequately for practice. In Experiment 3, the slopes of functions found with children decreased to levels near those obtained from normal adults. Performance in the retarded group improved more, relative to that in other groups, but at the end of seven sessions of practice the slopes and zero intercepts of functions for these subjects were still higher than those for nonretarded adults. However, unlike the situation with nonretarded adults and children, the data showed that the performance of retarded subjects had not yet reached an asymptote. Moreover, individual differences within the retarded group were being reduced with practice. For all three groups of subjects, correlations were found between the slopes and zero intercepts of individual item recognition functions in certain sessions of practice.

Experiment 4 examined whether the improvement in memory performance found with practice among retarded adults in Experiment 3 would be retained by these subjects after an intermission of three months without further practice. The experiment also tested whether the slopes and zero intercepts of item recognition functions for retarded subjects could be reduced to an asymptotic level by substantial additional practice. From the beginning of Experiment 4, retarded subjects did perform at levels well below those found for the same subjects at the beginning of Experiment 3, and after only one session achieved their previous best performance. After extended practice, slopes for item recognition functions in the retarded group were near those found with nonretarded adults, individual differences within the retarded group were considerably reduced, and performance for this group was generally very similar to that of nonretarded adults. However, while negative correlations between the slopes and zero intercepts of item recognition functions were somewhat reduced by practice, substantial correlations remained, suggesting that a memory scanning operation was not independent from other operations.

It was concluded that while the generally poorer performance of retarded adults in tasks of the kind employed here may reflect some structural impairment to the processes controlling memory scanning, any initial level of deficiency is certainly not permanent, as shown by improvement in performance after extended practice. Different patterns of RT under the fixed set and varied set procedures suggested that procedural factors should be carefully examined when studying younger mental age groups, more so than is necessary when normal adults are studied. It was also found that the four mental operations postulated by Sternberg were not as likely to be independent among nonretarded children or retarded adults, although they generally appeared to be so for nonretarded adults. This may have been due to less efficient control of attentional processes by children and retarded adults. Alternative models of recognition memory to that proposed by Sternberg have been considered in an attempt to accommodate the results presented.

DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or Diploma in any university, and to the best of my knowledge and belief, it contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

Signed

Colleen J. Phillips

December, 1981

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Chapter 1

A REVIEW OF THE INFORMATION PROCESSING APPROACH TO MEMORY ABILITY IN MENTAL RETARDATION

1.1 INTRODUCTION

The association between memory ability and intelligence was first formally acknowledged with the development of intelligence tests. The idea of short-term memory span as a measure of individual ability was mentioned by Jacobs (1887), who experimented with classes of schoolchildren. His main findings were that memory span, or 'span of prehension', varied with the kind of material, increased with age, and was highest for outstanding pupils in the class. Following Jacobs' work, Galton (1887) carried out a study with mentally retarded adults, and found that memory span was much lower than normal in these subjects. Cattell (1890), Gilbert (1894) and Sharp (1898) all included tests of immediate recall in their investigations of individual differences. The extension of this work was the development of standardised intelligence tests, following Binet and Simon. For example, the Stanford-Binet and Weschler tests require the individual to reproduce a spoken list of digits, and poor performance on this memory task is well established as a component of less intelligent behaviour.

The experimental investigation of retarded persons' memory has mostly concentrated on individuals who cope with the framework of experimental methods developed in the study of non-retarded memory, that is, individuals classified as mildly (IQ = 55-69) or moderately (IQ = 40-54) retarded (American Association of Mental Deficiency classifications, Grossman, 1973). Mildly retarded persons with no identifiable central nervous system disorder ('cultural-familial' retardation) have been estimated as constituting 80-85 per cent of the total mentally retarded population (Neisworth & Smith, 1978), and they have received the bulk of attention in cognition research. The literature reviewed here is mainly concerned with this group.

While it is obvious that retarded persons are limited in their ability to process information, intelligence tests have not yielded a clear explanation for retarded performance. Early investigation of memory performance was hampered by unconstrained experimental conditions and the global nature of tasks, such as the memorization of long lists (Ebbinghaus, 1885). Retarded individuals recalled fewer items than normal, but the discussion of reasons for such performance required a shift of emphasis from the number of items recalled to the processes involved in learning and recalling those items (Robinson & Robinson, 1976).

Once material is registered in long term memory, it seems to be retained equally well by normal and retarded individuals (see Belmont, 1966, for a review of long term memory research). Investigations of paired associate learning suggested that normal and retarded retention are equal in this task, given equal original learning. Thus, it was suggested that the retarded individual's poor performance in learning tasks is primarily due to a short term memory deficit. Most memory research during the past twenty years has attempted to explain this deficit, while long term memory has remained virtually unresearched.

This thesis is concerned with the application of Sternberg's information processing model (Sternberg, 1975) to the study of recognition memory in mildly retarded adults. In this chapter, earlier models of memory processes in mental retardation will be briefly outlined, then the model which is the main concern of the present research will be described, followed by a selective review of its application to memory performance of retarded persons, other groups with memory deficits, and intellectually average persons. Chapter 2 will consider methodological differences in retarded studies to date and report empirical evidence for the importance of these when considering nonretarded and retarded performance. The second part of this thesis will review and report effects of practice and training on memory, as well as the contribution of individual differences to patterns of group performance.

1.2 EARLY MODELS OF MEMORY IN MENTAL RETARDATION

1.2.1. The Structure-Function Distinction

If intelligence is conceived as a stable trait (Fisher & Zeaman, 1973), then some stable mechanism may underlie reduced levels of performance on tasks that assess intelligence. Early theorists adopted this idea, and tried to isolate structural or permanent limitations to retarded performance. Structural features of performance were accepted as invariant, so that poor memory performance due to structural limitations would be unmodifiable by training. Structural differences in retarded and nonretarded performance would define retardation in terms of basic psychological processes.

While structural theories in the early 1960s were not strictly physiological, possible neurophysiological mechanisms were described. An example of a structural hypothesis is the model of Ellis (1963), who assumed that, following stimulus presentation, a stimulus trace made up of reverberatory circuits occurs in the central nervous system. Ellis hypothesized that mentally retarded persons have a diminished or more rapidly fading stimulus trace, which leads to poorer performance than nonretarded persons of equal chronological age on a variety of short term memory tasks. Spitz (1963) also suggested a neurophysiological model in which retarded performance was characterized by sluggish electrical, chemical or physical changes in stimulated cortical cells. According to his model, this would lead to less spread of electrochemical activity from stimulated cells into surrounding 'cortical fields', the behavioural consequences of which would be slower, less efficient performance.

However, theories of this type met a number of difficulties, and their proponents subsequently modified their position, as discussed further below. Ellis (1963) postulated that if the period for which material must be retained was increased, retarded performance would be disproportionately poorer than that of nonretarded subjects. However, there was only equivocal evidence for such an interaction (Belmont & Butterfield, 1969). There was also difficulty in accumulating neurophysiological evidence for the memory mechanisms suggested.

It has become increasingly obvious that the division of structural (or permanent) and functional (or remediable) deficits is an oversimplification of the factors underlying retarded performance. If factors responsible for poor performance are structural then training should produce little or no improvement. However, training effects on retarded performance are typically very significant. Training of nonretarded groups may, of course, reinstate group differences so that the possibility of structural differences remains, but research continues to identify control deficiencies, such as deficiency in the spontaneous use of rehearsal. Underlying structural features are not as readily verified using current experimental methods because their definition depends on the effectiveness of the training procedure used. On the other hand, while functional deficits must ultimately depend on structure, the possibility of modification to functional control of processing exists. Furthermore, processes that are trainable are of immediate concern to the amelioration of problems of the slow learner. Memory research has accommodated these considerations by a growing trend towards studying memory in the context of the whole human information processing system, rather than as an isolated feature of retarded persons' behaviour.

1.2.2 The Rehearsal Deficit Hypothesis

Belmont & Butterfield (1969) argued that deficient memory performance could reflect either faulty storage of material or inadequate retrieval of stored material, or some interaction of the two. They analysed the patterns in pauses of subjects performing a self-paced serial position memory task, and found that while normal adults rehearsed initial items presented, the mentally retarded group failed to rehearse in a similar manner.

Subsequently, Ellis (1970) modified his stimulus trace theory to incorporate the idea that retardates do not spontaneously produce the memory strategy of rehearsal, so that information is liable to be lost before it can be stored. Ellis therefore presented a multi-process model in which external stimulation is sensed through an attention process and passed to primary, secondary and tertiary levels of memory processing. The level of processing was held to depend on the rehearsal strategies used. Thus, in this model, primary memory would not be affected by mental deficiency, but the inadequate use of rehearsal strategies would result in deficient secondary memory storage.

Others have made similar proposals based on the possible influence of verbal ability on memory systems. Retarded persons' performance on verbal subtests of standardized intelligence tests is poorer than normal. Luria (1961, 1963) reasoned that retarded persons do not use verbal mediators in their cognitive behaviour to the same extent as nonretarded persons. That is, retarded persons often do not, or cannot, provide labels for stimuli and even if induced to do so, performance with verbal material remains poor. A defect in retarded memory could therefore be due to a structural, verbal mediation deficiency. However, other investigators have shown that while retarded subjects do not rehearse material spontaneously, their performance can be improved substantially by training. Thus, poor memory performance due to inadequate verbal rehearsal may be treated as a 'production' deficiency

(Flavell, 1970), since retarded subjects can rehearse appropriately when trained to do so.

However, a major difficulty with the approach of dividing performance into structure/control, or mediation/production deficiencies is the post hoc nature of explanations put forward. A clear resolution to any of the above approaches is hampered by a lack of empirically testable predictions. Fortunately, since the 1960s memory research has progressed towards more precise models of performance which provide clearer predictions of behaviour, and allow for more flexibility in possible underlying mental operations. Thus, research has moved from studying the degree of short-term memory loss to the number of short-term memory stores through which information is processed, and to the integration of constructs like encoding and rehearsal within the first few seconds following presentation of the memory stimulus.

1.3 STERNBERG'S MEMORY SCANNING MODEL AND AND THE ADDITIVE FACTOR METHHOD

A vast memory literature can be divided into studies of recall and recognition, and within those categories, studies using time to react to a stimulus (reaction time - RT) or number of errors made as the dependent variable. This thesis is concerned with a particular approach to recognition memory which investigates the slowness rather than the inaccuracy of mildly retarded persons' performance. One of the most researched methods for studying recognition memory is the additive factor analysis of RT. This approach assumes performance is essentially error free, providing an alternative to methods where the number of errors made is the dependent variable. This paradigm has recently been applied to the study of information processing in mentally retarded individuals.

The concept of RT being divisible into a number of mental operations or stages was first tested by Donders (1868), who developed the 'subtractive' method. Mean RTs from two different tasks were compared, where the second task was assumed to require all of the mental operations present in the first, plus an additional stage. The difference between mean RTs in both tasks was taken as an estimate of the duration of the interpolated stage. In this way, the duration of each mental operation could be calculated. However, this method was subject to two criticisms. Firstly, differences in an individual's RT were found from experiment to experiment; and secondly, introspective reports questioned the assumption of the pure insertion of stages. Instead, it seemed that when a task was made more complex by the requirement of an additional stage, processing in other stages could change as well.

The basic idea of dividing RT into a number of components has been re-examined recently. A number of studies have used the basic proposition that mean RT is composed of additive components, such that

$$RT = Tw + Ta + Tb \qquad \text{(Equation 1)}$$

where Ta and Tb are random variables representing the durations of different processing stages, and Tw represents the total duration of all other events between stimulus and response.

Sternberg (1966, 1969) has applied the 'additive factor' method to a recognition memory paradigm, typically involving a sequence of trials on each of which a test item* is presented visually. There is an ensemble of possible test stimuli, a subset of which is called the 'positive set', these items requiring a 'yes' response, and the remainder in the ensemble (the 'negative set') each requiring a 'no' response if presented. RT to the probe stimulus is analysed into a number of additive components, each representing a separate stage or mental operation.

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* The item to which the subject must respond has been termed 'test item', 'target', or 'probe'. The latter convention will be adopted here. Memory scanning and memory search are used interchangeably.

One deduces the existence of the stages in processing by manipulating factors experimentally. A 'factor' is an experimental variable, or a set of two or more related treatments called 'levels'. The 'effect' of a factor is the change in RT induced by a change in the level of that factor. Where two factors influence no processing stages in common, the effect on RT will be additive. Where two factors influence at least one stage in common, the likely relation between the factors is some degree of interaction. Thus, the experimenter tests for pairs of factors that are additive, and given no stronger arguments to the contrary, assumes the existence of a corresponding pair of stages. Additivity is evaluated by testing the interaction term in an analysis of variance. The usual convention has been that where this is found to be not significant at the 5 per cent level of confidence, then the two factors are assumed to be additive and inferences can then be made about corresponding mental operations.

The subsets of interacting factors associated with a stage permit one to infer the operations performed by that stage, and also its location within a sequence of stages.

A strong supplementary assumption to additivity of mean RT is independence between processing stages. RT components (see Equation 1) are stochastically independent when there are additive factor effects on variances and higher cumulants of RT as well as on mean RT. This assumption is not critical to the additive factor analysis, but can be viewed as a more powerful test of the hypothesis of separate stages. Thus, while evidence that RT components are stochastically independent adds strength to the proposition that they represent the durations of different stages, stages can still be additive without the stronger assumption of independence being met.

For example, Sternberg (1969) suggested that if some factor which was subject-controlled rather than experimenter-controlled (e.g. attention or preparation for presentation of a particular stimulus) varied from trial to trial, the duration of some or all stages may vary along with this factor. This would lead to a positive or negative correlation between stage durations, the sign depending on whether the varying factor influenced the duration of different stages in the same or the opposite direction. Within an information processing model that required independence of stages, such a correlation might be viewed as due to poor experimental control, and if trials on which the factor in question assumed the same level could be separated out, then stages within that subset would be independent. As another example, a negative correlation between stage durations could occur, even though stages were additive, if the duration of a stage was shorter when its output was of higher quality. If the high quality input was due to the previous stage taking longer, then on trials when the first stage was long, the second would be short, and vice versa. If independence as well as additivity were required to identify separate stages, then in this case these two stages could not be seen as discrete; they should be viewed as a single stage, despite their additivity.

Sternberg (1969) conceived of a stage as part of a series of successive mental processes operating on an input to produce an output, and each being an additive component of RT. He also included independence of mean stage durations together with additivity, making the following points when describing his conception of stages or mental operations:

> "1) Given its input, the output of a stage should be independent of factors influencing its duration:
>
> 2) The stages in a series should be functionally interesting, and qualitatively different and should 'make sense' in terms of other knowledge:

3) A stage should be able to process no more than one 'signal' at a time*:

4) Stage durations should be stochastically independent."

(Sternberg, 1969, p. 283).

1.3.1 Basic findings of the Sternberg model

Sternberg (1969) manipulated a number of factors to determine what mental operations take place when subjects are asked whether they recognise an item. He deduced four separate mental operations between presentation of a probe and the subject's response. When a probe item is presented, the subject must perceive the item, translate it into some stable form, compare this form with items held in memory, and select and execute a response. These stages are shown in Figure 1.1. It is assumed that the number of elements from the ensemble scanned in memory (i.e. the 'positive set') is under experimental control. Whether the memory search is serial or parallel is inferred by evaluating the linearity of the function relating mean RT to the number of items scanned. A typical result of varying positive set size is shown in Figure 1.2. The RT/set size function, or 'item recognition function', is linear, and the addition of one item to the positive set causes a set increment in RT, suggesting that memory search is serial. Sternberg inferred that the probe item is compared with each item in memory in turn, hence the term 'serial comparison'.

The angle of the slope of the item recognition function is held to reflect the speed of scanning memory items; the steeper the slope, the slower the scan of memory since the increment in RT for the addition of one item to the positive set is larger. The zero intercept is extrapolated from the slope of the function, and represents the combined durations of all events other

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*Sternberg refers here to the single-channel hypothesis of Welford (1960) whereby central mechanisms can only deal with one signal or group of signals at a time.

FIGURE 1.1:

The four stages in item recognition, with four experimental factors believed to influence the stages. Vertical arrows show that each factor influences only one stage. Dashed lines above the four factors show the pattern of additivity deduced by Sternberg (1969) (after Sternberg, 1975).

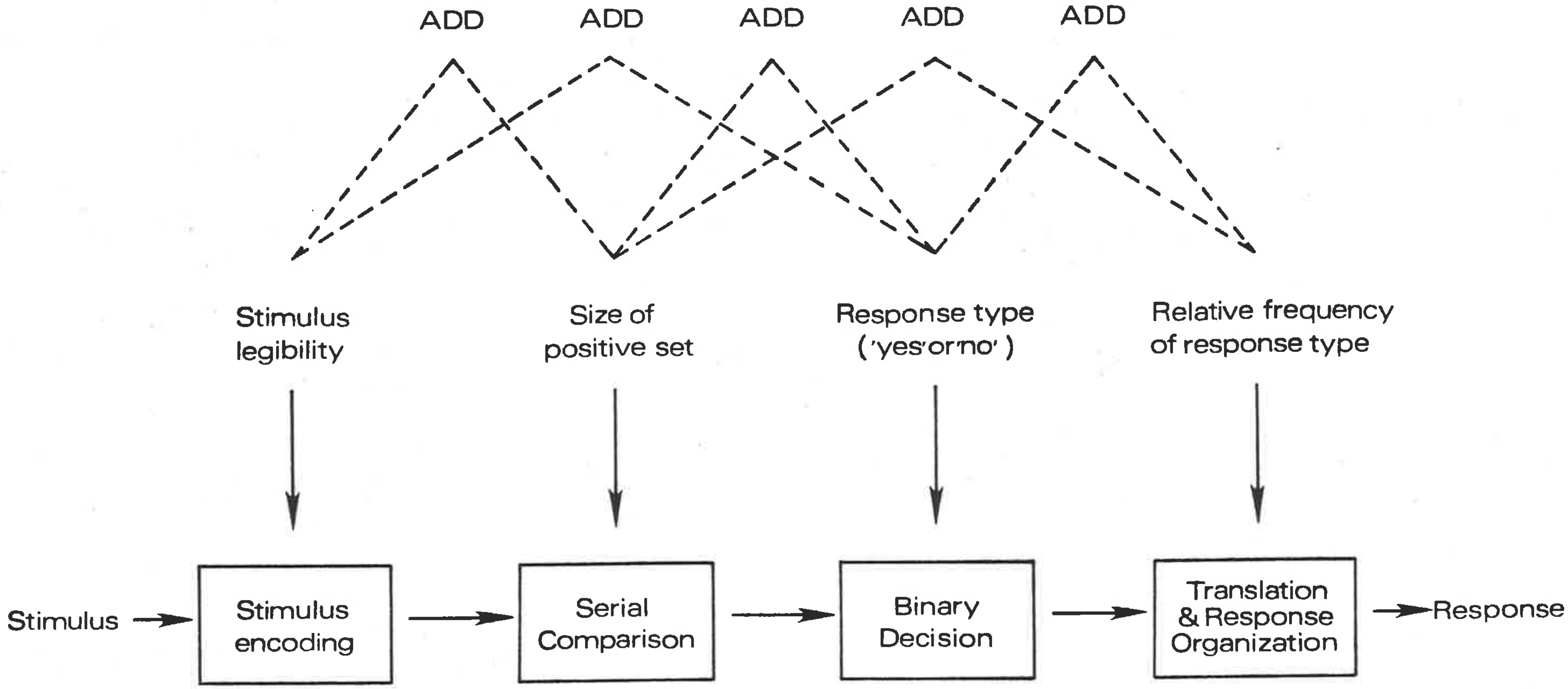
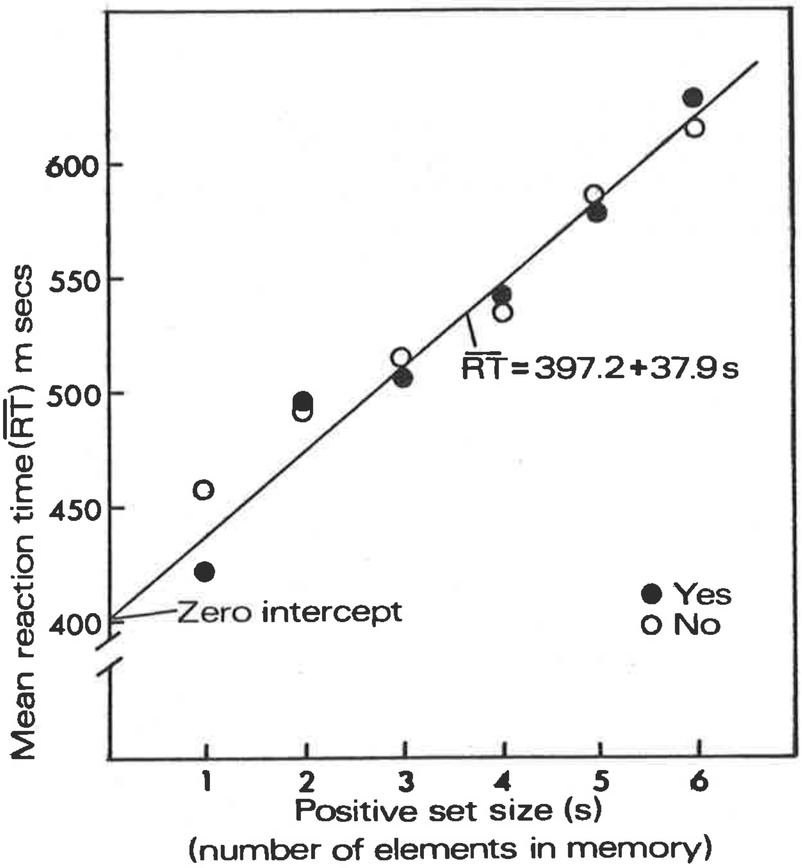

ADD
ADD
ADD
ADD
ADD
Stimulus legibility
Size of positive set
Response type ('yes' or 'no')
Relative frequency of response type
Stimulus
Stimulus encoding
Serial Comparison
Binary Decision
Translation & Response Organization
Response

FIGURE 1.2:

The item recognition function, showing the relationship between RT and positive set size, or number of elements assumed to be held in memory, for 'yes' and 'no' responses.


600
550
500
450
400
Mean reaction time ($\overline{RT}$) m secs
$\overline{RT}$ = 397.2 + 37.9 s
Zero intercept
Yes
No
1
2
3
4
5
6
Positive set size (s)
(number of elements in memory)

than memory scanning, or RT when no elements are scanned. Thus mean RT can be expressed in terms of the components of the item recognition function:

$$\overline{RT} = a + bs \qquad \text{(Equation 2)}$$

where $\underline{s}$ is the number of items held in memory, $\underline{b}$ is the time taken to compare the probe with one item (i.e. slope) and $\underline{a}$ is the time taken for all the remaining operations. Assuming independence of stages as well as additivity the zero intercept value and slope value should not correlate if they represent separate stages.

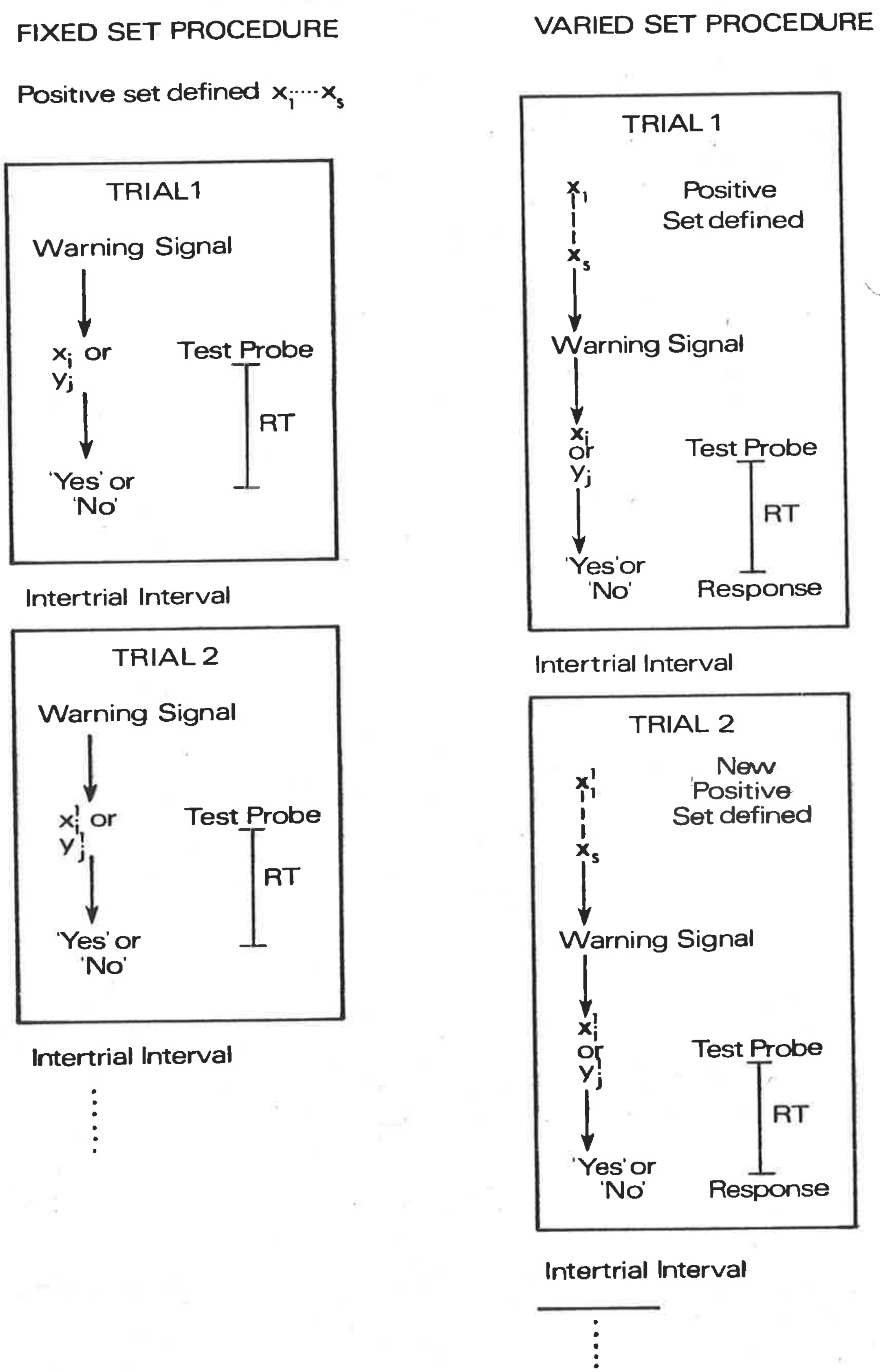
Sternberg (1966) found parallel 'yes' and 'no' slopes, suggesting that the addition of an item to the positive memory set causes the same increment in RT regardless of whether a match with the probe item occurred in the memory search. This is termed 'exhaustive scanning', whereby the whole list in memory is searched at each trial, even after a match with the test item has been made. Thus RT would be unaffected by the probed item's position in the positive memory set, since every item position is searched on every trial. An alternative operation would be 'self-terminating' scanning, in which the list was only scanned until a match with the probe item was found. Here, the slope for 'yes' responses would be half that for 'no' responses, since on average only half the memorized items would be scanned for a positive probe.

Two procedures gave equivalent results with normal adults (Sternberg, 1969). In the 'varied set' procedure, the subject memorized a different positive set on each trial. Positive set stimuli were presented successively (see Figure 1.3), and both the size (1 to 6 digits) and the items of the positive set changed from trial to trial. Data shown in Figure 1.2 were obtained using this procedure. Similar results were also found using a 'fixed set' procedure (Sternberg, 1969, expt. 2), in which the same positive set was used over a series of trials.

Generally, normal adults appear to scan memory in a varied set procedure at a rate of approximately 38 msecs/item, while other mental

FIGURE 1.3:

The time sequence for presentation of fixed set and varied set procedures. The positive memory set is defined as the elements x1 to xs, and the test probe as xi (positive probe) or yj (negative probe). RT is the time between presentation of the probe and the subject's response (after Sternberg, 1969).


FIXED SET PROCEDURE
Positive set defined $x_1 \cdots x_s$
TRIAL 1
Warning Signal
x_i or y_j
Test Probe
RT
'Yes' or 'No'
Intertrial Interval
TRIAL 2
Warning Signal
x_i^1 or y_j^1
Test Probe
RT
'Yes' or 'No'
Intertrial Interval
VARIED SET PROCEDURE
TRIAL 1
x_1
x_s
Positive Set defined
Warning Signal
x_i or y_j
Test Probe
RT
'Yes' or 'No'
Response
Intertrial Interval
TRIAL 2
x_1^1
x_s
New Positive Set defined
Warning Signal
x_i^1 or y_j^1
Test Probe
RT
'Yes' or 'No'
Response
Intertrial Interval

operations, reflected in the zero intercept of the item recognition function, take approximately 400 msecs altogether. Operations other than memory scanning take slightly less time when a fixed set procedure is used, while memory scanning speed is the same in both procedures.

The similarity of results from these two procedures led Sternberg to postulate that the same short-term memory store was being searched. In the varied set procedure, a serial exhaustive scan of material held in short term store was required. He concluded, however, that in the fixed set procedure, material is apparently maintained in short-term store as well as being stored in long-term memory.

1.4 MENTAL RETARDATION AND MEMORY SCANNING

Two possible advantages of the additive factor method over previous methods of studying memory in mental retardation are:

(i) it places memory performance in the context of other processing, such as encoding and binary decision processes, and

(ii) it has the potential for refining the locus of any memory deficits further than the early gross measures used.

Four studies have compared mildly retarded persons with nonretarded persons using variants of the Sternberg memory paradigm. Retarded memory scanning has generally been found to be serial and exhaustive, like non-retarded scanning, but the rate of memory search and other mental operations, and so the exact relation to normal performance, is unresolved. Thus, three studies suggested that mildly retarded adults or adolescents scanned memory more slowly than normal mental age or chronological age controls (Dugas & Kellas, 1974; Harris & Fleer, 1974; Maisto & Jerome, 1977), as shown in higher slopes for the retarded groups' item recognition functions. The general consensus was that slow memory scanning represented a structural impairment in the process of memory search. This was supported by the finding of Harris & Fleer (1974), that brain damaged, retarded adolescents scanned memory even more slowly than cultural-familial retarded subjects. However, Silverman (1974) found that memory scanning speed was the same for retarded subjects as for three nonretarded groups, so the issue is not clearcut. Furthermore, the absolute scanning speed of retarded subjects varied greatly across studies - from 66 msecs/item (Harris & Fleer (1974), cultural-familial group) to 126 msecs/item (Maisto & Jerome, 1977) - so there is as yet no typical item recognition function for such subjects.

Comparisons of zero intercepts from item recognition functions of retarded and nonretarded subjects have resulted in similar conflicts between studies. Three studies using chronological age controls reported approximately equal intercepts in nonretarded and retarded subjects (Harris & Fleer, 1974; Maisto & Jerome, 1977; Silverman, 1974). Of the studies with mental age controls, Harris & Fleer (1974) and Silverman (1974) found that retarded subjects had lower zero intercepts than nonretarded children, while Dugas & Kellas (1974) found higher intercepts in their retarded subjects.

Thus, although some retarded subjects may be able to encode material and select responses as quickly as their chronological age controls, their rate of memory scanning may be slower. The relation of their performance to mental age controls is less clear, since there is contradictory evidence from different studies for scanning being slower among retarded subjects (Dugas & Kellas, 1974; Harris & Fleer, 1974), or the same (Silverman, 1974). Again, evidence is contradictory as to whether encoding and response selection processes are faster among retarded subjects when compared with nonretarded children of the same mental age (Harris & Fleer, 1974; Silverman, 1974), or slower (Dugas & Kellas, 1974). These findings are no doubt confounded by the ambiguous results of developmental studies of recognition memory in normal children. There have been no equivalent investigations into the development of memory related processes in retarded children.

Although there are some consistencies between different studies, it is difficult to draw valid conclusions from so few studies, which give disparate results. How can the performance of mildly retarded persons on this recogni tion memory task be explained? There are three possibilities which will be considered here.

Firstly, slowness could reflect a developmental lag in processing efficiency. If that was the case, then intellectually average children of similar mental age to retarded persons should also perform differently to normal adults. Secondly, the memory scanning task may tap some structural deficiency in the memory processes of retarded persons, as suggested by those studies which found slower memory scanning in their retarded group only. If the task is sensitive to structural deficiencies in memory, then other persons with short term memory deficits may exhibit similar memory retrieval performance. Thirdly, the slowness or inconsistency of retarded persons' retrieval may be due to their sensitivity to procedural variables. It is the case that some experimental procedures result in changes in the slope and/or intercept of the item recognition functions obtained with normal adult subjects, so that performance is significantly different to that shown in Figure 1.2. These topics will be reviewed to determine whether any evidence exists in the literature which could account for the results of the four studies involving retarded subjects referred to above.

1.5 THE DEVELOPMENT OF MEMORY SCANNING IN NORMAL CHILDREN

If the performance of mildly retarded adults on the memory scanning task could be attributed solely to slower ontogenesis then the performance of nonretarded children of a similar mental age should be comparable to that of retarded adults. Most of the studies of retarded performance suggested that retarded persons scanned memory more slowly but encoded material faster than mental age controls. Silverman's (1974) study was an exception, the results suggesting that retarded adults scanned memory as quickly as mental age controls. However, the developmental literature does not provide clear evidence as to whether memory scanning is developmentally sensitive. Although it as been established that RT decreases with increasing age, the literature is divided as to which processing stage contributes most to the increasing efficiency of performance. Most studies agree that encoding, binary decision and especially response selection processes become faster with age, this conclusion being inferred from the general finding that older children and adults have lower zero intercepts for their item recognition functions than younger children. The development of memory scanning speed is not clearcut, however, and differences between slopes for the item recognition functions of adults and children have frequently been found.

Three early studies did not find differences between the memory scanning rates of nonretarded young children and adults. Hoving, Morin & Konick (1970) compared kindergarten, fourth grade primary school and tertiary college students on a fixed set procedure, and found that although there was a significant decrease in zero intercept with increasing age, slopes of the item recognition functions were similar for all three groups. The longer RTs of children were therefore attributed to slower perceptual and motor processes, not slower memory search. Similarly, Harris & Fleer (1974) compared normal 8 and 16 year old children and normal adults on a varied set procedure and found that the slopes were similar in all three groups, while zero intercepts decreased with increasing age. Again, Maisto & Baumeister (1975) compared 5, 8 and 11 year old children on a fixed set procedure and found memory search rates comparable to those for normal adults. Furthermore, Chi (1977) concluded from a selective review of the area that there was evidence that memory scanning is equally efficient in children and adults.

Contrary to this early evidence, however, several recent studies have found substantial increases in speed of memory scanning with increasing mental age. Hermann & Landis (1977) compared normal children aged approximately 7, 12 and 17 years on a fixed set procedure, finding that while zero intercepts decreased significantly with increasing mental age, slopes also decreased, mainly from 7 years to 12 years. In line with Sternberg's model, this was interpreted as meaning that while encoding and response selection processes continued to improve in efficiency into early adulthood, memory scanning improvement slowed down after about the age of 12 years.

Naus & Ornstein (1977) compared normal third and sixth grade primary school children on a fixed set procedure. They found a significant decrease in both zero intercept and slope of the item recognition function with increasing mental age, but they attributed the difference between their findings and earlier findings of no change in scanning speed with age, to their use of alphanumeric stimuli, which they assumed would be more familiar to older children. However, Harris & Fleer (1974) found fast scanning rates in third grade children who were tested with alphanumeric stimuli, so that there is not strong evidence to suggest that familiarity with alphanumeric stimuli is an important determinant of search rate in young children.

Keating & Bobbitt (1978) compared average and high ability 9, 13 and 17 year old subjects on a varied set procedure. While slope of the item recognition function did not change with age in the high ability groups, the average groups exhibited a decrease in slope with increasing age. In a similar experiment, Keating, Keniston, Manis & Bobbitt (1980) compared low, average and high ability 8, 11, 13 and 15 year old children on a varied set procedure. Although they did not find an interaction of age and ability, the slope for item recognition functions did decrease with increasing age, mainly due to an increase in speed from the 8 year old group to the 11 year old group.

From the summary of these results shown in Table 1.1, it can be seen that there is no clear relationship between memory scanning, as indicated by the slope of the item recognition function, and mental age. Although the overview shown in this table should be regarded with caution because of differences in procedures between the various studies, it is fair to say that existing research provides no clear resolution as to whether memory scanning rates are developmentally sensitive, or invariant across mental age. The question as to whether the memory deficit shown by some retarded adults can be related to a developmental lag cannot be answered by existing literature.

1.6 PSYCHOPATHOLOGY AND MEMORY SCANNING

If poor performance on the memory scanning task is related to a short-term memory deficit, then mildly retarded adults will be only one of a number of groups who perform slowly on the task. If the memory scanning task can differentiate between diffuse and specific brain damage, as suggested by the slower memory scanning of brain damaged retarded subjects when compared with cultural familial retarded subjects (Harris & Fleer, 1974), then other brain damaged groups may exhibit slower performance. Evidence for poor performance in other groups with known short-term memory deficits would confirm the memory scanning task's ability to differentiate between normal and pathological memory and support the suggestion that slow memory scanning reflects a structural impairment in memory.

1.6.1 Aphasia and Memory Scanning

Swinney & Taylor (1971) reported that their aphasic subjects scanned memory in a qualitatively different way to normal controls, using a slow, self-terminating process. However, Warren, Hubbard & Knox (1977) have indicated that aphasic subjects can search memory exhaustively, although the

Experimenters	Chronological Age (years)	Slope (msecs/item)	Intercept (msecs)
Hoving, Morin & Konick (1970)	4.0	30	670
Maisto & Baumeister (1975)	5.5	38	935
Hermann & Landis (1977)	7.3	223	895
Silverman (1974)	7.5	136	756
Maisto & Baumeister (1975)	8.5	39	838
Harris & Fleer (1974)	8.5	42	688
Hoving, Morin & Konick (1970)	9.0	30	500
Naus & Ornstein (1977)	9.0	42	579
Naus & Ornstein (1977)	9.0	45	600
Keating & Bobbitt (1978)	9.2	113	1070
Keating, Keniston, Manis & Bobbitt (1980)	9.7	85	946
Maisto & Baumeister (1975)	10.5	49	689
Silverman (1974)	11.0	101	518
Keating, Keniston, Manis & Bobbitt (1980)	11.7	62	739
Naus & Ornstein (1977)	12.0	25	506
Naus & Ornstein (1977)	12.0	30	530
Hermann & Landis (1977)	12.5	84	621
Keating & Bobbitt (1978)	13.2	73	687
Keating, Keniston, Manis & Bobbitt (1980)	13.7	55	569
Silverman (1974)	14.0	88	408
Keating, Keniston, Manis & Bobbitt (1980)	15.7	52	503
Harris & Fleer (1974)	16.0	42	395
Hermann & Landis (1977)	17.2	42	509
Keating & Bobbitt (1978)	17.3	62	419

Table 1.1: A review of developmental studies of memory scanning, showing that slope and intercept are neither invariant across age nor showing any consistent change.

estimated rates of search and encoding and response selection processes were somewhat slower than normal adults. Warren et al. (1977) suggested that Swinney & Taylor's (1971) subjects may have switched to a self-terminating strategy because the highest set size presented exceeded their visual retention span, and that the higher slope for the negative function may have been due to more than one scan of the positive set in memory before making a 'no' response. Warren et al. (1977) also found considerable individual differences between the search procedures adopted by their aphasic subjects. For six out of their ten subjects item recognition functions for 'yes' and 'no' responses were not parallel, while the remaining four subjects had parallel slopes.

1.6.2 Alcohol and Memory Scanning

The effect of alcohol on memory has been studied in Korsakoff patients, chronic alcoholics and social drinkers. If subjects are not brain damaged, alcohol appears to slow down the response selection stage only and more errors are made, but memory search speed and encoding are unaffected (Huntley, 1974; Mills & Ewing, 1977; Tharp, Rundell, Lester & Williams, 1975). Parsons & Prigatano (1977) noted that memory impairments seen in alcoholics without organic brain syndrome are only slight, and in detoxified alcoholics, there is little to suggest that memory functions are permanently impaired. Other central nervous system depressants such as secobarbital, methaqualone and meprobomate also affect the encoding and response selection stages, but again there is no evidence for slower memory search than normal controls (Rundell, Williams & Lester, 1977; Williams, Rundell & Smith, 1981).

On the other hand, persons with obvious brain damage, as in Korsakoff's syndrome, exhibit both slower memory search and slower encoding or response selection processes than other alcoholics. Naus, Cermak & De Luca

(1977) found that brain damaged alcoholics had a 40 per cent slower search rate than alcoholic controls who were not brain damaged. Other stages of memory retrieval were also slowest among brain damaged alcoholics, as indicated by a zero intercept for the item recognition function that was about 260 msecs higher than the intercept found for non-brain-damaged alcoholic subjects. This result is therefore in agreement with Harris & Fleer's (1974) finding of slowest memory search among brain damaged retarded subjects.

1.6.3 **Schizophrenia and Memory Scanning**

Several studies have found that, overall, the slower than normal RT found among schizophrenic patients is not due to a slower scanning rate, but is centred in the encoding or response selection stages. Checkosky (cited by Wishner, Stein & Peastrel, 1978) studied chronic and acute schizophrenic persons and non-brain damaged alcoholics, using letters, digits, geometric figures and colours as stimuli. He found group differences in intercept, but no difference between the slopes of the item recognition functions for the three groups. This result has been replicated by Wishner et al. (1978) using digits as stimuli, and by Neufeld (1977) using sentences. However, when sentences had to be retained in memory, schizophrenic subjects scanned memory more slowly than normal controls (Neufeld, 1978). Neufeld suggested that this was due to diminished quality of the sentence representation, so that output from the encoding stage of processing had an adverse effect on the serial comparison stage.

Russell, Consedine & Knight (1980) tested process schizophrenics on a task where subjects were presented with more than one probe stimulus at a time. Although RT of schizophrenic subjects exceeded RT for normal controls, the slopes of item recognition functions for the two groups were not different. The authors found that elevated intercepts were predictable from a combination of biographical variables such as age, sex, vocabulary, drug dosage and paranoid status.

However, wide individual differences have been found within many of these studies. Koh, Szoc & Peterson (1977) noted that the schizophrenic population is particularly difficult to study because of individual differences in severity of illness, chronicity, age, education, length of hospitalization, history of neuroleptic medication and other variables that could contribute to heterogeneity of performance within a group. Using a fixed set procedure, they found that a logarithmic item recognition function fitted data for schizophrenic subjects better than a linear one, and that the average slope for negative probes (36 $\log_2 s$) was lower than for positive probes (82 $\log_2 s$). Despite these findings they concluded that slopes for positive and negative probes were "roughly equal" (Koh et al., 1977, p.459), presumably because of the lack of a theoretical framework within which to explain the shape and relation of the two functions.

After analysing individual data, Wishner et al. (1978) found two subgroups among their schizophrenic subjects; these were slow schizophrenics (slope = 74 msecs/item) and fast schizophrenics with slopes approximately the same as alcoholic controls (slope 22 msecs/item). Reanalysis of individual data from Checkosky's study also produced a significantly steeper slope for the item recognition functions of some schizophrenics. Wishner et al. (1978) also distinguished between motor coordination and discoordination, so that four separate strategies could be identified: both slow memory search and motor discoordination; slow search and motor coordination, fast search and motor discoordination; or defects on neither of these dimensions.

1.6.4 Aging and Memory Scanning

As well as being a symptom of various psychopathologies, a deficit of short-term memory has sometimes been associated with advanced age among normal adults. Studies of memory scanning in older normal adults have consistently demonstrated slower RT, with steeper slopes to item recognition functions suggesting slower memory search, as well as higher intercepts indicating slower peripheral activities.

For example, Anders, Fozard and Lillyquist (1972) found that as the age of normal subjects increased beyond approximately 33 years of age, both the slope and zero intercept of the item recognition function increased. Simon & Pouraghabagher (1978) have concluded that the higher zero intercept of older adults represented slower stimulus encoding rather than slower response selection operations. Furthermore, since they did not find an interaction of stimulus quality and age when analysing simple RT, they concluded that the difference between older and younger adults was not related to deteriorating sensory processes, but to a central processing deficit.

Slower information processing in adults older than approximately 50 years is well established using the memory scanning task (e.g. Anders & Fozard, 1973; Thomas, Waugh & Fozard, 1978), although the performance of normal adults between the ages of 20 and 50 years is not consistent across experiments. Anders et al. (1972) found slower memory search in a group of 33-43 year old adults than 19-21 year old adults, whereas Eriksen, Hamlin & Daye (1973) found no difference in memory search speed between groups of 35-40 year old and 20-25 year old subjects. However, Anders et al. (1972) did not control the age range of subjects within each group (ranges for young, middle and old groups respectively being 2 yrs, 10 yrs and 33 yrs). Variability in memory search between subjects increases with age (Thomas et al., 1978), so that results from Eriksen et al. (1973), where memory search did not slow down until after 50 years of age, may be a more accurate representation of general performance at each age group.

Although the evidence for slower memory search in elderly adults is well documented, there is also evidence that variability in RT is a significant characteristic of the slower performance of elderly persons, so that as in schizophrenia research, group data may not be an accurate representation of individual performance. Thomas et al. (1978) tested five groups of normal adults with average ages of approximately 33, 40, 50, 60 and 70 years. They found four main results:

(i) For all age groups, random letters took longer to search for in memory than lists of familiar material;

(ii) Older subjects were disproportionately slower when stimuli were random letters;

(iii) Within subject variability in RT increased with age;

(iv) Between subject differences were larger in the slower, older groups.

The authors suggested that increasing variability of RT performance with age was due to less consistent use of strategies by older subjects, perhaps because these individuals experienced greater difficulty in adapting to novel laboratory situations.

There is also some evidence that the combined effects of old age and brain damage produce qualitatively different performance on the memory task to that seen in non-brain damaged adults. Hilbert, Niederhe & Kahn (1976) compared three groups of elderly adults who were either brain damaged, identified clinically as depressed or served as normal controls. All subject groups had a mean age of approximately 60 years (range = 50-86 yrs). Brain damaged subjects responded very slowly and with more errors than were made in either of the other two groups. Furthermore, the item recognition function for the brain damaged group was non-linear, and there was more between subject variability than in the other groups.

Both depressed and normal control subjects responded more slowly, with steeper item recognition functions having higher zero intercepts than has typically been found in younger normal adults. Although the slopes of functions were similar for these two groups, subjects rated as depressed exhibited higher zero intercepts than elderly controls, while neither group was as slow as brain damaged persons. However, depressed subjects were also of a lower educational level than control subjects, so that the higher zero intercepts could not be attributed to depression alone.

In summary, short term memory deficits appear consistently in the memory scanning task as slow memory search rates as well as slower encoding or response selection operations. The most consistent aspect of pathological memory is slower encoding and/or response selection processes. The degree of slowing may be predictable from biographical variables (Hilbert et al., 1976; Russell et al., 1980). Evidence from studies of specific organic syndromes shows that memory search is slow as well, but greater between subject variability may diminish the validity of group results. Thus, although the slower average memory search performance found in some retarded subjects resembles that of other groups from the studies reviewed above, there is greater likelihood that group data are not a close representation of individual performance in these slow groups. This between subject variability could explain in part the disparate results found between studies of retarded memory scanning.

1.7 EFFECTS OF PROCEDURE ON MEMORY SCANNING

There is comprehensive research showing that normal young adults perform differently to the results shown in Figure 1.2, when certain aspects of the procedure of the task are altered. The final possibility to be considered when accounting for the memory scanning performance of retarded persons is that the different slope or zero intercept of retarded persons' item recognition functions reflects their sensitivity to the experimental procedure used within this paradigm. This implies that a different procedure may lead to a different relationship between retarded and nonretarded performance. The following sections will review literature in which procedure change affects either the zero intercept or the slope of the item recognition function of normal adults, compared with performance shown in Figure 1.2. Sections of the literature concerning the generalizability of the memory scanning paradigm have been reviewed by Briggs (1974), Corballis (1975), Eysenck (1977), Shiffrin & Schneider (1974) and Sternberg (1975).

The main effects that have been studied are:

a) The nature of stimuli presented for memorizing;

b) The influence of additional stimuli and the effects of irrelevant information;

c) The effects of stimulus quality;

d) The effects of stimulus probability;

e) The effects of instructions;

f) The influence of response set;

g) The effects of the rate of presentation of stimuli;

h) The effects of category and organization of memory sets;

i) The effects of very long memory lists.

This literature will be reviewed briefly to demonstrate that procedural sensitivity is a significant factor in the memory performance of normal adults, so that a similar sensitivity among retarded adults, although perhaps to different aspects of procedure, cannot be disregarded in an assessment of retarded performance.

1.7.1 The nature of stimuli presented for memorizing

Some studies using visual stimuli have changed the nature of the stimuli in an attempt to equate subject groups for familiarity (e.g. Briggs & Swanson, 1970; Hoving et al., 1970; Maisto & Jerome, 1977; Silverman, 1974), or to investigate the effect of complex or unfamiliar stimuli on memory processes (e.g. Dumas, 1972; Lyons & Briggs, 1971; Sternberg, 1969). Materials used with normal adults have included familiar stimuli of varying complexity, such as letters and words, and unfamiliar abstract stimuli varying on a number of experimentally determined dimensions. Stimuli have included digits (Baddeley & Ecob, 1973; Clifton & Birenbaum, 1972; Sternberg, 1966), letters (Chase & Calfee, 1969; Darley, Klatzky & Atkinson, 1972; Klatzky & Smith, 1972), words of various lengths (Burrows & Okada, 1971; Clifton & Tash, 1973; Graboi, 1971), phonemes (Foss & Dowell, 1971), colours (Williams, 1971), drawings of common objects (Hoving et al., 1970), pictures of faces (Sternberg, 1969) and nonsense forms or random forms (Sternberg, 1969; Swanson, Johnsen & Briggs, 1972).

Less familiar, less easily verbalized and more complex stimuli appear to increase the slope of the item recognition function, that is, to reduce the rate at which memory is scanned (Cavanagh, 1972; Sternberg, 1969). Klatzky, Juola & Atkinson (1971) found that the slope for pictures was much higher than for letters, and Juola & Atkinson (1971) indicated that slopes for categories were higher than for words. Thus, the higher slopes found for some retarded subjects could be related to their being less familiar than for nonretarded subjects with stimulus material, although there is only equivocal evidence for such a suggestion (Maisto & Jerome, 1977; Silverman, 1974).

Bigham (1894) was the first to note the constant relationship between the type of material recalled and the rate at which this was recalled. He investigated memory span for digits, colours, forms, words and syllables and found increasing error rates for each of these. More recently, Cavanagh (1972) has reviewed the memory scanning literature and discovered a reciprocal relationship between scanning rate and memory span; that is, the slower the scan in memory, the shorter the memory span for that material. Cavanagh has proposed that the representation of the stimulus in memory is composed of lists of features, and short-term memory can only hold a certain number of features at a time. Thus, the more features each 'list' or stimulus contains, the fewer 'lists' will fit into the memory store.

However, while the relationship that Cavanagh describes could explain the slower scanning rate of retarded subjects whose memory span may be shorter than nonretarded subjects working with the same material, Cavanagh's suggestion has three shortcomings. Firstly, Cavanagh's model is based on only an average figure from a number of complicated studies with several different conditions under which subjects were tested. For example, Cavanagh's figure for Sternberg (1967) is averaged over two separate conditions, while his figure for the study of Checkosky & Checkosky is a regression line calculated on only two positive memory set size points. Some other figures are linear regressions based on nonlinear data (e.g. the figures for Egeth & Smith, 1967; Nickerson, 1966; Smith, 1967). Secondly, as will be discussed in Chapter 3, the slopes obtained from individual subjects can change across sessions, while presumably their memory span for the stimulus material used remains unchanged (Kristofferson, 1972). Thirdly, memory span and scanning rate should be correlated for individual subjects, if recognition and recall are part of the same control system, as Cavanagh has suggested. However, Brown & Kirsner (1980) have provided convincing evidence that subjects with high memory spans for a particular kind of stimuli are not necessarily those with fast memory search rates.

Thus, less familiar stimuli lead to a relatively slow memory scan, but there is no clear evidence to suggest that slower scanning is related to memory span.

1.7.2 The influence of additional stimuli and the effects of irrelevant information

Adding irrelevant stimuli or interpolating tasks has been used to study the amount of memory capacity taken up by the memory scanning task. This approach is based on the assumption of a single store, limited capacity system.

Where the extra task is unrelated or irrelevant to the memory task, no change in rate of memory scanning is found, but an increase in response selection time may occur (Acosta & Simon, 1976). Similarly, Simon, Acosta & Mewaldt (1975) also showed that an irrelevant cue presented prior to the onset of a relevant stimulus can interfere with the processing of that stimulus, but again only producing slower response selection. Attempts to prevent rehearsal by the use of tasks interpolated between presentation of the memory set and probe have also resulted in increases in the time taken for response selection or encoding without changes in memory search (Burrows & Okada, 1975; Okada & Burrows, 1978). These results may be relevant to the finding of slower encoding or response selection processes in some psychopathological groups, reviewed in section 1.6, whereby a similar effect to experimenter-controlled distraction may be produced by subjects' attention deficits.

On the other hand, De Rosa (1969) found that where the two tasks presented require memory capacity, slope can be affected. He showed normal young adults two successive sets of items followed by a single probe. A probe was only critical if it had been in the first set and not in the second. De Rosa suggested two possible strategies for this task. When the second set is presented, items in common to the two sets could be deleted from the first, so that subjects would scan a reduced set; or the subjects could scan the two sets without a selective deletion operation. His results suggested that a selective deletion operation occurred, otherwise slopes for two-set trials would have been twice as steep as for one-set trials.

However, Atkinson and his associates have shown that long and short term memory can be accessed simultaneously, without affecting the nature of either process. When subjects are required to hold two positive sets in memory, one a fixed set which does not change across trials and the other a varied set, the items of which change from trial to trial, memory search appears unchanged when item recognition functions are plotted separately for each type of memory set. Results replicate those found when fixed set and varied set procedures are presented in separate sessions.

These studies demonstrate that normal adults can adapt the search strategy employed so that responding is as efficient when dealing with two memory lists as with one.

1.7.3 The effects of stimulus quality

Among normal subjects, degrading the test probe, for example by placing a checkerboard pattern over it, typically results in a higher zero intercept to the item recognition function. The effect is located in the encoding stage (Bracey, 1969; Sternberg, 1967), while memory scanning is unaffected. Hardzinski & Pachella (1980) have suggested that during encoding, an abstract internal code is derived from the probe, so that if the probe is degraded, this process is slower, but all effects of stimulus quality are removed before the memory scanning stage.

However, Maisto & Jerome (1977) reported that retarded adolescents were more sensitive than nonretarded subjects to degradation of the probe. Thus, for retarded subjects, RT to a degraded probe was disproportionately slower than to an intact probe. Furthermore, retarded subjects traded off time spent in encoding and memory scanning, as shown by higher zero intercepts but lower slopes when responding to a degraded probe when compared to an intact probe.

Sternberg (1967) found a small effect of degrading the probe on the slope as well as on the zero intercept of the item recognition functions of unpracticed normal adults, but the effects disappeared with practice. Bracey (1969) suggested that the 'filtering operation' which occurs during encoding may become more efficient with practice, so that the large effect of stimulus quality on retarded subjects' RT may be reduced by practice.

1.7.4 **The effects of stimulus probability**

In most experiments in the literature, the probability of each member of the positive set being presented is equal. However, there is evidence that normal adults' memory retrieval performance is sensitive to the frequency with which probe stimuli are presented. In those studies where the probability of a particular item occurring has been varied, RT to stimuli with high probability of presentation has been faster than to stimuli with low probability (Biederman & Stacy, 1974; Miller & Pachella, 1973; Theios, Smith, Haviland, Traupmann & Moy, 1973). The location of this effect in the series of mental operations required for retrieval has been disputed.

Some theorists have proposed that more frequent stimuli are searched first, in a 'self-terminating' scan of both positive and negative set items (Krueger, 1970; Theios et al., 1973; Theios & Walter, 1974). If this were the case, then stimulus frequency would affect memory scanning time. However, these experiments have typically presented memory ensembles with equal numbers of positive set and negative set items, so that subjects could search either set equally fast, and they have never clearly demonstrated an interaction between stimulus probability and factors affecting the memory scanning stage.

An alternative suggestion by Sternberg (1975) is that frequency effects are located in the encoding or response selection stages, that is, they only affect the zero intercept of the item recognition function. This hypothesis was supported by Miller & Pachella (1973), who showed that stimulus probability and stimulus quality interacted, and by other experimenters who have found interactions between stimulus probability and factors thought to affect the encoding or response selection stages (e.g. Klatzky & Smith, 1972).

Thus, while normal adults are sensitive to this procedure change, the effect appears again to be on the zero intercept rather than the slope of their item recognition function.

1.7.5 The effects of instructions

Instructions emphasizing speed over accuracy also appear to influence encoding or response selection stages rather than the rate of memory search.

Several investigators have shown that emphasizing speed reduces the zero intercept of normal adults' item recognition functions without altering the slope (e.g. Briggs & Shinar, 1972; Lively, 1972; Pachella, 1974; Swanson & Briggs, 1969). Pachella (1974) showed that up to approximately 10 per cent errors may be made without the rate of memory search being affected. However, Coots & Johnston (1972) found that both zero intercept and slope were lower when a speed set was induced than when accuracy was emphasized, so that under some circumstances instructions may change the search rate as well.

1.7.6 The effects of response set

Normal adults also appear to be sensitive to the response requirements of the task. When only one type of response is required, a different strategy to serial, exhaustive scanning may be employed, and the slope of the item recognition function may be affected.

When responses are only required to positive set probes (a 'yes-only' condition), the slope of the function is reduced significantly (Egeth, Marcus & Bevan, 1972; Corballis, Roldan & Zbrodoff, 1974). A possible explanation for this result is that subjects terminate memory search when a match with the probe is found in the 'yes-only' condition, thereby reducing the slope of the item recognition function when compared with exhaustive scanning. However, a 'self-terminating' strategy would produce serial position effects, since RT would depend on the position of the probed item in the memory set, and there is no evidence for this effect in the experiments reported.

Egeth et al. (1972) have interpreted the interaction between factors of memory set size and response condition as evidence for the non-independence of memory search and other stages. However, Corballis et al. (1974) indicated that an alternative explanation could be that the two factors of memory set size and response condition influence a common stage (see Sternberg, 1969, p.282). To test this hypothesis, one would need evidence of the independent existence of the response selection stage in these experiments, from an additive relation between memory set size and a third factor. This is illustrated in Figure 1.4. The two suggestions of Egeth et al. (1972) and Corballis et al. (1974) cannot be resolved at this time, because an appropriate third factor was not included in either set of experiments.

Kristofferson (1975), however, found that the conditions which Egeth et al. (1972) tested would not have produced serial, exhaustive scanning in normal, two response conditions. When particular stimuli were not consistently associated with one response and more positive memory set sizes were tested, there was no difference in slope between one response and two response conditions. Therefore, the response set effect appears to be peculiar to particular arrangements of memory sets.

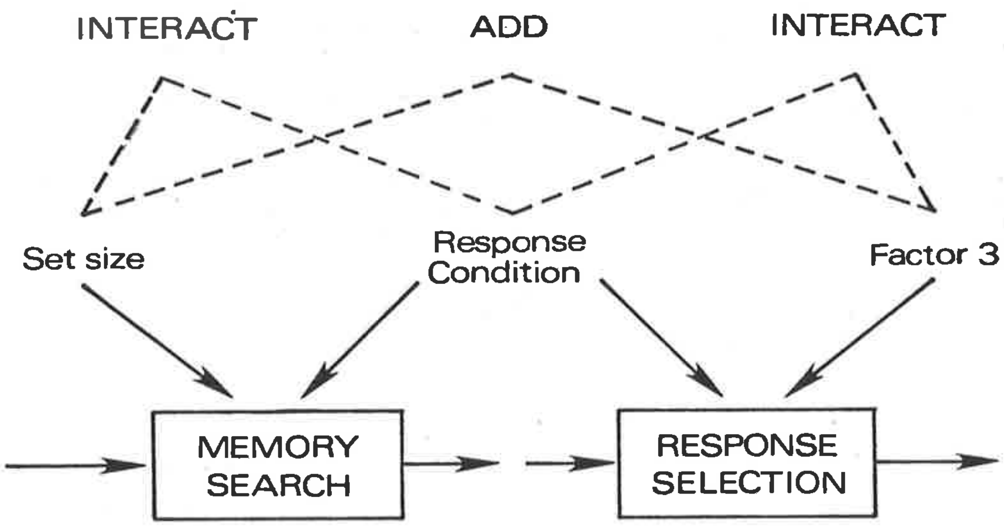
1.7.7 The effects of the rate of presentation of stimuli

If the probe item was compared with every positive set item held in memory, even after an item which matches the probe has been found, the position of the probed item in the positive memory set should not affect RT. However, there is some evidence that when items to be memorized are presented rapidly and the interval between list and test probe is brief, serial position effects on RT occur. When the interval between list and probe is greater than about two seconds, the effect of serial position of the probed item disappears (Corballis, 1967).

Moreover, such effects have been found in data that otherwise suggested exhaustive memory scanning. Some researchers have shown recency effects (e.g. Clifton & Birenbaum, 1970), others primacy effects (e.g.

FIGURE 1.4:

The pattern of additive and interactive factors required to demonstrate independence of the response selection stage under 'yes-only' conditions.


INTERACT
ADD
INTERACT
Set size
Response
Condition
Factor 3
MEMORY
SEARCH
RESPONSE
SELECTION

Klatzky et al., 1971) and others both (e.g. Burrows & Okada, 1971). Recency effects have been accommodated by assuming that RT is inversely related to the strength of the memory trace that corresponds to the probe (Corballis, 1967). Such a model would predict that stimulus presentation rate and the time between the last memory item and the probe affects the recency effects obtained. Clifton & Birenbaum (1970) provided some support for this suggestion, only finding recency effects with the shortest delay between the last item in the memory set and the probe item.

Thus it appears that serial position effects are likely to occur when there is little opportunity for rehearsal or under conditions likely to produce temporary, unstable storage of material (Forrin & Cunningham, 1973; Sternberg, 1975).

1.7.8 The effects of category and organization of memory sets

While several conditions can be identified which increase the zero intercept of normal adults' item recognition functions, there is no evidence that adults respond to particular procedures by increasing the slope of their item recognition function, or by slowing the rate at which they search for material in memory. However, there is evidence that certain conditions lead to faster memory search or a change in strategy of search.

When negative set items can either belong to the same or a different category to that of the positive set items (as for example where positive set items are digits and negative set items are either digits or letters), the slope of a function for negative set unrelated items (i.e. letters) is lower than other slopes (Hermann, Conti & Frisna, 1978; Lively & Sanford, 1972; Reynolds & Goldstein, 1974). Clifton (1973) also indicated that when highly familiar sets such as siblings' names are presented with unfamiliar sets, normal adults can employ the strategy of serial search for unfamiliar sets while some other strategy which is independent of set size is used for the familiar set.

Other evidence that the slope of the item recognition function is sensitive to categorization within the positive set has been found when memory set items can be grouped in any of a number of ways: either perceptually (Crain & De Rosa, 1974; Williams, 1971), semantically (Naus, 1974; Naus, Glucksberg & Ornstein, 1972); symbolically (Naus, 1974), or syntactically (Clifton & Gutschera, 1971). Normal adults are also able to modify their search behaviour under specific instructions (Seamon, 1972; Schmitt & Scheirer, 1977), but there can be considerable individual differences in the search strategy that subjects adopt initially (Maniscalco & De Rosa, 1979).

1.7.9 The effects of very long memory lists

The other main group of studies in which very low slopes have been found are those where very long memory lists, which are generally considerably longer than the short term memory span for that material ('supra-span' lists), are presented. Such evidence demonstrates that the speed of memory search is sensitive to the number of items which are supposedly stored in long term memory and retrieved during the memory scanning task.

For example, Atkinson & Juola (1972) presented normal adults with positive memory sets of 16, 24 and 32 words. Subjects searched through these long lists at a rate of 4.12 msecs/item on trials requiring a positive response and O.5 msecs/item on trials requiring a negative response. Similarly, Juola, Fischler, Wood & Atkinson (1971) presented subjects with lists of 10, 18 or 26 words and found that subjects searched memory at a rate of 5 msecs/item. This is much faster than results typically found with shorter lists and illustrated in Figure 1.2, where memory sets were searched at a rate of approximately 38 msecs/item. While these data could simply indicate a faster rate of serial search, several theorists favour the idea that a different mechanism, which is not reliant on set size, operates when larger memory sets are presented (Atkinson & Juola, 1974; Freedman & Loftus, 1974).

These data from long memory lists suggest that a linear item recognition function which encompasses both short and long memory lists must have a breakpoint, beyond which subjects search memory at a faster rate or employ a different strategy for retrieval. Burrows & Okada (1975) reported that the breakpoint in the item recognition function occurred somewhere around the memory span for the material presented. However, Corballis & Miller (1973) reported a linear function for memory sets of up to 15 letters, and Corballis, Katz & Schwartz (1980) found that data in the literature using both short and long lists could be fitted with logarithmic functions as easily as bi-linear functions, so there is no clear evidence that short term memory span is an important determinant of the speed of search employed.

1.8 SUMMARY

The hypothesis that mildly retarded persons are slow to scan items held in memory because of some structural or permanent impairment in memory processes derives some support from studies of other groups with short term memory deficits, who were also slow to scan memory. However, evidence that the scanning rate of nonretarded children may also be slow suggests that a developmental lag may be responsible for poorer performance. Three main factors have shown that further research is necessary before any conclusion can be drawn about structural impairments in the memory processes of retarded persons: firstly, the inconsistency of results from studies of memory scanning in mildly retarded persons; secondly, the variability in memory scanning performance found between subjects in other groups characterized by memory deficits; and thirdly, the sensitivity of both the slope and the intercept of item recognition functions for normal young adults to procedural variables.

Chapter 2

EFFECTS OF PROCEDURE ON MEMORY SCANNING IN MENTAL RETARDATION

2.1 INTRODUCTION

In Chapter 1, a survey of the literature on memory retrieval in normal young adults using the memory scanning paradigm indicated that procedural details can influence the duration of the four mental operations hypothesized to constitute RT (i.e. encoding, memory scanning, binary decision and response organization). Pathological and normal responding were characterized by different stage profiles within a particular procedure. However, there were also considerable differences between response profiles found for similar pathological groups across experimental studies, suggesting that slow, variable responses may be even more influenced by changes in procedure than the faster responses of normal subjects. The variable nature of pathological responding also meant, moreover, that group profiles often provided an inadequate description of performance.

Increased variability due to positively skewed distributions of RT poses some difficulty for an additive factor analysis of mean RT, since differences between slow and fast responders can be exaggerated. Sternberg (1969) specified that the basic measurement in his conception of the additive factor method should be mean RT, an index which of course is relatively sensitive to increased variance. However, analysis of medians would make interpretation in additive factor terms impossible because the median of a sum of components need not be the sum of the component medians. Since additivity is destroyed by nonlinear transformations, these are also inappropriate. The alternative solutions are therefore either to manipulate the experimental procedure so as to minimize variability of responding, or to choose statistical analyses which are sufficiently robust to render group variability differences relatively unimportant.

The extent of variability of RT both within individual subjects with memory deficits and among such subjects may be of critical importance to the effects of procedural changes on the duration of the four stages of retrieval. Some procedural changes affect slow, normal responding more than fast responding (Thomas et al., 1978). One would expect then that the combined effects of procedural change and slow, variable pathological responding would hinder consistency of results. This chapter considers the effect of procedural change on the relationship between retarded and normal memory retrieval.

2.1.1 Methodology and mental retardation

In a heterogeneous population such as that of retarded persons, marked response variability between different subjects may be inevitable if RT reflects aetiology or biographical variables. In memory scanning research to date, retarded samples have been restricted to mildly retarded adolescents and young adults (IQ 55-69) between the ages of 16 and 20 years. Harris & Fleer (1974) attempted a division between encephalopathic and cultural-familial retardation, while other studies have selected subjects on the basis of IQ scores and the apparent absence of gross sensory or motor defects. Maisto & Jerome (1977) selected retarded subjects from special classes at a normal public school, but retarded subjects in other experiments have been from residential state hospitals or institutions.

Although the basic Sternberg paradigm has been followed in all studies of retardation, procedural details have varied, which may account for the range of outcomes obtained from different experiments (See Chapter 1, Section 1.4):

(i) The stimulus ensemble has consisted of digits (Harris & Fleer, 1974), random forms (Maisto & Jerome, 1977), and geometric stimuli (Silverman, 1974). The effects of unfamiliar stimuli on retarded processing have not been investigated fully. Maisto & Jerome (1977) and Silverman (1974) suggested that subjects should be equated for stimulus familiarity. However, no attempt was reported to determine the retarded subjects' familiarity with digits, so the introduction of the additional unknown of how subjects would cope with an unfamiliar stimulus has no empirical advantage. It certainly remains possible that retarded subjects may be less disadvantaged by stimuli composed from digits than by more abstract or complex stimuli.

(ii) Positive and negative sets can be arranged so that they are overlapping across trials in a varied set procedure or across blocks in a fixed set procedure; for example, in a varied set procedure the following presentations may occur -trial 1, positive set 3, 5, 7; trial 2, positive set 2, 4, 6, with the negative set consisting of complementary digits on each trial. Positive sets could also be nested, in a fixed set procedure (e.g. block 1, positive set 3, 5, 7; block 2, positive set 3, 5, 7, 8) or mutually exclusive, so that positive set stimuli never occur as negative set stimuli. Sternberg (1975) has indicated that effects of practice on the slope of the item recognition function are more likely to occur when sets are arranged in a nested or mutually exclusive design. Thus of the studies involving a comparison of retarded and nonretarded subjects, practice effects may have contributed to the results of Maisto & Jerome (1977) and Silverman (1974), since these experiments presented mutually exclusive and nested memory sets. Those experiments presenting digits as stimuli (Dugas & Kellas, 1974; Harris & Fleer, 1974) used overlapping positive and negative sets, an arrangement which would control for practice effects on the slope of the item recognition function, according to Sternberg (1975). None of the experiments comparing retarded and nonretarded performance has considered the effects of practice on memory performance, and the number of practice trials has varied between experiments from 16 per session (Harris & Fleer, 1974) to 96 per session (Maisto & Jerome, 1977).

(iii) The response required has also varied between experiments. Thus, Maisto & Jerome (1977) subjects' responses were verbal instead of the more widely used hand-key press. Dugas & Kellas (1974) allowed subjects to pace themselves, so that both the inter-trial and inter-item intervals could vary not only between subjects but within subjects also.

Since a major hypothesis of the Sternberg model is that a linear increase in mean RT across set size reflects scanning of items in memory, it is surprising that previous experiments have based tests of linearity on only three set sizes, or four in one case (Harris & Fleer, 1974). Sternberg (1969) demonstrated serial, exhaustive scanning with six set sizes in the varied set procedure and three in the fixed set procedure. Also, given the sensitivity of slow, normal responding to changes in procedure (Thomas et al., 1978), it would seem likely that fixed and varied set procedures need not necessarily always result in an equivalent outcome, despite suggestions to this effect by research involving only normal subjects. It is possible, for example, that retarded subjects might find a varied set procedure, where stimulus events change quickly, more difficult than a fixed set procedure. Since detailed error rates have not been reported to this time, it has not been possible to test this idea by examining results available in the literature.

2.2 EXPERIMENT 1

A detailed examination of procedural differences in previous research into memory scanning and mental retardation suggests that experimenters have made two assumptions which need to be examined:

(i) Linearity found with three of four set sizes is sufficient evidence for serial memory scanning in the retarded population. The likelihood of finding spurious differences between item recognition functions would be greater when only a few set size points are used to calculate slope, especially if the fit to a straight line is less than perfect;

(ii) The fixed set procedure, where there is only one memory set to be remembered in each block of trials, and the varied set procedure, where the size and set to be remembered are changed on each trial, are interchangeable when demonstrating memory scanning in the retarded population.

Experiment 1 is designed to examine the validity of these two assumptions. Basically it replicates previous studies which have compared retarded subjects' memory scanning with that of nonretarded subjects, but with factors which make it a more complete investigation of memory processing in retarded persons. Six memory set sizes were presented to subjects in both a fixed set procedure and a varied set procedure. The difference between retarded and nonretarded performance was of central interest, so nonretarded mental age and chronological age controls were included in the design.

2.2.1 **Method**

Design

One between-subjects variable and three within-subject variables were manipulated in a 3x2x6x2 repeated measures, nested factors design (Winer, 1971). Three groups of subjects (mentally retarded adults, nonretarded children and nonretarded adults) constituted the between-subjects variable, Group. The within-subject variables were Procedure (fixed/varied), the Set Size to be remembered (1-6 items), and Response required to the probe stimulus (yes/no).

Subjects

The three groups of ten subjects are described in Table 2.1. Retarded subjects were day workers from a sheltered workshop, selected on the basis of Performance IQ scores (Wechsler Adult Intelligence Scale) if they had normal vision and no physical disability preventing them from completing the experiment. Mental age controls were third and fourth grade primary school children selected on the basis of average reading scores for their age; each child's reading age (Schonell Reading Test) was accepted as an index of mental age. Chronological age controls were first year university students and were assumed to be of average or above average intelligence.

Apparatus

Subjects sat with index fingers on two round reaction time buttons 15cm apart, facing an ITC closed-circuit TV monitor placed at a distance of 30cm from the reaction time buttons. White numbers were presented on a dark grey background in the centre of the screen, which was at approximately eye level for all subjects. A PDP8 F computer controlled stimulus presentation and recording of all responses.

Procedure

Each subject was tested individually in at least two sessions, the fixed and varied set procedures occurring on separate days, and these being balanced for order across subjects. The dependent variable (RT) was time elapsed between the appearance of the probe item and a button press.

Half of the subjects used their dominant hand for a 'yes' response while the other half used their nondominant hand. Subjects were given a two minute rest between blocks of trials and a five minute rest halfway through the experimental session. Each session lasted approximately one hour.

GROUP	CA		MA		PIQ	
	x	sd	x	sd	x	sd
Retarded Adults (n = 10)	18-10	1-8	10-8	1-1	67	7
Nonretarded children (n = 10)	9-4	0-10	10-2	0-7	-	
Nonretarded adults (n = 10)	18-11	2-3	-			

Table 2.1: Experiment 1: Subject details, showing mean (x) and standard deviation (sd) in years and months for chronological age (CA), mental age (MA) and performance IQ (PIQ) where measured. Normal IQ has been assumed for nonretarded subjects.

Training

Initially, the subject read out loud twenty successively presented digits to ensure that these could be identified correctly. The retarded adults and nonretarded children were also given additional preliminary training sessions in which they were trained to a criterion of ten consecutive responses before qualifying to continue with the experiment. Two retarded subjects and three children failed to achieve the criterion after three sessions and did not continue in the experiment.

The initial training session consisted of seven short stages, each of which had to be completed successfully:

(i) Random sets of from one to six digits were presented at a rate of 1.5 seconds/digit with a 5 second gap between each set, and subjects were required to say "Finished" at the end of each set;

(ii) A trial consisted of one digit presented for 1.5 seconds followed by a 2 second gap, then a visual warning signal lasting for 1 second (small cross in centre of screen) then another digit. Subjects were required to say "yes" or "no" depending on whether the digit following the warning signal was the same as the one which had preceded it.

(iii) The experimenter said "yes" or "no" in random order and the subject pressed the appropriate reaction time key as quickly as possible;

(iv) Stage (ii) was repeated with subjects pressing the appropriate reaction time button instead of making a verbal response. There was an inter-trial period of 2 seconds;

(v) A trial could now consist of a set of either one digit, or two digits presented successively. Presentation of a set was followed by a gap, a warning signal and a probe digit in that order. Subjects were required to indicate whether or not the probe digit following the warning signal had been included in the preceding set;

(vi) The size of the set of digits was varied randomly from one to three across trials;

(vii) In the last stage of the training session, the varied set procedure of the experiment proper was presented, except that trials were in blocks of 10. The size of the set of digits was varied randomly from one to six across trials.

Fixed set procedure

Each subject completed practice trials in blocks of 20 until the criterion of 10 consecutive correct responses was reached. For the experimental session, there were 6 blocks, one for each set size from 1 to 6 digits. A complete set of digits was displayed for 3 minutes, followed by 30 test trials consisting of a 1-second visual warning signal (small cross in the centre of the screen), probe digit and a 2-second inter-trial interval.

Varied set procedure

A trial consisted of from one to six nonrepeating digits (the positive memory set) presented successively at a rate of 1.5 seconds per digit in the same central position on the TV monitor, followed by a 2-second gap, 1-second visual warning signal, probe digit and 2-second inter-trial interval. Thirty test trials at each of six set sizes were randomly distributed within a sequence of 180 trials which was then broken down into 6 separate blocks for the experimental session. In each block, 15 of the probe digits were from a positive set and 15 from a negative set. Within each session, the serial position of positive set probe digits was distributed as evenly as possible across all set positions.

2.3 RESULTS AND DISCUSSION

Results are presented in sections to assist interpretation of the multifactorial experiment. Additional factors of Hand used when responding, and Order in which the two procedures were completed, were controlled for experimentally but were not included in the analysis of variance model, since they were not of theoretical significance, and preliminary analysis indicated that they were not significant. The model excluding these factors is thus conservative, any effects of Hand and Order adding to the error terms within analysis of variance.

The number of errors made by each subject has been analysed to determine that the small error rate required in the Sternberg paradigm was uniform across levels of each factor. Further analysis is presented in four main sections:

(a) The effect of Procedure on mean RT was analysed firstly by a Procedure x Group x Response x Set Size analysis of variance, and secondly by examining the effect of procedure within each group separately.

(b) Any relationship in slopes and intercepts for the item recognition functions of retarded and nonretarded groups was analysed by comparing groups within each procedure separately. This method of presentation also allowed a direct comparison with previous experiments reported in the literature.

(c) If results of analyses of variance are to be interpreted in terms of the four stage model of memory retrieval, it is first necessary to demonstrate that stages are independent. The independence of the memory scanning stage from other stages was tested by correlating the slope of the item recognition function for subjects within groups with the intercept of that function.

(d) Standard deviations were analysed to determine whether group differences in variability among some groups with established short-term memory deficits were replicated here.

In the following discussions, the factors Group, Procedure and Set Size refer respectively to the three subject groups, fixed set and varied set procedures, and the six set sizes presented. The factor Response refers to the type of response required to the probe stimulus.

2.3.1 Errors

Errors were analysed in a Group x Procedure x Response x Set Size analysis of variance (see Appendix 2.1). All four main effects were significant (Group $F = 12.05$, 2/27 df, $p < 0.01$; Procedure $F = 18.94$, 1/27 df, $p < 0.01$; Response $F = 25.08$, 1/27 df, $p < 0.01$; Set Size $F = 28.36$, 5/135 df, $p < 0.01$. As can be seen in Table 2.2, the retarded group and nonretarded children made more errors than the nonretarded adults; more errors were made overall in the varied set procedure; more errors were also made overall when the response required was 'yes' (indicating a bias towards a 'no' response); and errors increased with increasing set size.

There was a significant Group x Set Size interaction ($F = 4.25$, 10/135 df, $p < 0.01$), since the retarded group made disproportionately more errors at set sizes 5 and 6 than either of the nonretarded control groups. The significant interaction between Response and Set Size ($F = 3.81$, 5/135 df, $p < 0.05$) was due to the relatively large number of errors made to positive set probes from set sizes 5 and 6.

Thus the retarded group found the varied set procedure particularly difficult, making more errors where set sizes were large than was the case for the fixed set procedure. They also made more errors overall than nonretarded children of similar mental age or nonretarded adults. All groups were biased towards responding 'no', thereby occasionally missing positive set probes, but this was most pronounced in the retarded group.

Although individual error rates were not excessive, subsequent analysis of mean RT should be qualified by the individual differences found here.

FIXED SET PROCEDURE

GROUP/ RESPONSE REQUIRED		SET SIZE 1	2	3	4	5	6	Overall
Retarded Adults	NO	0.0	1.3	2.0	0.7	6.7	2.7	2.2
	YES	4.0	0.7	0.7	4.0	7.3	16.0	5.4
Nonretarded Children	NO	0.7	0.0	1.3	1.3	4.7	4.0	2.0
	YES	0.0	4.0	2.0	6.7	6.0	10.7	4.8
Nonretarded Adults	NO	0.0	2.0	0.0	1.3	2.7	3.3	1.5
	YES	0.7	0.7	2.0	2.7	4.7	2.7	2.2
Overall		0.9	1.4	1.3	2.8	5.4	6.6	3.0

VARIED SET PROCEDURE

GROUP/ RESPONSE REQUIRED		SET SIZE 1	2	3	4	5	6	Overall
Retarded Adults	NO	2.7	0.0	2.0	6.0	7.3	10.0	4.7
	YES	1.3	3.3	5.3	9.3	20.7	24.7	10.7
Nonretarded Children	NO	1.3	2.7	2.0	2.7	4.7	6.0	3.2
	YES	1.3	4.0	4.7	6.0	9.3	13.3	6.4
Nonretarded Adults	NO	1.3	2.7	1.3	1.3	2.0	4.7	2.2
	YES	2.7	2.7	4.7	3.3	5.3	6.7	4.2
Overall		1.8	2.4	3.3	4.8	8.2	10.9	5.2

Table 2.2: Experiment 1: Mean percentage of errors for responses required to probes from each of six set sizes, for retarded adults, nonretarded children and nonretarded adults. Overall percentages are also shown.

Differences in error rate between levels of each factor pose problems for the interpretation of changes in mean RT (Pachella, 1974). However, the discussion of the possible effects of accuracy on speed has typically been in terms of a speed-accuracy tradeoff, whereas in the data presented here, groups with the higher error rates also had slower RT, and there was no evidence of a significant speed-accuracy tradeoff within groups. Therefore the error differences supplement RT analysis, providing further support for the group differences found.

2.3.2 Effects of procedure on memory scanning

Correct mean RT was analysed in a Group x Procedure x Response x Set Size analysis of variance (see Appendix 2.2). All four main effects were significant (Group $F = 13.49$, 2/27 df, $p < 0.01$; Procedure $F = 9.40$, 1/27 df, $p < 0.01$; Response $F = 8.85$, 1/27 df, $p < 0.01$; Set Size $F = 38.78$, 5/135 df, $p < 0.01$).

There was also a significant interaction between Group and Procedure ($F = 4.33$, 2/27 df, $p < 0.01$) and inspection of the profile for that interaction showed that while both control groups responded more slowly in the varied set procedure, the retarded group was equally slow in both procedures. Overall, the varied set procedure resulted in a less steep slope for the average item recognition function than the fixed set procedure, as reflected in a significant Procedure x Set Size interaction ($F = 4.00$, 5/135 df, $p < 0.01$). The significant interaction between Response and Set Size ($F = 3.60$, 5/135 df, $p < 0.01$) showed that, averaged across procedures and groups, 'no' responses produced a less steep slope than 'yes' responses.

Three interactions approached significance: the Group x Set Size interaction (Obtained $F = 1.74$, 10/135 df, critical $F = 1.90$); the Group x Procedure x Set Size interaction (Obtained $F = 1.72$, 10/135 df, critical $F = 1.90$) and the Group x Response x Set Size interaction (Obtained $F = 1.50$, 10/135 df, critical F = 1.90). Taken together, these interactions suggest group differences in slope, between procedures as well as between responses.

When the effects of Procedure, Response and Set Size were analysed within each group separately, the retarded adult and nonretarded children were found to respond differently to nonretarded adults, as illustrated in Figure 2.1.

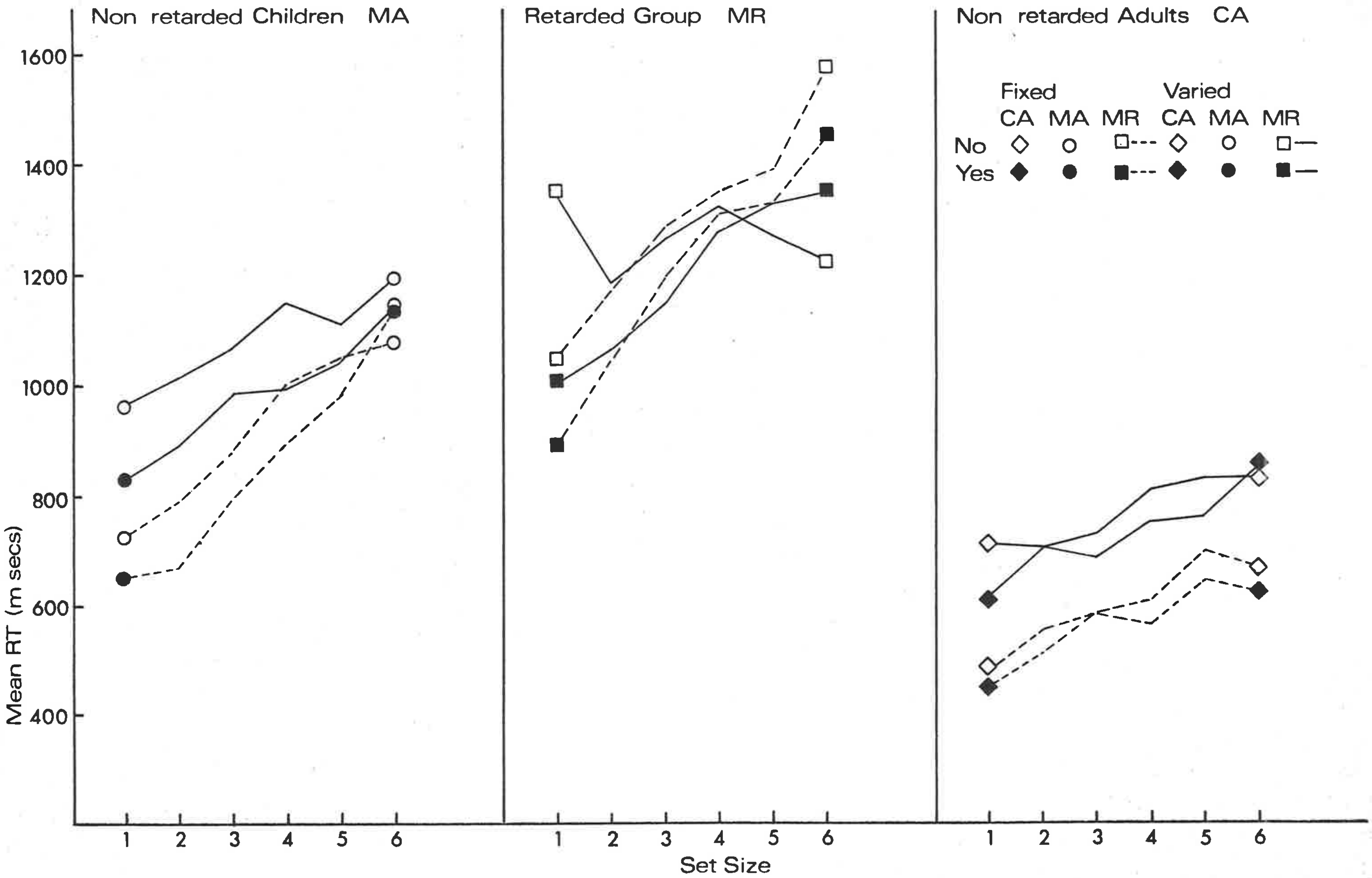
In a Procedure x Response x Set Size analysis of variance of correct mean RT within the retarded group, a significant difference between set sizes was found ($F = 8.59$, 5/45 df, $p < 0.01$), but there were no significant differences in mean RT between procedures or between responses (see Appendix 2.3). However, the interaction between Procedure and Set Size approached significance (Obtained $F = 2.39$, 5/45 df, critical $F = 2.43$), and there was a significant difference in linear trend between the two procedures ($F = 9.89$, 1/45 df, $p < 0.01$). The interaction between Response and Set Size also approached significance (Obtained $F = 2.25$, 5/45 df, critical $F = 2.43$) and averaged across procedures, there was a significant difference in linear trend between the 'yes' and 'no' responses ($F = 10.66$, 1/45 df, $p < 0.01$).

Within the group of nonretarded children, a Procedure x Response x Set Size analysis of variance showed that there were significant differences in mean RT in all three main effects (Procedure $F = 6.71$, 1/9 df, $p < 0.05$; Response $F = 19.71$, 1/9 df, $p < 0.01$; Set Size $F = 37.42$, 5/45 df, $p < 0.01$: see Appendix 2.4). There were also significant interactions between Procedure and Set Size ($F = 3.02$, 5/45 df, $p < 0.05$) and Response and Set Size ($F = 2.51$, 5/45 df, $p < 0.05$).

When mean RTs among nonretarded adults were analysed, the three main effects of Procedure, Response and Set Size were significant (Procedure $F = 10.27$, 1/9 df, $p < 0.05$; Response $F = 13.56$, 1/9 df, $p < 0.01$; Set Size $F = 19.98$, 5/45 df, $p < 0.01$: see Appendix 2.5). However, neither interactions between Procedure and Set Size nor Response and Set Size were significant.

FIGURE 2.1

Experiment 1: Profiles of mean RT per set size under fixed set and varied set procedures, for retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA). The fixed set procedure is shown in dotted lines and the varied set procedure in solid lines.



Non retarded Children MA
Retarded Group MR
Non retarded Adults CA
Fixed
Varied
CA MA MR CA MA MR
No
Yes
1600
1400
1200
1000
800
600
400
Mean RT (m secs)
1 2 3 4 5 6
Set Size

Therefore, while the two control groups responded overall more slowly in the varied set procedure than the fixed set procedure, the retarded group responded very slowly in both procedures. Separate analyses of each group showed that both the retarded adults and nonretarded children responded differently from nonretarded adults to the two procedures. However, the patterns of responding were not the same within these two groups. Inspection of the profiles for the Procedure x Set Size interaction for the two groups showed that while the responses of nonretarded children were characterised by a slightly less steep slope in the varied set procedure than the fixed set procedure, the retarded group exhibited markedly different patterns of responding between the two procedures. Furthermore, while the significant interaction between Response and Set Size was due mainly to different responding at set sizes 5 and 6 among nonretarded children, a similar explanation did not hold for the retarded group, where the Response x Set Size interaction was due to the irregular function for 'no' responses in the varied set procedure.

2.3.3 Group differences in memory scanning and response strategy

In Sternberg's model of memory retrieval, serial memory scanning is reflected in significantly linear item recognition functions, and exhaustive scanning is assumed to occur when 'yes' and 'no' responses are parallel. However, as can be seen in Figure 2.1, 'no' responses for the retarded group under the varied set procedure were not linear across set size. While mean RTs for 'no' responses at set sizes 2, 3 and 4 followed the slope expected from the varied set 'yes' function, mean RT to a set size of one item was very slow, and mean RTs to set sizes of 5 and 6 were faster than expected. Thus, when each set of data points in Figure 2.1 was tested for linearity, all were found to have a significant linear trend, apart from the retarded group's 'no' responses in the varied set procedure (see Appendix 2.6).

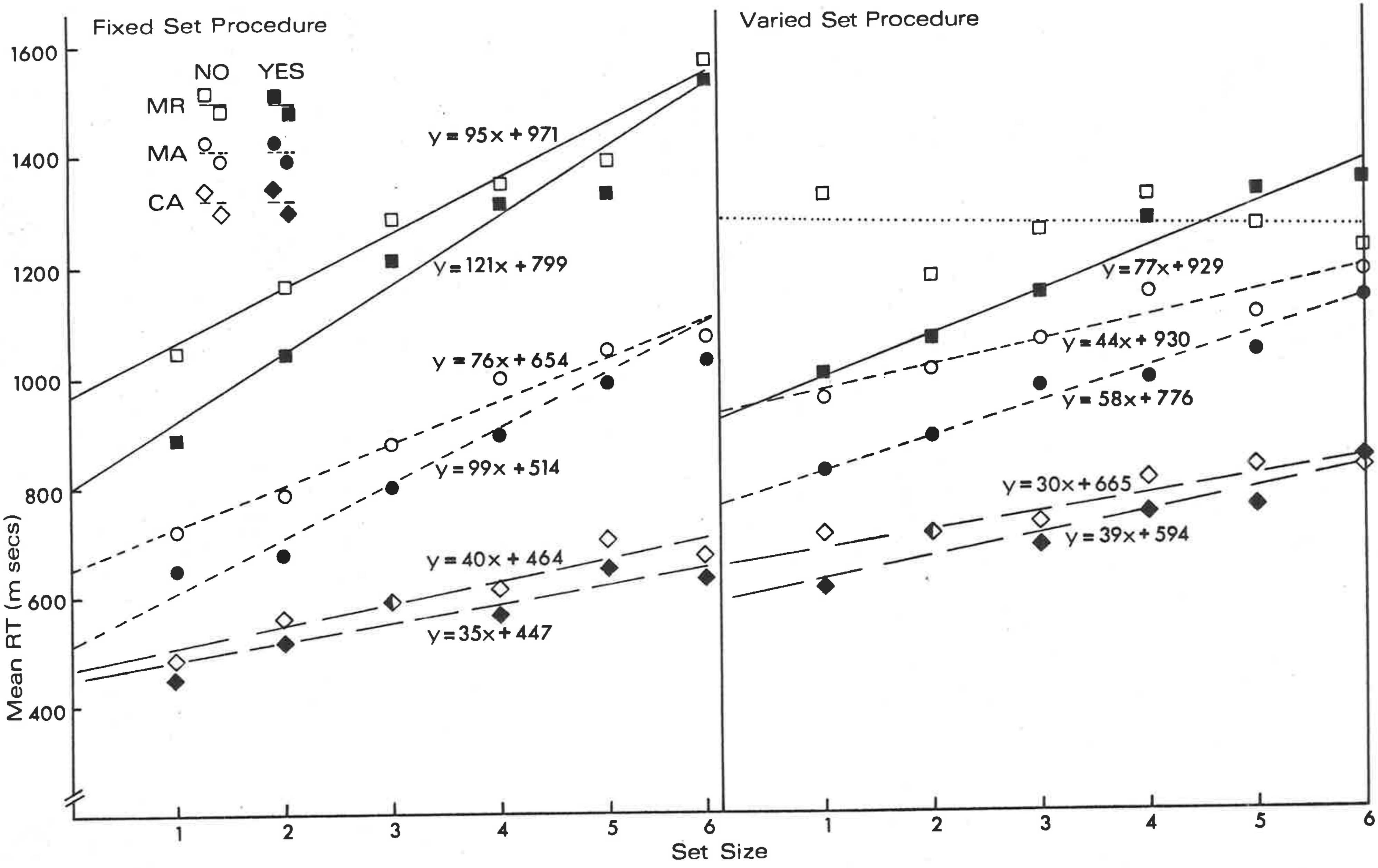
Figure 2.2 shows best fitting straight lines for each group's 'yes' and 'no' responses. Partition into the two procedures enables a direct comparison between the present results and previous studies which have only used one procedure to analyse individual differences in memory scanning. Slopes and intercepts were estimated for the regression equation for each subject's item recognition function. The nonlinear 'no' varied set data found for the retarded group were not included in the analysis of slopes and intercepts, which are assumed to reflect respectively speed of memory scanning and other mental operations when the item recognition function is linear.

When slopes and intercepts of item recognition functions obtained from nonretarded children and adults (the two control groups) were analysed, there was a significant difference between group slopes ($F = 17.05$, 1/18 df, $p < 0.01$: see Appendix 2.7), the children having a steeper slope than adults. There was also a significant difference for Procedure ($F = 6.92$, 1/18 df, $p < 0.05$) and a significant Group x Procedure interaction ($F = 4.83$, 1/18 df, $p < 0.05$), confirming the mean RT analysis in which it was shown that nonretarded children produced a less steep slope in the varied set procedure than in the fixed set procedure, while the slope among nonretarded adults was the same for both procedures. However, there were no main effects or interactions involving the Response factor, indicating that these two groups responded in a similar manner for 'yes' and 'no' responses. Sternberg (1969) interpreted a similar finding for normal adults as evidence for the use of a serial, exhaustive scanning strategy.

Analysis of zero intercepts for item recognition functions indicated that the nonretarded children had a higher zero intercept than nonretarded adults ($F = 4.35$, 1/18 df, $p < 0.05$: see Appendix 2.8), and that the varied set procedure resulted in a higher zero intercept overall than the fixed set procedure ($F = 23.74$, 1/18 df, $p < 0.01$). These results are in agreement with previous studies which have found higher intercepts for children than for

FIGURE 2.2

Experiment 1: Item recognition functions of retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA) showing 'yes' and 'no' responses under fixed set and varied set procedures. The 'no' response function of retarded adults' data from the varied set procedure was not significantly linear.



Fixed Set Procedure
Varied Set Procedure
NO
YES
MR
MA
CA
y = 95x + 971
y = 121x + 799
y = 76x + 654
y = 99x + 514
y = 40x + 464
y = 35x + 447
y = 77x + 929
y = 44x + 930
y = 58x + 776
y = 30x + 665
y = 39x + 594
1600
1400
1200
1000
800
600
400
Mean RT (m secs)
1
2
3
4
5
6
Set Size

adults (e.g. Hoving et al., 1970), and that the varied set procedure generally leads to higher zero intercepts than the fixed set procedure (Sternberg, 1969). There was also a significant Response effect ($F = 19.22$, 1/18 df, $p < 0.01$) and a significant Group x Response interaction ($F = 5.50$, 1/18 df, $p < 0.05$), due to 'no' responses being slower than 'yes' responses, and the difference between these being greater for nonretarded children than for nonretarded adults.

Under the fixed set procedure all three groups exhibited near-parallel 'yes' and 'no' functions, as reflected in the statistically insignificant Response effect in the analysis of slopes (see Appendix 2.9). There was, however, a significant difference between Groups ($F = 4.06$, 2/27 df, $p < 0.01$), attributable to a significant difference between retarded adults' and nonretarded adults' slopes (Newman-Keuls analysis). This outcome therefore indicates a gradation of slopes from nonretarded adults to nonretarded children to retarded adults. Analysis of zero intercept showed a significant difference between groups ($F = 6.11$, 2/27 df, $p < 0.01$), attributable to the retarded group zero intercepts being significantly higher than those for either control groups (Newman-Keuls analysis), and also between Responses ($F = 8.60$, 1/27 df, $p < .0.01$: see Appendix 2.10).

Thus the analysis of group differences indicated that the response profiles of nonretarded children were characterized by both a steeper slope and a higher zero intercept than was the case among nonretarded adults. The performance of children was also different to that of nonretarded adults, in that the average item recognition function obtained under a varied set procedure had a flatter slope as well as a higher intercept than was found under a fixed set procedure. The performance of retarded adults, on the other hand, led to both a steeper slope and a higher zero intercept than was found for either of the two control groups. However, the most noticeable effect among retarded subjects was the marked qualitative difference in responding between the fixed set and the varied set procedures.

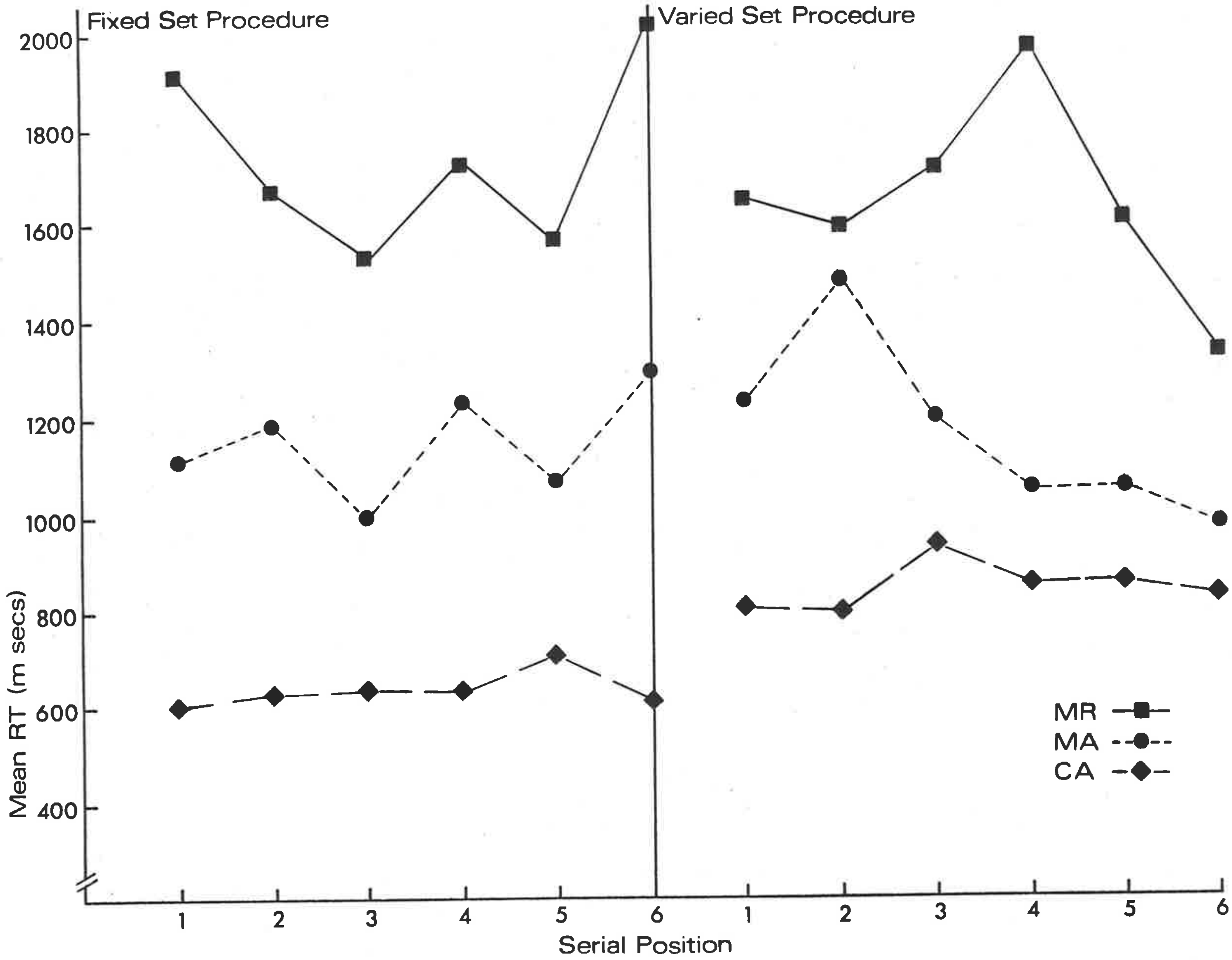
2.3.4 Independence of processing stages

Data from the recognition paradigm used here can be interpreted in terms of the four stage model first proposed by Sternberg (1969) if two main characteristics are present: firstly, evidence supporting serial exhaustive memory scanning and secondly, evidence that this stage is independent from other mental operations.

An explanation in terms of a serial exhaustive comparison of the probe item with the positive memory set has been suggested where the item recognition RT function increases linearly at the same rate across set size for both positive and negative responses. In this study, this requirement was met by nonretarded adults and nonretarded children in both procedures, but not by the retarded group under the varied set procedure. A concomitant implication of exhaustive scanning is that RT should not vary systematically with the serial position of the probe item in the memory set. Therefore, as a further test of exhaustive scanning, mean RTs to probe items from a positive memory set of six items were broken down according to the serial position which the probe item held in the set. Separate analysis of data for each group under both fixed and varied procedures showed that there was a significant effect of serial position in the responses of nonretarded children under the varied set procedure ($F = 4.02$, 5/39 df, $p < 0.01$), whereas significant serial position effects were not obtained for other groups (see Appendix 2.11). However, Figure 2.3 shows that while serial position curves among nonretarded adults were virtually flat, those for nonretarded children and retarded adults exhibited considerable variation in RT between positions. Data for these two groups under the varied set procedure suggested a recency effect, while data from the fixed set procedure suggested that central positions may have been searched first, followed by end positions. These results therefore provide further evidence for processing differences between

FIGURE 2.3

Experiment 1: mean RT to a positive probe from each serial position in a memory set size of six items, for retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA).



Fixed Set Procedure
Varied Set Procedure
Mean RT (m secs)
2000
1800
1600
1400
1200
1000
800
600
400
1
2
3
4
5
6
1
2
3
4
5
6
Serial Position
MR
MA
CA

nonretarded adults and the other two groups, and for a difference in both the two younger mental age groups for performance under the fixed set and varied set procedures.

Independence of processing stages was tested by correlating the item recognition function parameters of slope (assumed to represent the serial comparison stage) and zero intercept (assumed to represent the sum of the remaining three stages). For the retarded group slopes and intercepts were significantly negatively correlated. Among nonretarded adults, slopes and intercepts for the 'no' responses under the varied set procedure were also significantly negatively correlated. These results are shown in Table 2.3.

Thus an interpretation of the retarded group's results in terms of the Sternberg model of retrieval has to be reserved on the basis of three main outcomes. Firstly, negative response functions under the varied set procedure were not linear overall, so that a qualitatively different strategy may have been used by retarded subjects for this condition, both compared with their own performance in the fixed set procedure, and compared with the performance of nonretarded adults and children throughout. Secondly, the examination of serial position effects suggested possible strategic differences between retarded and nonretarded adults. Thirdly, processing stages could not be considered independent, even though additive effects were found in the analysis of mean RT, since Sternberg's (1969) model requires independence between stages as well as additivity of parameters.

2.3.5 Variability of RT

Examination of the item recognition functions of individual subjects revealed a great deal of variation between retarded subjects' data, both in the direction and size of the slope, and the percentage of variance accounted for by a linear regression. Overall, retarded subjects responded with more variability than nonretarded control subjects. However, greater variability in

	PROCEDURE			
	FIXED		VARIED	
GROUP/RESPONSE	NO	YES	NO	YES
MR (Retarded adults)	-0.82**	-0.68*	-0.89**	-0.13
MA (Nonretarded children)	-0.12	-0.06	-0.45	+0.34
CA (Nonretarded adults)	-0.44	-0.12	-0.70*	-0.03

Table 2.3: Experiment 1: Within group correlation (n = 10) of slope and intercept from each subject's item recognition function.

** $p < 0.01$ (two tailed)

* $p < 0.05$ (two tailed)

RT could not explain the retarded group's performance in the varied set procedure, since analysis of measures of standard deviation established that there was greater variability in the retarded group's performance when compared with nonretarded controls in both procedures (see Appendix 2.12).

To reduce variability differences between groups, further analyses excluded trials where RT was greater than 1500 msecs, on the basis that these very long times would not reflect the same kind of processing as shorter RTs. This adjustment was mainly confined to the retarded group. Of the remaining trials, those exceeding $\pm$ 1.96 standard deviations from the lowered mean were excluded as well. However, analyses on the mean RT of remaining data confirmed all of the main characteristics of the analyses presented above, so that the additional variability associated with slower responding did not invalidate the group differences found or the patterns of results described (see Appendix 2.13). A considerable proportion of retarded subjects' data was excluded from this analysis, which nevertheless demonstrated the robustness of results, even with this proviso.

In summary, the main outcomes of the present experiment were:

(i) A significant difference between performances under the fixed and varied set procedures among retarded adults and nonretarded children, while nonretarded adults responded similarly under the two procedures;

(ii) While 'yes' or 'no' responses could be combined in the item recognition functions found for nonretarded control groups, the retarded group responded differently to positive and negative set probes in the varied set procedure, where 'no' responses for the group overall were neither linear, nor increasingly slower across set size;

(iii) Within both the fixed and varied set procedures, there was an increasing gradation in the steepness of the slope of item recognition functions from nonretarded adults to nonretarded children to retarded adults;

(iv) Performance within the retarded group could not be characterized by discrete processing stages in terms of Sternberg's model, since the slope and intercept of item recognition functions in both procedures were significantly negatively correlated.

A number of methodological factors were checked when accounting for these results. Firstly, the error differences between procedures and groups were substantial enough to produce significant effects in multifactorial analysis of variance. However, the large numbers of errors to positive probes did not contribute to the nonlinearity of the retarded group's performance under the varied set procedure, since when mean RT was adjusted for the number of errors made by analysis of covariance, there was still no significant linear trend to 'no' responses of the item recognition function for the retarded group. Differences between positive and negative responses were inflated by the bias towards negative responses, but removing this bias did not remove the other significant main effects of Group and Set Size or the interactions between Response and Set Size. Therefore, retarded group responding cannot be attributed solely to making more errors than were made among nonretarded subjects in the two control groups.

Secondly, there was no evidence of increased errors towards the end of each block of trials, so that the number of trials within a block did not produce fatigue effects in the retarded group. Finally, the inter-trial interval of two seconds was sufficiently long not to cause interference effects between memory sets of one trial and the next (Baumeister and Kellas, 1968). If subjects had not had sufficient time to clear a short-term store of material before the next memory set was presented, then the build-up of material would have resulted in an increase of false positive errors - i.e., the opposite to the present finding of more misses than false positives.

Thus, the present experiment has shown that when retarded adults use memory sets larger than four items, qualitatively different responding occurs to that found among nonretarded subjects. It has also been shown that both retarded adults and their nonretarded mental age controls respond differently under a fixed set and a varied set procedure.

2.4 EXPERIMENT 2

Linear item recognition functions were obtained in Experiment 1 for up to six positive set items from all three groups under a fixed set procedure, but only for nonretarded children and adults only under a varied set procedure. Moreover, the relatively high error rates among all subjects in Experiment 1 meant that between-group comparisons were made under less than optimal conditions. Since error rates were higher than those specified by Sternberg (1975), especially in memory sets of 5 and 6 items, Experiment 2 was undertaken to test the replicability of the previous findings, but under conditions in which only smaller sets were presented. Thus, the experimental design and apparatus were identical to those for Experiment 1, with the exception that only four positive memory sets (1, 2, 3 or 4 items) were presented in an attempt to reduce the number of errors made.

2.4.1 Method

Subjects

Three groups of ten subjects again consisted of mildly retarded adults, nonretarded children of a comparable mental age, and chrononological age controls as described in Table 2.4. Retarded subjects were selected on the basis of full scale WAIS IQ scores between 50 and 70, chronological age between 17 and 25 years, normal vision and no physical disability which would prevent them from completing the experimental task. Populations from which subjects were drawn were the same as for Experiment 1.

GROUP/RESPONSE	CA		MA		IQ	
	x	sd	x	sd	x	sd
Retarded Adults (n = 10)	19-6	1-7	10-3	0-11	65	6
Nonretarded Children (n = 10)	9-10	0-1	9-6	0-10	-	-
Nonretarded Adults (n = 10)	18-10	6-6	-	-	-	-

Table 2.4: Experiment 2: Subject details showing mean (x) and standard deviation (sd) in years and months of chronological age (CA), mental age (MA) and full scale IQ where measured. Normal IQ has been assumed for nonretarded subjects.

Procedure

The same balance for order of procedures, probability of a 'yes' probe and response, position of the positive probe within the set and handedness of subjects was followed as was the case in Experiment 1. Mentally retarded adults and mental age control subjects again received additional preliminary training.

In the fixed set procedure, one memory set from each of four set sizes was presented at the beginning of a block of 36 trials. In the varied set procedure, 36 sets of digits at each of 4 set sizes were randomized to make a sequence of 144 trials, in which the size and set to be remembered changed after each trial. Seventy-two trials required a 'yes' response, and subjects received 6 blocks of 24 trials each.

2.5 RESULTS AND DISCUSSION

2.5.1 Errors

Reduction in the maximum number of items to be remembered reduced overall error rate when results were compared with those from Experiment 1. Exclusion of memory sets with 5 and 6 items resulted in retarded adults performing with low error rates in both fixed and varied set procedures. As shown in Table 2.5, error rates were less than 2% overall. A Procedure x Group x Response x Set Size analysis of variance found significant main effects for Procedure, Response and Set Size (Procedure $F = 4.57$, 1/27 df, $p < 0.05$; Response $F = 15.69$, 1/27 df, $p < 0.01$; Set Size $F = 3.38$, 3/81 df, $p < 0.05$; see Appendix 2.14). However, there was no significant difference in error rate between the three groups. As can be seen in Table 2.5, more errors were made overall in the varied set procedure than in the fixed set procedure, there were more errors to positive probes than negative and, overall, errors increased with increasing Set Size. The significant interaction between Procedure and Set Size ($F = 3.66$, 3/81 df, $p < 0.05$) was due to the

FIXED SET PROCEDURE

GROUP/ RESPONSE REQUIRED		SET SIZE 1	2	3	4	Overall
Retarded Adults	NO	0.6	0.0	0.6	0.0	0.3
	YES	0.6	1.1	5.0	1.1	1.9
Nonretarded Children	NO	0.6	0.6	0.0	0.6	0.3
	YES	0.6	0.6	0.2	0.0	0.8
Nonretarded Adults	NO	0.6	0.6	0.0	0.6	0.4
	YES	0.0	0.0	1.1	2.2	0.8
Overall		0.5	0.5	1.5	0.8	0.8

VARIED SET PROCEDURE

GROUP/ RESPONSE REQUIRED		SET SIZE 1	2	3	4	Overall
Retarded Adults	NO	0.0	0.0	0.0	1.6	0.4
	YES	1.1	1.1	1.6	7.2	2.8
Nonretarded Children	NO	2.2	0.0	0.0	1.7	1.0
	YES	1.1	1.7	1.1	2.8	1.7
Nonretarded Adults	NO	1.1	0.6	0.6	1.1	0.8
	YES	1.1	0.6	3.3	1.7	1.7
Overall		1.1	0.7	1.1	2.7	1.4

Table 2.5: Experiment 2: Mean percentage of errors for responses required to probes from each of four set sizes, for retarded adults, nonretarded children and nonretarded adults. Overall percentages also shown.

relatively large number of errors made at a set size of 4 under the varied set procedure, and the profile of the significant Group x Procedure x Set Size interaction ($F = 2.88$, 6.81 df, $p < 0.05$) showed that it was mainly the retarded group who made more errors at a set size of 4 than at other set sizes. The significant interaction between Response and Set Size ($F = 3.59$, 3/81 df, $p < 0.05$) was due to more errors being made to positive set probes than to negative set probes at larger set sizes.

Thus, although a similar pattern of error differences to that found in Experiment 1 was found here, error rates were lower and comparable to those reported by Sternberg (1969). While the most errors were again made by the retarded group to positive set probes in the varied set procedure, there was no significant difference between groups in errors made, so that group differences in RT should be attributable to factors other than accuracy.

2.5.2 Effects of procedure on memory scanning

Correct mean RT was analysed in a Group x Procedure x Response x Set Size analysis of variance. All four main effects were significant (Group $F = 9.59$, 2/27 df, $p < 0.01$; Procedure $F = 25.16$, 1/27 df, $p < 0.01$; Response $F = 45.57$, 1/27 df, $p < 0.01$; Set Size $F = 59.96$, 3/81 df, $p < 0.01$: see Appendix 2.15).

The profile of a significant interaction between Group and Response ($F = 4.97$, 2/27 df, $p < 0.05$) showed that there was a greater difference in RT between 'yes' and 'no' responses for the retarded group than for either of the nonretarded control groups. Inspection of the profile for the significant Procedure x Set Size interaction ($F = 6.59$, 3/81 df, $p < 0.01$) showed that while the varied set procedure resulted in slower responding than the fixed set procedure, it also resulted in flatter mean slopes in the item recognition functions. There was also a significant Response x Set Size interaction ($F = 3.60$, 3/81 df, $p < 0.05$) indicating that slopes for 'yes' and 'no' responses were not parallel when averaged across Group and Procedure.

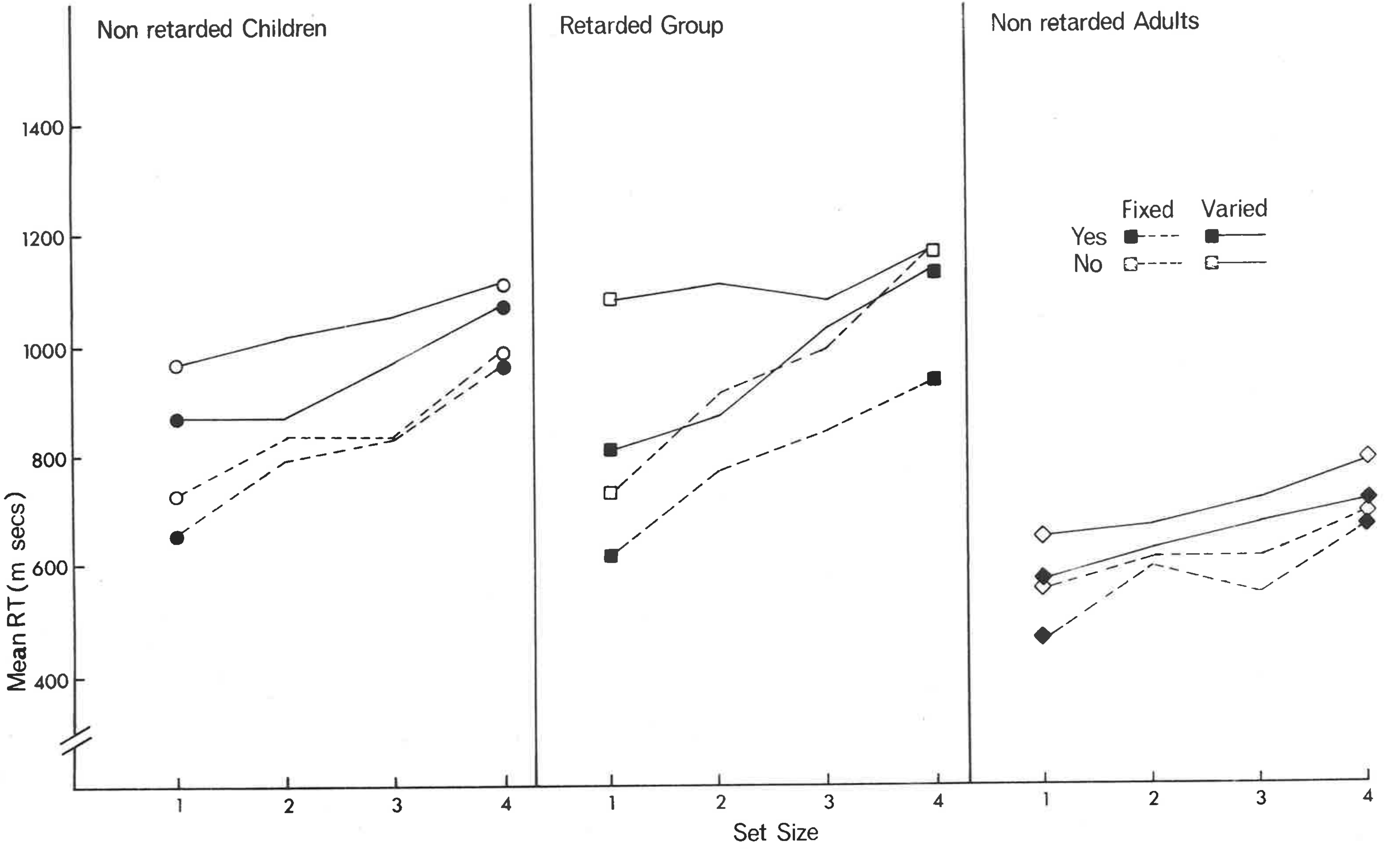
Three interactions approached significance; Group x Set Size (Obtained $F = 2.09$, 6/81 df, critical $F = 2.21$); Group x Procedure x Set Size (Obtained $F = 2.01$, 6/81 df, critical $F = 2.21$), and Procedure x Response x Set Size (Obtained $F = 2.15$, 3/81 df, critical $F = 2.72$). There was also a significant higher order interaction between Group, Procedure, Response and Set Size ($F = 3.14$, 6/81 df, $p < 0.01$). These effects may all be attributed to the mean item recognition function for 'no' responses obtained from the retarded group under the varied set procedure. As may be seen in Figure 2.4, this function was flattened by disproportionately slow RTs when set sizes were small. Together, these trends were compatible with the results of Experiment 1.

Groups were analysed separately using three-way Procedure x Response x Set Size analyses of variance. Within the retarded group, all three main effects were significant (Procedure $F = 12.68$, 1/9 df, $p < 0.01$; Response $F = 25.11$, 1/9 df, $p < 0.01$; Set Size $F = 18.86$; 3/27 df, $p < 0.01$: see Appendix 2.16). There was a significant interaction between Procedure and Set Size ($F = 4.74$, 3/27 df, $p < 0.01$) due to the slope of the mean item recognition function being flatter under the varied set procedure than under the fixed set procedure when RT was averaged across Response. The interaction of Procedure, Response and Set Size was also significant ($F = 3.65$, 3/27 df, $p < 0.05$) due to the relatively flat function for 'no' responses in the varied set procedure.

Within the group of nonretarded children, a Procedure x Response x Set Size analysis of variance found significant main effects for all three factors (Procedure $F = 8.03$, 1/9 df, $p < 0.05$; Response $F = 6.49$, 1/9 df, $p < 0.05$; Set Size $F = 22.11$, 3/27 df, $p < 0.01$: see Appendix 2.17). The Procedure x Set Size interaction also approached significance ($F = 2.22$, 3/27 df, critical $F = 2.96$), and there was a significant difference in linear trend between the two levels of Response in the Response x Set Size interaction ($F = 4.28$, 1/27 df, $p < 0.05$).

FIGURE 2.4

Experiment 2: Profiles of mean RT per set size under fixed set and varied set procedures, for retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA).



Non retarded Children
Retarded Group
Non retarded Adults
1400
1200
1000
800
600
400
Mean RT (m secs)
Fixed
Varied
Yes
No
1
2
3
4
1
2
3
4
1
2
3
4
Set Size

The analysis of mean RT for nonretarded adults established significant main effects for Procedure ($F = 5.33$, 1/9 df, $p < 0.05$), Response ($F = 28.17$, 1/9 df, $p < 0.01$) and Set Size ($F = 35.73$, 1/9 df, $p < 0.01$). This analysis is set out in Appendix 2.18. There were also significant interactions between Procedure and Set Size ($F = 4.08$, 3/27 df, $p < 0.05$) and Response and Set Size ($F = 2.99$, 3/27 df, $p < 0.05$) caused by digression from linearity by 'yes' responses under the fixed set procedure. However, despite the poor fit to a straight line in this instance, similar linear trends were obtained for both fixed and varied set procedures and for both positive and negative responses across set sizes.

These results therefore confirm the findings of Experiment 1, that retarded adults and nonretarded children respond differently to nonretarded adults under the two procedures. Nonretarded children once again produced item recognition functions with a slightly flatter slope in the varied set procedure than in the fixed set procedure. The negative responses of retarded adults to probe items from small set sizes in the varied set procedure were very slow, resulting in flat item recognition functions for 'no' responses under that procedure.

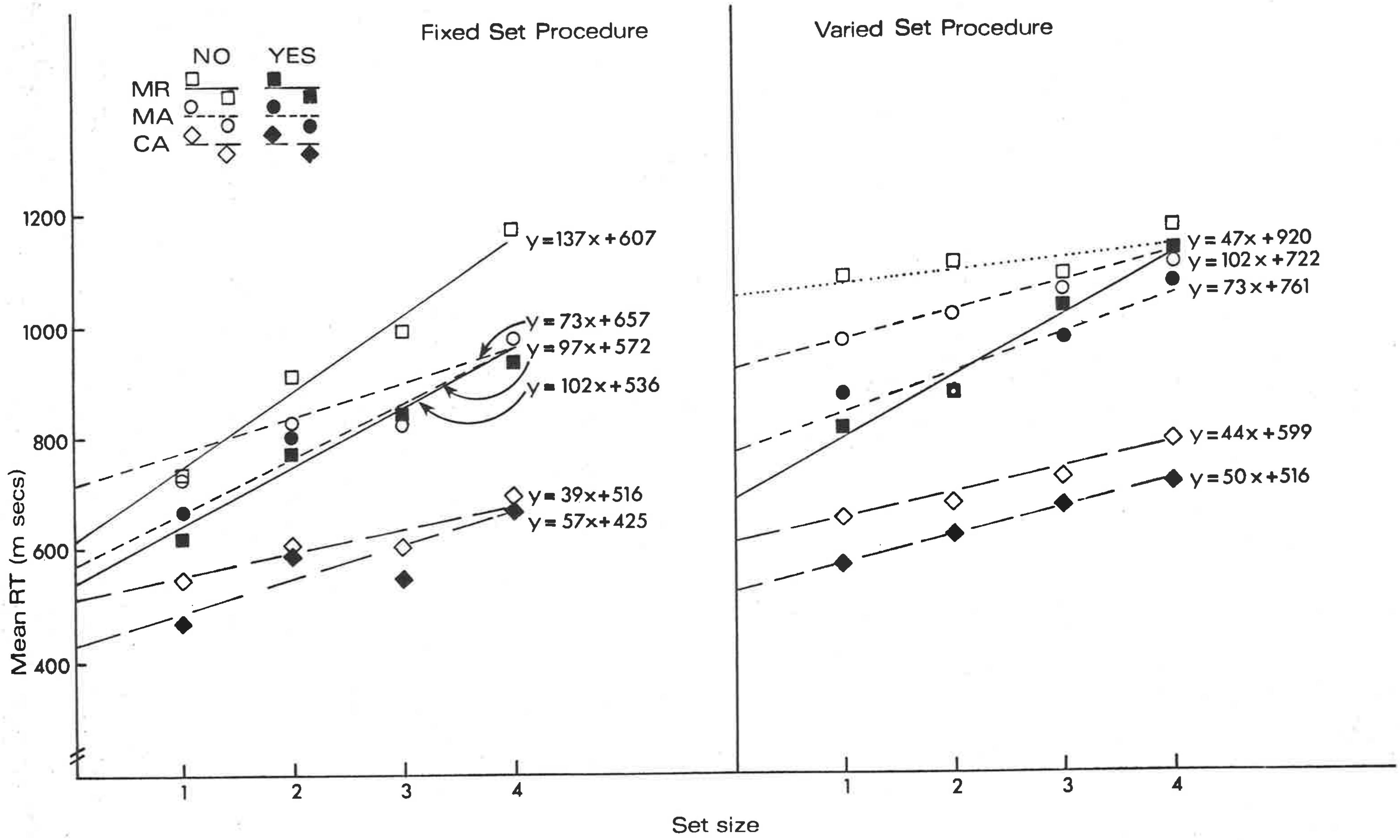
2.5.3 Group differences in memory scanning and response strategy

Item recognition function for each group in Figure 2.5 showed a significant linear trend, with the exception of the retarded group's function for 'no' responses under the varied set procedure (see Appendix 2.19).

Slopes and intercepts for item recognition functions were calculated on the best fitting straight line for each subject's data. An analysis of slopes (Group x Response x Procedure) for nonretarded adults and children found no significant difference in slope between these groups, although as may be seen in Figure 2.5, there did appear to be a trend towards a more steep slope among children. There was a significant main effect for Response ($F = 5.47$,

FIGURE 2.5

Experiment 2: Item recognition functions of retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA) showing 'yes' and 'no' responses under fixed set and varied set procedures. The 'no' response function of retarded adults' data from the varied set procedure was not significantly linear.



Fixed Set Procedure
Varied Set Procedure
NO
YES
MR
MA
CA
y=137x+607
y=73x+657
y=97x+572
y=102x+536
y=39x+516
y=57x+425
y=47x+920
y=102x+722
y=73x+761
y=44x+599
y=50x+516
1200
1000
800
600
400
Mean RT (m secs)
1
2
3
4
Set size

1/18 df, $p < 0.05$: see Appendix 2.20), due to 'no' responses producing a somewhat flatter function than 'yes' responses, when averaged across Procedure. As can be seen in Figure 2.5, this effect was mainly found for the fixed set procedure.

Analysis of zero intercepts among nonretarded controls found significant main effects for Group ($F = 12.69$, 1/18 df, $p < 0.01$), Response ($F = 15.29$, 1/18 df, $p < 0.01$) and Procedure ($F = 11.89$, 1/18 df, $p < 0.01$). This analysis is to be found in Appendix 2.21. Thus, zero intercepts were higher among nonretarded children than among nonretarded adults, the varied set procedure resulted in a higher intercept than the fixed set procedure for both groups, and 'no' responses were significantly slower than 'yes' responses.

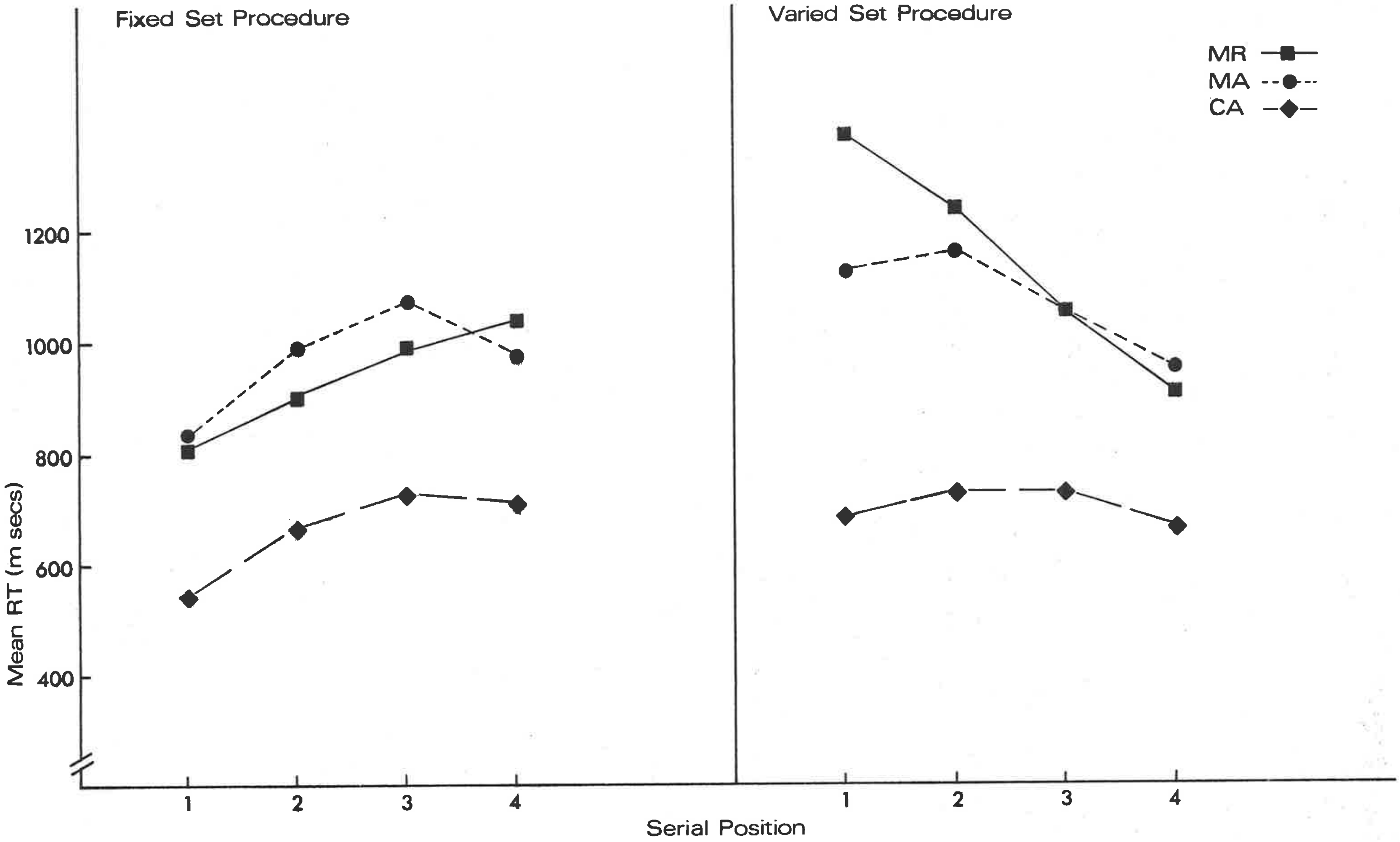
Analysis of slopes under the fixed set procedure showed a significant difference between group slopes ($F = 4.78$, 2/27 df, $p < 0.01$: see Appendix 2.22). This was due to a significant difference between retarded and nonretarded adults (Newman-Keuls analysis), confirming the results of Experiment 1 in which a gradation of increasing slopes was found from nonretarded adults to nonretarded children to retarded adults. Analysis of zero intercepts under the fixed set procedure revealed only a significant difference between 'yes' and 'no' responses, the latter being slower ($F = 20.60$, 1/27 df, $p < 0.01$; see Appendix 2.23), although separate analysis of data for the two control groups established that the difference between intercepts found for nonretarded children and nonretarded adults was significant.

2.5.4 **Independence of processing stages**

Analysis of serial position effects on probe items from a set size of 4 indicated that data for all groups showed position effects that were statistically significant or approaching significance (see Appendix 2.24). As can be seen in Figure 2.6, there was a trend in the fixed set procedure for mean RT to increase with serial position of the test probe, while the opposite occurred

FIGURE 2.6

Experiment 2: Mean RT to a positive probe from each serial position in a memory set size of four items, for retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA).



Fixed Set Procedure
Varied Set Procedure
MR
MA
CA
Mean RT (m secs)
1200
1000
800
600
400
1
2
3
4
Serial Position

in the varied set procedure. This outcome therefore confirmed the serial position effects found in Experiment 1, where similar differences between procedures were also found for retarded adults and nonretarded children. Serial position effects were most prominent in the performance of the retarded group under the varied set procedure, where there were obvious recency effects.

That recency effects occurred under the varied set procedure and primacy effects under the fixed set procedure, suggests differences in rehearsal strategies used between the two procedures, especially in the case of the retarded and nonretarded younger mental-age groups. In the fixed set procedure, where only one set size is tested over a number of trials, a disproportionate amount of rehearsal may be accorded to the first digit of the set (Atkinson & Shiffrin, 1978), whereas in the varied set procedure, subjects may forget digits from the beginning of the list.

Independence of processing stages was tested by correlating the slope and zero intercept of item recognition functions for individual subjects within each group. These correlations are set out in Table 2.6, where it can be seen that for the present experiment, data from nonretarded children correlated significantly, while those for the retarded group did not.

Thus, the conclusions of Experiment 1, that retarded adults and nonretarded children have responded differently to nonretarded adults and have been influenced differently by a fixed set procedure when compared with the varied set procedure, have been supported by the present experiment. Once again, we have evidence for nonlinearity of item recognition functions, differences in serial position effects and significant negative correlations between parameters hypothesized to represent separate processing stages.

	PROCEDURE			
	FIXED		VARIED	
GROUP/RESPONSE	NO	YES	NO	YES
MR (Retarded adults)	-0.32	+0.08	-0.51	-0.31
MA (Nonretarded children)	-0.66*	-0.64*	-0.62*	-0.12
CA (Nonretarded adults)	-0.46	-0.55	+0.24	+0.16

Table 2.6: Experiment 2: Within group correlation (n = 10) of slope and intercept from each subject's item recognition function.

* $p < 0.05$ (two tailed)

2.5.5 **Variability of RT**

Analysis of standard deviations found that both retarded adults and nonretarded children were more variable in RT under the varied set procedure than under the fixed set procedure. This difference was not so marked among nonretarded adults (see Appendix 2.25). However, when long RTs were excluded from analysis, following the same procedure outlined above for data in Experiment 1, there was no change in the pattern of results presented here (see Appendix 2.26).

In summary, the present experiment has largely replicated the results found in Experiment 1, although there were some inconsistencies. However, even when small set sizes were used, there was some difference apparent in the processing of retarded adults under fixed and varied set procedures, a result common to both experiments. While the analysis of mean RT and the slopes for item recognition functions indicated no difference in the search rate of nonretarded children under fixed and varied set procedures, serial position effects raised doubts about this conclusion, suggesting that such differences may exist for this group as well. Nonretarded adults responded in a manner similar to that reported for Experiment 1 and in previous studies. Some "noisiness" in their data under the fixed set procedure produced a significant interaction between Response and Set Size, but as can be seen in Figure 2.4, the interaction profile is unlike that of retarded adults, where functions for 'no' responses were quite different to those for 'yes' responses under the varied set procedure. In both experiments, a gradation of increasing slope was found in the item recognition functions under each procedure - from nonretarded adults to nonretarded children to retarded adults. However, significant negative correlations between the slope and intercept of the item recognition function for the nonretarded children in this experiment, and for retarded adults in Experiment 1, suggested that the slope of the functions for these groups did not necessarily represent a separate stage of memory search.

2.6 GENERAL DISCUSSION

A number of differences have been found between the three groups studied in these experiments. The phenomenon of memory scanning as proposed by Sternberg seems fairly robust in nonretarded adult subjects, who performed consistently in the two experiments presented in this chapter. An interpretation of the performance of retarded adults and nonretarded children is more limited, however, since the assumptions of additivity and independence of stages upon which the memory scanning model is based can apparently only be met under quite restricted conditions.

Data obtained for nonretarded children are in agreement with previous developmental studies which have indicated that search rate may increase with age (Hermann & Landis, 1977; Keating et al., 1980), conflicting with data which have indicated that search rate is constant as mental age increases (Harris & Fleer, 1974; Hoving et al., 1970). The search rates estimated for nonretarded children in the present experiments are much higher than those reported for previous studies, in which nonretarded children of a similar mental age to participants here have responded with search rates comparable to those found among nonretarded adults (Dugas & Kellas, 1974; Harris & Fleer, 1974; Hoving et al., 1970; Maisto & Baumeister, 1975). The results from several of such studies are summarized in Table 2.7. However, the requirements of Hoving et al. (1970), that subjects respond within 0.85 seconds of the probe stimulus being presented, may have led to artificially depressed reaction times in that study. Error rates were also higher among children than among adults in that study (12% and 10% for kindergarten and fourth grade primary school children compared with 5% for tertiary college students). Hermann & Landis (1977) cite Banks & Atkinson's (1974) finding that 'reward' in the form of a light providing information about performance diminished the search rate of adults. This may be relevant to the low search rates found by Hoving et al. (1970), where subjects only received such feedback if they responded correctly within the required time.

NONRETARDED SUBJECTS Experimenter	Mental Age (yrs)	Chron. Age (yrs)	Slope (msecs/ item)	Inter-cept (msecs)	Pro-cedure
Hoving, Morin & Konick (1970)		4.0	30	670	F
Maisto & Baumeister (1975)		5.5	38	935	F
Herman & Landis (1977)		7.3	223	895	F
Silverman (1974)		7.5	136	756	F
Maisto & Baumeister (1975)		8.5	39	838	F
Harris & Fleer (1974)		8.5	42	688	V
Hoving et al. (1970)		9.0	30	500	F
Dugas & Kellas (1974)		10.5	45	1224	V
Maisto & Baumeister (1975)		10.5	49	689	F
Silverman (1974)		11.0	101	518	F
Herman & Landis (1977)		12.5	84	621	F
Maisto & Jerome (1974)		13.0	65	408	F
Silverman (1974)		14.0	88	588	F
Harris & Fleer (1974)		16.0	42	395	V
Expt. 1 Fixed Set (Y+N)/2		9.0	88	584	F
Expt. 2 Fixed Set		9.8	85	613	F
Expt. 1 Varied Set		9.0	51	851	V
Expt. 2 Varied Set		9.8	60	840	V
RETARDED SUBJECTS					
Harris & Fleer (1974)	8.2	16.1	66	422	V
Harris & Fleer (1974)	8.3	16.5	111	563	V
Silverman (1974)	9.9	18.5	88	452	F
Maisto & Jerome (1977)	10.3	14.2	126	580	F
Dugas & Kellas (1974)	10.5	16.9	90	1645	V
Expt. 1 Fixed Set (Y+N)/2	11.0	19.0	114	888	F
Expt. 2 Fixed Set (Y+N)/2	10.0	19.0	119	573	F
Expt. 1 Varied Set 'Yes'	11.0	19.0	77	928	V
Expt. 2 Varied Set 'Yes'	10.0	19.0	106	723	V

Table 2.7: Comparison of results from developmental and retardation studies of memory search. The mental age of normal children is assumed to be equivalent to chronological age. Slopes and intercepts are averaged across 'yes' and 'no' responses to permit comparison between studies. Procedure is specified as either Fixed (F) or Varied (V).

Wickens (1974) indicated that children were more susceptible than adults to the effects of practice, and this may account for the slower RTs of children when compared with adults only occurring in those studies where less practice has been allowed. For example, Harris & Fleer (1974) reported results from the second session of the experiment only, and subjects in the study by Maisto & Baumeister (1975) were given 10 minutes of simple RT training, and 48 practice trials before each block of test trials. These studies therefore report more practice for subjects than was allowed by Hermann & Landis (1977), Silverman (1974) or in the present experiments, all of which found lower memory search rates in younger subjects. However, Hermann & Landis (1977) also found decreasing errors with increasing age. Furthermore, Silverman (1974) confounded memory search with visual search, and used unfamiliar stimuli that would increase the likelihood of practice effects on search rate, so that very few studies in the literature provide adequate comparisons between groups.

The slower RTs in the present experiment may also have been due to no reinforcement being given between trials (Wickens, 1974).

These possible influences on the performance of nonretarded children may also be applicable to retarded adults' performance as well, since the present experiments suggested that there may be processing similarities between the two younger mental-age groups, as evidenced by similar serial position curves.

When the results for the retarded group were considered, it was found that scanning rates under the fixed set procedure were similar to those found in other studies where a fixed set procedure had been employed with retarded subjects (Maisto & Jerome, 1977; Silverman, 1974). However, much greater variability of responding was found for the retarded group under the varied set procedure. Here the pattern of results was unlike that of nonretarded controls, or the performance of subjects under fixed set or varied set procedures as reported in the literature. For individual subjects, item recognition functions for 'yes' and 'no' responses were often not parallel, and overall, the 'no' functions were flatter than the 'yes'. This was mainly due to very slow responses to test probes from small positive memory sets.

Similar patterns of responding, where 'no' functions are flatter than 'yes' functions, have been reported for studies of normal adults that have found high error rates which increase across set size. For example, Aube & Murdock (1974) found steeper slopes for item recognition functions for 'yes' responses than for 'no' responses, so that 'yes' responses were faster than 'no' at smaller set sizes, but slower at larger set sizes. There were also suggestions of this kind of responding in the data of Burrows & Okada (1971), Corballis, Kirby & Miller (1972), and Forrin & Morin (1969). Generally, the procedure of these experiments involved the fast presentation of positive memory sets, which would have contributed to the relatively high error rates. Such conditions suggest that the storage of material could be inaccurate and fragile, accentuating individual differences in the item recognition functions. Aube & Murdock (1974) suggested that when high error rates occur, there is a change in the relative perceived frequency of 'yes' and 'no' items, so that manipulating the relative frequency of the probe may reinstate parallel functions. However, Experiment 2 indicated that bias toward one response is not necessarily associated with high error rates, at least in the retarded group, and analysis of covariance in Experiment 1 confirmed that when such bias is removed statistically, the pattern of results does not change.

Other experimenters (e.g. Corballis et al., 1972) have suggested that subjects may change strategy across set size. When individual item recognition functions from Experiment 1 were examined, a number of different response patterns could be identified. Of the ten retarded subjects, only two seemed to generate serial, exhaustive scanning functions. Among the remaining eight subjects, 'no' responses had markedly less steep functions than 'yes' responses for the first four set sizes. Thus, most retarded subjects may have adopted qualitatively different strategies to those generally exhibited by nonretarded adults, although there is the possibility of some variation in both populations.

O'Connor (1976) has reported an experiment by Miklausic (1976) which suggested that visually, successively presented digits are stored in visual or aural codes depending on verbal IQ, and that children show an increasing tendency towards aural or verbal-sequential coding with increasing mental age. The training for the varied set procedure, which encouraged verbal labelling of digits and used successive presentation, may have encouraged retarded subjects to abandon less efficient visual spatial storage codes on trials with smaller set sizes, while when larger sets were presented, subjects reverted to their more familiar strategy of coding visually*. There would then be more errors among items in the positive set for larger set sizes, because not all items would have been efficiently coded. However, negative set items would not be affected. With small set sizes, encoding by this group may have been in terms of the unfamiliar, slower but more efficient verbal code that is adopted spontaneously by more mature information processors. This may also explain the finding of disproportionately slow 'no' responses to a single probe in the data of Dugas & Kellas (1974), who have also suggested that their subjects used a different strategy for that set.

A negative correlation between the slope and intercept of item recognition functions and differences in the serial position curves found for nonretarded adults and the two retarded and nonretarded younger mental-age groups have provided further evidence to suggest differences in processing strategies between these groups. In the present experiment there were significant correlations between slope and intercept for the retarded group in

* I am indebted to Dr N. Brewer (personal communication) for this suggestion.

Experiment 1 and the nonretarded children in Experiment 2. It seems therefore that the independence of processing stages reflected by these values is more precarious in younger mental age groups, suggesting that less stable processing strategies may be employed by these subjects than by nonretarded adults.

Chapter 3

EFFECTS OF PRACTICE ON MEMORY SCANNING IN MENTAL RETARDATION

3.1 INTRODUCTION

Two important considerations were raised by the experiments of Chapter 2. Firstly, several alternative strategies appear available to subjects when retrieving information in a recognition task. Memory search may be exhaustive or self-terminating, serial or spasmodic. Alternative strategies may be adopted which are characterized by steeper 'yes' than 'no' slopes in the item recognition function. Retarded responding is generally based on less efficient or inconsistent strategies, as seen in slower RTs and variable independence of processing stages. These suggestions find support from evidence that normal adults and children can also exhibit inconsistent or inefficient strategies under some circumstances (Aube & Murdock, 1974; Seymour & Moir, 1980).

Secondly, an orderly progression of stable, discrete mental operations may not adequately describe the performance of the retarded subject group, as suggested by the significant negative correlations found between slopes and intercepts from item recognition functions for some retarded subjects. Dependence or inconsistent independence between processing stages held to be reflected in the slope and intercept of the item recognition function is important because it suggests that the additive factor method used in the Sternberg model of recognition may not provide a means for analysing the processes underlying slow, variable responses of retarded persons.

These considerations led to the suggestion that procedural variables, such as small amounts of practice and no explicit reinforcement, may inflate group differences because of the heightened sensitivity of younger mental age groups to such variables. Evidence from the developmental literature suggested that those studies where equivalent memory scanning times were found for children and adults had either provided more practice or had biased children towards very fast responding. If inefficient strategies are adopted because of lack of training or practice, one would expect changes in strategy when training was increased. Thus, Sanders (1977) noted that additivity of stages may well be affected by practice, and Sternberg (1967) observed an interaction, between stimulus-response compatibility and stimulus degradation, which disappeared after practice given to normal adults.

This chapter considers the effect of practice on individual differences in memory search. The main focus of practice studies in the memory search literature to date has been on normal adults and their reaction to varying sequences and sets of stimuli. Little attention has been given to developmental studies of practice and memory scanning, and no work has directly studied the effect of practice on memory search in retarded persons. Relevant studies are reviewed in the sections that follow, together with evidence from other tasks for the improvement in memory performance of retarded persons and nonretarded children, given appropriate training. This review provides the background for the presentation of empirical evidence that both retarded adults and nonretarded children can increase their speed of memory search.

3.1.1 Practice and memory scanning in normal adults

For normal adults, the effect of practice in an item recognition task is dependent on the stimulus-response mapping characteristics of the task at hand*. Where stimulus response mapping is consistent during the course of

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* Stimulus-response mapping refers to whether a particular item from the memory ensemble is repeatedly associated with one response ('consistent mapping') or not. In consistent mapping, for example, the letters 'a,b,c' may always be members of the negative memory set, and the letters 'd,e,f' always in the positive set.

practice, then only the slope of the item recognition function is affected. Two main bodies of findings are relevant:

(i) Several studies have shown that where there is consistency of stimulus-response mapping across trials, extended practice leads to faster scanning rates. Briggs & Blaha (1969) used mutually exclusive positive and negative memory sets of random figures, which were consistently associated with only one response type across days. They varied the number of items held in memory ('memory load') as well as the number of simultaneous test items presented as a probe for the subject to respond ('display load'). Central processing times approximating those reported by Sternberg (1966) (i.e. 37 msecs/item) were found initially at a display load of one item. However, after twelve days of practice, scanning rates were reduced to approximately 15 msecs/item. That further improvement was not found could have been due to the combination of unfamiliar stimulus materials and the stimulus-response mapping used. Although the ensemble from which the positive set stimuli were drawn remained constant across days, the actual composition of any particular positive set changed from day to day.

In a similar study, Lively (1972) presented subjects with mutually exclusive positive and negative sets of letters and digits, and subjects worked with exactly the same memory sets for three successive days. Lively reported a reduction in both the slope and intercept of item recognition functions, although these recognition functions were not tested for linearity, so that it is not possible to tell whether subjects were searching memory serially.

When positive and negative sets are mutually exclusive, or nested so that items in smaller memory sets must appear in larger sets, the item recognition function is generally nonlinear and negatively accelerated, and becomes flatter with practice. For example, Simpson (1972) tested subjects with mutually exclusive sets of letters over three days and found that item recognition functions were best fitted by a logarithmic function of the positive set size. Ross (1970) also gave subjects extended practice (twenty days) with mutually exclusive sets that were nested within as well as between sessions, so that the stimulus-response association was closer than in previous studies. Once again, a nonlinear negatively accelerated item recognition function was found, and slopes of the functions were reduced with practice. In a similar study, Kristofferson (1972) practiced subjects for 36 daily sessions using nested, mutually exclusive sets of digits or photographs of faces. She found that the mean item recognition function was negatively accelerated for both kinds of item presented. After 36 days, the mean item recognition function was still not completely flat. Corballis (1975) has reported that nested sets produce flatter slopes than mutually exclusive sets.

Thus, extended training with consistent stimulus-response mapping will lead to a reduction in search time, and may alter the nature of the search as well.

(ii) The second body of findings relevant to the effect of practice on memory search is concerned with those tasks where particular items are not consistently associated with one response. In these tasks, items in the stimulus ensemble appear equally often in positive and negative memory sets, so that subjects do not have the same opportunity as in a consistent arrangement to associate a particular stimulus with each response. Practice, in this case, does not affect the rate of memory search, any reduction in RT being apparently due to increased efficiency in processes reflected in the intercept of the item recognition function, such as encoding, binary decision and response selection.

Nickerson (1966) practiced subjects for twenty-two days in a combination of visual search and memory search paradigms. He found that RT increased linearly with increases in either the display set or the memory set, and although RT decreased across days, the set size effect did not decrease.

This was contrary to Neisser (1964) who found that after extensive practice subjects could search a visual array for any of several characters as efficiently as searching for a single one. However, Neisser used mutually exclusive sets, which have been shown to produce changes in search speed with practice. Nevertheless, Nickerson's subjects traded accuracy for speed, errors increasing with days of practice.

Burrows & Murdock (1969) compared subjects' performance on a response consistent 'fixed target' procedure, and a response inconsistent 'varied target' procedure over fourteen days of practice. Errors were more stable than in the Nickerson study. An increase in RT with increasing memory set size was not reduced by extended practice, or influenced by the procedure used. However, Burrows & Murdock did not report on the effects of practice where only one probe stimulus was used, a situation which would be directly comparable to Sternberg's paradigm. In a directly comparable study, Kristofferson (1972) gave subjects thirty days of practice in a procedure which was 'fixed set' within each day, but not across days so that it did not permit stimulus-response consistency. The outcome suggested that subjects searched memory at a constant speed throughout the entire experiment, although total RT was reduced considerably, as reflected in decreasing zero intercepts. Corballis, Roldan & Zbrodoff (1974) confirmed this result, giving subjects practice with positive sets which were changed each day for eighteen days. Schmitt & Scheirer (1977) also found reduced RT to words and random letters, without affecting memory comparison speed, as a consequence of two main sessions of practice.

In summary, when stimuli are not consistently associated with a particular response, practice leads to reduced zero intercepts of mean item recognition functions, suggesting faster encoding or response selection, but not to flatter slopes of such functions, suggesting that memory search speed is unaffected. With normal adults, practice can apparently alter the slope of a mean item recognition function if stimuli are consistently mapped to a particular response. Shiffrin & Schneider (1977) have suggested that consistent mapping leads, with practice, to automatic detection. Thus, attention is directed to the probed item automatically, and no serial search through the memory set is needed. Varied stimulus-response mapping, on the other hand, remains attention-demanding and may be dependent on rehearsal. From these suggestions, one can hypothesize that if retarded persons have poor control of attention processes (Anderson, Halcomb & Doyle, 1973; O'Connor & Hermelin, 1971), then they would have greater difficulty in developing automatic detection in response to consistent mapping, that is the slope of an item recognition function would not decrease as much as for nonretarded subjects. On the other hand, if the serial search typically used with inconsistent mapping is dependent on rehearsal, as Shiffrin & Schneider (1977) have suggested, then the performance of retarded subjects may benefit from training to use rehearsal in a varied stimulus-response mapping paradigm.

3.1.2 Practice and memory scanning in mental retardation

While there is no direct evidence in the literature for systematic changes in the memory scanning of retarded persons, the effect of training on related functions such as retrieval of material presented in a recall memory paradigm, and simple RT, suggests that similar improvement in memory scanning is plausible.

Considerable research, directed towards the poorer recall of items by retarded groups, has indicated that such subjects are capable of improving memory performance where the amount of rehearsal is increased. Thus, Ellis (1970) studied retarded persons' performance in a serial recall task. The absence of primacy effects or any effect of presentation rate led Ellis to conclude that retarded subjects did not use rehearsal. Other studies have since confirmed the rehearsal deficit in retarded recall (e.g. Belmont &

Butterfield, 1971; Butterfield, Wambold & Belmont, 1973), though there are data indicating that some retarded subjects may rehearse spontaneously (Glidden, 1972).

It is possible, however, to train retarded subjects to respond similarly to normal subjects, by encouraging rehearsal (Belmont & Butterfield, 1971; Butterfield et al., 1973). Hagen, Streeter & Raker (1974) trained retarded children to use verbal labelling, so that subjects performed as well as nonretarded children of a similar mental age. McBane (1972) showed that the total number of items that can be rehearsed efficiently is related to the developmental level of the subject. His high level group (mean IQ = 74, mean MA = 10.8) learned to rehearse over twice as many items as the low level group (mean IQ = 50, mean MA = 6.2).

Thus, studies of recall performance indicate that retarded persons can be taught to use rehearsal to facilitate memory performance. Research on the retarded subject's inadequate control over the direction of attention has also indicated that performance can be improved. An ability to concentrate on essential information is a characteristic of the more mature information processer, and the generally poor ability of retarded persons to focus on relevant task dimensions or to exploit redundancy is well established (Spitz, 1963; Zeaman & House, 1963). Brown (1972) showed that retarded subjects have difficulty concentrating exclusively on current information in a serial recognition task, this being reflected in their declining accuracy between tests due to the number of intrusions from previous sets. Subjects were trained successfully to use a signal to forget, but training did not generalise to the situation where no signal was given. Bray (1973) also demonstrated that after an extensive training procedure, retarded adolescents could use a cue to forget, but he concluded that appropriate attentional strategies were not adopted spontaneously by the retarded subject.

Similarly, awareness of organization in the stimulus array can be trained. When categorized lists are presented for recall, retarded subjects tend to recall fewer items and show less 'clustering' than nonretarded chronological age controls, and the difference between random and clustered lists is greater for higher IQ subjects. However, when organizational principles are made salient somehow, retarded persons' performance improves (Bilsky & Evans, 1970; Gerjuoy, Winters, Pullen & Spitz, 1969).

In summary, the memory performance of retarded persons is hampered by their inadequate use of strategies such as rehearsal and clustering, and by poor attention. Brown and her associates (Brown, 1974, 1975; Campione & Brown, 1977) indicated that retarded persons are deficient in evaluating task demands, leading to the absence of appropriate, efficient strategies. However, retarded performance can be improved, either by direct training of the skills necessary for efficient performance of the task, or, as Brown (1972) suggested, by selection of tasks assumed not to involve strategies. Brown (1974) used a recognition memory task with pictures as stimuli to demonstrate that retarded persons could perform as well as nonretarded persons on a non-strategic task. However, Blaney & Winograd (1978) cited their own research and other studies as evidence that recognition memory for pictorial material can also be developmentally sensitive, that is, under strategic control.

Thus, given that retarded subjects are able to improve performance on a number of memory tasks by learning more efficient strategies, and that the memory scanning task has been shown to involve control strategies of rehearsal and attention and to generate a number of alternative response strategies, the evidence suggests that retarded subjects have the potential to improve their performance on this task as well.

RT studies also indicate that the performance of retarded persons improves with practice. Using severely and moderately retarded adults, Hoover, Wade & Newell (1981) studied the effect of extended training on RT, defined in this study as the time to remove a finger from a key in response to a visual signal, and movement time (MT), or time to move the hand to a target. When both RT and MT were measured, MT was reduced over a thirteen day training period, and this reduction remained throughout a period of five months without further practice. RT in these conditions showed no improvement, but when measured alone, and with feedback given for fast RTs, a significant decrease in RT over ten days was found. Variability also decreased significantly.

Therefore, some reinforcement or feedback may be necessary to effect improvement in RT among retarded subjects. Baumeister & Ward (1967) demonstrated that latencies could be reduced over a ten day period when contingent reward was used, while no improvement was demonstrated by a nonretarded control group who did not receive feedback or reinforcement. Spence (1966) found that retarded children required more complete feedback than nonretarded children.

Given sufficient training and appropriate conditions, control processes of rehearsal and attention can be improved, facilitating the memory performance of retarded persons. RT can also be improved with practice. Taken together, studies reviewed above suggest that retarded persons may be able to improve performance in the memory scanning task.

3.1.3 Relation of memory in mental retardation to normal memory development

Just as particular cognitive strategies can be taught to retarded persons in order to improve their performance, the same process can be applied to young normal children who can be taught to use strategies which would not normally be used spontaneously until a later stage of development. For example, five year old normal children do not usually rehearse, but can be induced to do so (Kingsley & Hagen, 1969). For five to seven year old children, rehearsal is only effective when prompts are provided, and benefits are only temporary (Hagen, Hargreave & Ross, 1973). Hagen & Kail (1973) found that by about the age of eleven years, normal children are proficient in using rehearsal to improve recall.

Young children aged approximately eight years do not appear to use categorization to facilitate memory search either, and will search one and two category lists at a similar speed, unlike children aged approximately eleven years who can use the presence of categories to end their search earlier (Naus & Ornstein, 1977). Thus, developmental differences between younger and older children and between retarded persons and normal children may result from differences in the voluntary strategic behaviours applied to the task. The general course of memory development may be seen as a change from passive to active involvement, characterized by an increasing mastery and repertoire of voluntary, active strategies (Flavell, 1970; Smirnov & Zinchenko, 1969). In this way, the passive approach of young children and retarded persons to memory tasks, as shown in their failure to apply strategies such as rehearsal or organization, may be seen as a primary source of their memory inefficiency.

Another source of memory inefficiency may be these subjects' greater reliance on variables such as reinforcement and feedback. Wickens (1974) has reviewed evidence that the RTs of adults and children are differentially affected by three factors which were not associated with central processing limitations - practice, attentiveness and incentive. Firstly, practice affects children's RT more than that of adults. Wickens (1974) cited Yonas & Gibson's experiment, in which visual search time of children continued to decrease for 25 days of 27 trials of practice per day, suggesting that children may take longer to reach an asymptotic level of RT than adults. Secondly, older children are able to maintain preparatory set or general attentiveness over longer periods of time than young children. Thirdly, Elliott (cited by Wickens, 1974) found that incentive such as noncontingent verbal praise or contingent money rewards reduced the RTs of younger children much more than it reduced RTs of older children. He thus attributed age differences in RT to effects of incentive as well as to attention.

Therefore, any developmental comparison of memory performance which involved strategic behaviour would be likely to find group differences, as outlined in Section 3.1.2. However, evidence from studies of normal children indicates that group differences may be overestimated if variables such as practice and incentive were not controlled for. This may have been the case in the study by McCauley, Kellas, Dugas & Devellis (1976) who reported only 20 practice trials given to children aged approximately eleven years. Furthermore, no attempt was reported to control for incentive. However, McCauley et al. (1976) concluded that the steeper slope and higher zero intercept of item recognition functions obtained from data of children with lower IQs represented a permanent or structural deficit since RT was not substantially reduced by training to use a serial rehearsal strategy. Thus, the differences reported in this study may have been accentuated by uncontrolled practice and incentive variables.

3.2 EXPERIMENT 3

Experiment 3 was designed to investigate the effects of practice on the performance of retarded persons in the Sternberg memory scanning task. Normal mental age controls were included to compare their expected improvement with the retarded group. Chronological age controls were necessary to determine whether the extent of improvement with practice is the same in all groups, since practice would not be an important factor if the relation between the three groups is the same regardless of the stage of practice.

An attempt was made to control for non-processing variables such as incentive and motivation by providing aural, accuracy feedback on every trial, visual feedback regarding accuracy and speed at the beginning of each session of practice and noncontingent reward at the end of the experiment.

Three main questions were investigated:

1. Does practice have a differential effect on RT in the three groups?
2. Do presumed differences in response strategy, reflected in non-parallel 'yes' and 'no' functions found for the retarded groups in Experiments 1 and 2 compared with parallel functions obtained from control groups, persist with practice?
3. Does practice decrease the correlation found between the slope and intercept of the item recognition functions, this correlation being assumed to reflect independence between processing stages?

Two procedures were compared to determine whether the difference in retarded subjects' responding between the two procedures persisted with practice. In the varied set procedure, a different memory set was presented on each trial, and sets changed from day to day. The fixed set procedure was different in that only one memory set from each set size was presented repeatedly within each day, but sets changed from day to day.

3.2.1 Method

Design

One between-subjects variable and four within-subjects variables were manipulated in a 3x2x3x2x7 repeated measures, nested factorial design (Winer, 1971). The three groups of subjects (mentally retarded adults, nonretarded children and nonretarded adults) constituted the between-subjects variable, Group. The within-subjects variables were Procedure (fixed/varied), Set Size (three positive memory set sizes), Response (one of two alternatives to the test probe) and Practice (seven sessions of practice). Because of limitations on the time for which subjects were available, only three memory set sizes were tested. However, it was considered that the large amount of data collected for each set size and suitable statistical precautions could compensate for this.

The two procedures were balanced for order within subjects across days, so that from session to session individual subjects alternated between having the fixed set procedure first and the varied set procedure first. Presentation of the three set sizes in the fixed set procedure was also balanced for order across sessions, and peripheral response factors were controlled for by having half of the subjects use their dominant hand for a 'yes' response while half of the subjects used their non-dominant hand. The probability of the test item coming from the positive set was 0.5 in both procedures, and the serial position of positive set test items was distributed as evenly as possible across all set positions.

Subjects

Three groups of eight subjects consisted of mildly mentally retarded adults and mental age and chronological age controls, as described in Table 3.1. The mental age controls were fifth grade children selected on the basis of average reading scores (GapR3 Reading Test) for their age. Thus the mental age for nonretarded children shown in Table 3.1 is the mean reading age for the group.

	CA		MA		IQ	
GROUP	x	sd	x	sd	x	sd
Retarded Adults (n = 8)	21-11	4-5	11-4	0-5	71	3
Nonretarded Children (n = 8)	9-6	0-4	10-8	0-11	-	
Nonretarded Adults (n = 8)	22-6	5-11	-		-	

Table 3.1: Subjects in Experiment 3, showing mean (x) and standard deviation (sd) in years and months for chronological age (CA) and mental age (MA) for each group and full scale IQ where measured. Normal IQ has been assumed for nonretarded subjects.

Chronological age controls were second year university students. Retarded subjects were selected on the same basis as for Experiments 1 and 2, and were day-workers from a sheltered workshop for the physically and mentally handicapped. All subjects received a small financial reward for their participation at the end of the experiment.

Apparatus

Apparatus was identical to that used in Experiments 1 and 2 (see Section 2.2.1). An auditory tone generator was also used, as described below.

Procedure

Subjects received 204 trials in one session which lasted approximately fifty minutes per day, for seven consecutive working days.

Each subject was presented with two different procedures - a 'fixed set' procedure in which the positive memory set remained unchanged over a number of trials, and a 'varied set' procedure in which the positive memory set changed from trial to trial. The positive set could consist of two, three or four nonrepeating digits which were not consistently associated with one type of response, across blocks in the fixed set procedure or across trials in the varied set procedure. The composition of sets changed each session.

Fixed set procedure

The three positive memory sets were tested in three blocks of thirty trials. The positive set was displayed for three minutes at the beginning of a block, and the experimenter notified the subject when he had about a minute left before trials began. One trial consisted of a warning signal, which was a small cross displayed in the centre of the screen for one second, followed by the probe stimulus to which the subject responded, and a four second inter-trial interval. After 15 trials, the subject was required to recall the numbers in the positive positive set. Thus, each block only tested one memory set. Three new positive memory sets had to be learned each session.

Varied set procedure

Thirty trials at each of three positive set sizes (two, three and four) were randomized to make a sequence of 90 trials, broken down into five blocks of 18 trials. The size and composition of the memory set varied from trial to trial. One trial consisted of either two, three or four digits presented successively in the centre of the screen for 1.5 secs/digit, followed by a two-second gap, a warning signal identical to that used under the fixed set procedure, a probe stimulus to which the subject responded, and a four-second inter-trial interval.

In the first session subjects were instructed to be very careful while performing as fast as possible, and to try to make only one or two errors over the whole session. On the remaining days, the speed-accuracy instructions were repeated at the beginning of each block of trials, the experimenter instructing subjects to perform as fast as they could without making too many mistakes.

During the first session, an additional block of trials identical to the first experimental block was presented for practice, but not included in statistical analyses. Furthermore, the first three trials of any block were not included in analysis.At the beginning of each subsequent session, each subject was shown a graph depicting his/her mean RT and the total number of errors for the previous session. These were displayed alongside other subjects' results for the course of the experiment. Feedback about correctness of responding was given at each trial by means of an auditory tone generator, which sounded for 500 msecs coinciding with the subject pressing one of the reaction time buttons. The tone was set at 300 Hz (low) for a correct response and 1700 Hz (high) for an error.

3.3 RESULTS AND DISCUSSION

As in Experiments 1 and 2, the effects of Hand used and Order of procedures were controlled for experimentally, and were not of theoretical significance to the Sternberg model. Preliminary analysis confirmed that these effects were not significant. The numbers of errors made were analysed to determine whether the hypothesized increase in speed with practice was accompanied by a decrease in accuracy, which would signify a speed-accuracy trade-off and thus no real improvement in efficiency of processing. Correct mean RT data from Sessions 1 and 2 were also examined separately to determine whether the conclusions of Chapter 2 regarding group response strategy differences and memory search speed differences were replicated in the present experiment. Subjects in Experiments 1 and 2 had been practised to the equivalent of one or two sessions of practice, thus permitting early practice data for the present experiment to be compared with data from the previous experiments.

Further analysis is presented in three main sections:

(a) The differential effect of practice in the three groups have been analysed firstly by examining total mean RT in each procedure across sessions;

(b) The question relating response strategies to practice has been analysed by examining changes in slope and intercept values from individual item recognition functions; firstly, by way of summary with 'yes' and 'no' functions combined and then in more detail, with 'yes' and 'no' values separated. Analysis of mean RT per set size is presented in support of regression results;

(c) The independence of processing stages and the applicability of the additive factor model of Sternberg to retarded persons' performance has been examined, firstly by correlations of slopes and intercepts of average item recognition functions within each group, and secondly by analysing measures of individual and group variability.

In these analyses, the factors of Group, Set Size and Procedure refer respectively to the three subject groups (a between-subjects variable), size of the positive memory set presented (a within-subjects variable) and type of procedure, that is, fixed set or varied set (a within-subjects variable). The factor Response refers to the type of response required to the probe item (either 'yes' or 'no'). The within-subjects variable Practice refers to seven experimental sessions of 204 trials each, divided between the fixed set and varied set procedures.

3.3.1 **Errors**

The overall error rate was 2.6 % and with the exception of two days of performance among the nonretarded children, rates were 5% or less. Table 3.2 provides a summary.

Number of errors made daily by individual subjects were analysed in a five way, Group x Procedure x Response x Set Size x Practice analysis of variance (see Appendix 3.1). There was no significant main effect of Practice, but the other four main effects were significant (Group $F = 7.86$, 2/21 df, $p < 0.01$; Procedure $F = 37.23$, 1/21 df, $p < 0.01$; Response $F = 9.63$, 1/21 df, $p < 0.01$; Set Size $F = 44.08$, 2/42 df, $p < 0.01$). Analysis was limited to three way interactions since higher order interactions in the error data

FIXED SET PROCEDURE

GROUP/RESPONSE REQUIRED		SESSION 1	2	3	4	5	6	7	Overall
Retarded Adults	NO	1.4	0.6	1.9	0.6	0.3	1.1	1.1	1.0
	YES	1.4	1.7	2.8	1.4	2.5	1.1	0.6	1.6
Nonretarded Children	NO	2.8	1.4	2.8	1.1	1.9	0.6	1.4	1.7
	YES	2.8	2.8	4.2	3.1	3.3	1.4	4.7	3.2
Nonretarded Adults	NO	0.3	0.3	1.4	1.7	0.6	1.1	0.6	0.8
	YES	1.9	1.9	2.2	1.4	2.2	1.9	1.4	1.9
Overall		1.8	1.4	2.6	1.5	1.8	1.2	1.6	1.7

VARIED SET PROCEDURE

GROUP/RESPONSE REQUIRED		SESSION 1	2	3	4	5	6	7	Overall
Retarded Adults	NO	5.0	4.2	5.8	3.9	5.8	4.7	1.4	4.4
	YES	4.4	4.7	4.4	3.6	3.9	4.7	3.3	4.2
Nonretarded Children	NO	3.6	1.7	4.0	5.8	8.6	2.8	4.2	4.5
	YES	5.8	5.3	3.9	7.5	5.6	8.1	4.4	5.8
Nonretarded Adults	NO	1.1	0.8	0.8	0.6	1.4	0.6	1.7	1.0
	YES	1.4	1.9	2.8	0.8	2.5	1.9	1.9	1.9
Overall		3.6	3.1	3.8	3.7	4.6	3.8	2.8	3.6

Table 3.2

Experiment 3: Mean percentage of errors for responses required at each session of practice for retarded adults, nonretarded children and nonretarded adults. Each figure is calculated as an average of 360 trials.

were low, were not of interest and would be uninterpretable. Significant interactions of Group and Procedure ($F = 8.25$, 2/21 df, $p < 0.01$) and Group and Set Size ($F = 4.33$, 4/42 df, $p < 0.01$) were obtained, due to retarded adults and nonretarded children making more errors in the varied set procedure than the fixed set procedure, and more errors at a positive set size of four items than lower set sizes, while nonretarded adults were not affected by either Procedure or Set Size. Significant interactions of Procedure and Set Size ($F = 5.21$, 2/42 df, $p < 0.01$) and Group, Procedure and Set Size ($F = 6.13$, 4/42 df, $p < 0.01$) were due to more errors being made at high set sizes in the varied set procedure, this trend again only being evident in retarded adults' and nonretarded children's data. Finally, these significant interaction of Response x Set Size ($F = 4.17$, 2/42 df, $p < 0.05$) was due to the relatively large number of errors made to positive set probes from set sizes of four items.

This pattern of results was similar to that seen in previous experiments. The absence of an increase in errors across sessions of practice indicated that any reduction in correct mean RT with practice was not due to a speed-accuracy tradeoff. That the slower groups of retarded subjects and children again made more errors also indicated that differences in correct mean RT discussed below between these groups and nonretarded adults were not due to differing speed-accuracy criteria.

A nonparametric signal detection theory analysis of errors in each group showed very little difference in caution levels between the three groups. All subjects appeared to respond less cautiously, and with less sensitivity, as shown by lower beta and d' values under the varied set procedure than the fixed set procedure (see Appendix 3.2).

3.3.2 Sessions 1 and 2

So as to permit a comparison with Experiments 1 and 2, Session 1 data have been summarized in the item recognition functions set out in Figure 3.1. Correct mean RT was analysed in a Group x Response x Procedure x Set Size analysis of variance (see Appendix 3.3). All four main effects were significant (Group $F = 8.64$, 2/21 df, $p < 0.01$; Procedure $F = 17.83$, 1/21 df, $p < 0.01$; Response $F = 37.67$, 1/21 df, $p < 0.01$; Set Size $F = 18.00$, 2/42 df, $p < 0.01$). There was no interaction of Response and Set Size, indicating that 'yes' and 'no' functions could be considered parallel. However, there were significant interactions between Group and Response ($F = 6.40$, 2/21 df, $p < 0.01$), and Group, Procedure and Response ($F = 5.04$, 2/21 df, $p < 0.05$), due to the markedly slower 'no' responses of the retarded group in the varied set procedure. This result is consistent with the findings of Experiments 1 and 2. The previously found indication that speed of memory scanning and other mental operations increase with mental age is evident in Table 3.3, in the values for group slopes and intercepts of the item recognition functions.

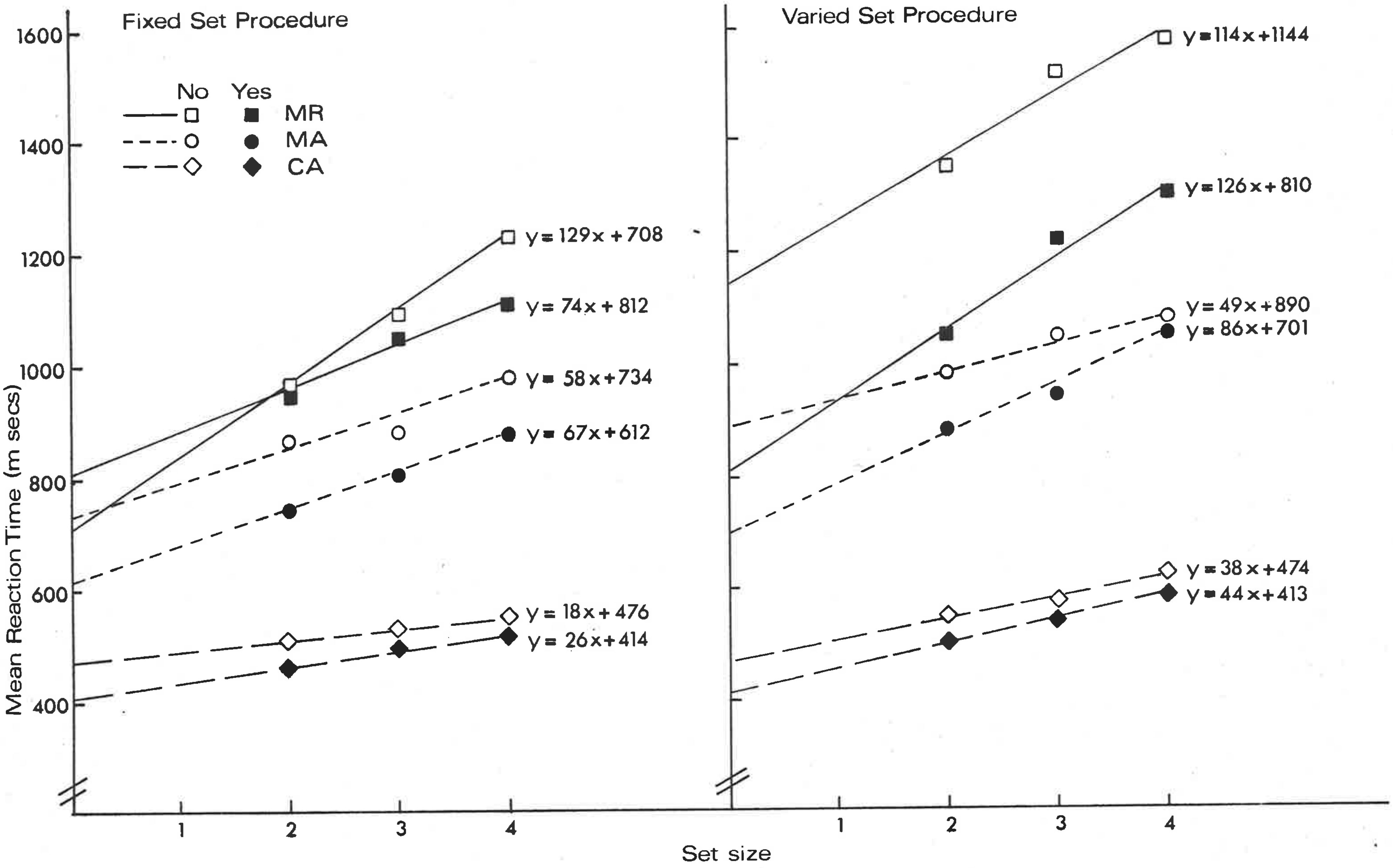
GROUP/ RESPONSE REQUIRED		PROCEDURE			
		FIXED		VARIED	
		Slope	Intercept	Slope	Intercept
Retarded Adults	NO	129	708	114	1143
	YES	74	812	126	810
Nonretarded Children	NO	59	734	49	890
	YES	67	612	86	701
Nonretarded Adults	NO	18	476	37	474
	YES	26	414	44	413

Table 3.3

Experiment 3: Slopes (msecs/item) and intercepts (msecs) from Session 1 item recognition functions of retarded adults, nonretarded children and nonretarded adults, calculated for each procedure (fixed, varied) and response required (no, yes).

FIGURE 3.1

Experiment 3: Item recognition functions for session 1, showing 'yes' and 'no' responses of retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA) under fixed set and varied set procedures.



Fixed Set Procedure
Varied Set Procedure
No
Yes
MR
MA
CA
1600
1400
1200
1000
800
600
400
Mean Reaction Time (m secs)
y= 129x + 708
y= 74x + 812
y= 58x+734
y= 67x+612
y= 18x+476
y= 26x+414
y=114x+1144
y=126x+810
y=49x+890
y=86x+701
y=38x+474
y=44x+413
1
2
3
4
Set size

Session 2 data yielded a similar pattern of results, and these are summarised in Figure 3.2. Again, there was a trend towards increasing scanning speed with increasing mental age. Analysis of correct mean RT (see Appendix 3.4) found no significant difference in RT under the two procedures, although other main effects of Group, Response and Set Size remained significant (Group $F = 8.99$, 2/21 df, $p < 0.01$; Response $F = 15.36$, 1/21 df, $p < 0.01$; Set Size $F = 24.37$, 2/42 df, $p < 0.01$). The significant interactions between Procedure and Set Size ($F = 3.37$, 2/42 df, $p < 0.05$) and Group, Response and Set Size ($F = 2.91$, 4/42 df, $p < 0.05$) were due to a flat 'no' function in the retarded group under the varied set procedure. Thus, although Session 2 results showed that the difference in RT between the two procedures is reduced after some practice, the pattern of responding was similar to that in the two previous experiments.

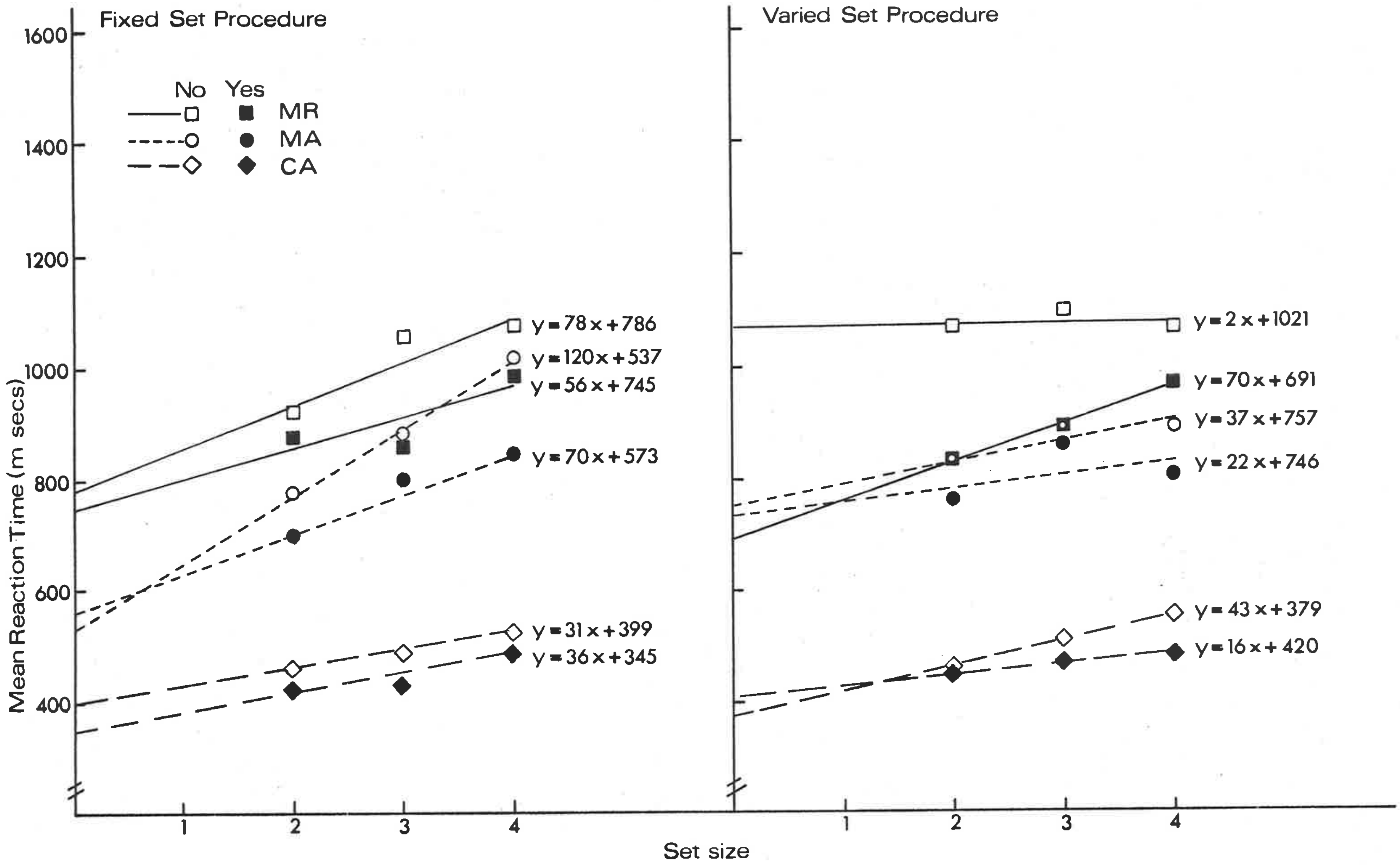
3.3.3 Practice effects on correct mean RT

Mean correct RT was collapsed across Response and Set Size to provide a single value for individual fixed set and varied set performance on each day. Figure 3.3 shows practice curves for overall performance. Progression through seven sessions of practice resulted in retarded group performance reducing to the same level or slightly faster than that for nonretarded children. The initial difference between procedures was reduced with practice. Both retarded adults and nonretarded children improved mean correct RT with practice, whereas improvement was not as marked in the nonretarded adult group. The nonretarded children's RT appeared to level off after approximately three to four days of practice, but the retarded group continued to improve up to Session 7.

In a Group x Procedure x Practice analysis of variance, there were significant main effects of Group ($F = 11.03$, 2/21 df, $p < 0.01$) and Practice ($F = 17.70$, 6/126 df, $p < 0.01$) while no significant effect was found for the

FIGURE 3.2

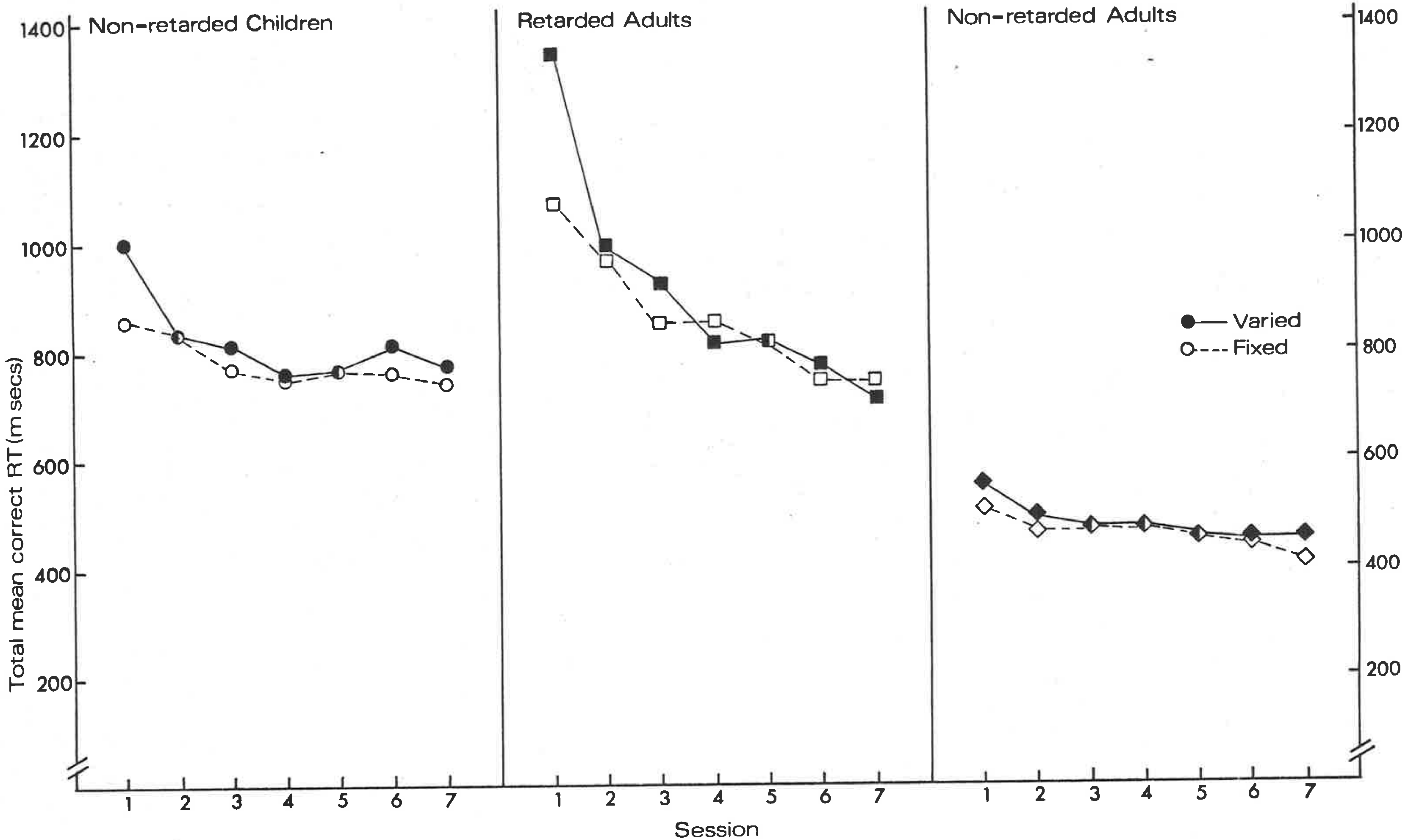
Experiment 3: Item recognition functions for session 2, showing 'yes' and 'no' responses of retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA) under fixed set and varied set procedures.



Fixed Set Procedure
Varied Set Procedure
No Yes
MR
MA
CA
Mean Reaction Time (m secs)
1600
1400
1200
1000
800
600
400
y = 78 x + 786
y = 120x + 537
y = 56 x + 745
y = 70 x + 573
y = 31 x + 399
y = 36 x + 345
y = 2 x + 1021
y = 70 x + 691
y = 37 x + 757
y = 22 x + 746
y = 43 x + 379
y = 16 x + 420
1
2
3
4
Set size

FIGURE 3.3

Experiment 3: Total mean correct RT graphed for each session of practice given to retarded adults, nonretarded children and nonretarded adults under fixed set and varied set procedures.



Non-retarded Children
Retarded Adults
Non-retarded Adults
Total mean correct RT (m secs)
1400
1200
1000
800
600
400
200
1 2 3 4 5 6 7
Session
Varied
Fixed

Procedure factor (see Appendix 3.5). The significant interaction of Practice and Procedure ($F = 8.96$, 6/126 df, $p < 0.01$) confirmed the observation from separate Session 1 and 2 analyses that the significantly slower responding in the varied set procedure only occurred on Day 1. The interaction of Group and Practice was significant ($F = 4.41$, 12/126 df, $p < 0.01$). This confirmed the hypothesis that when compared with normal adults, younger mental-age groups are differentially sensitive to effects of practice, this applying to memory scanning tasks as well as to other tasks already discussed above (see Sections 3.1.2 and 3.1.3).

The significant interaction of Group, Procedure and Practice ($F = 2.32$, 12/126 df, $p < 0.05$) further indicated that performance in the retarded group benefited more from practice under the varied set procedure than under the fixed set procedure.

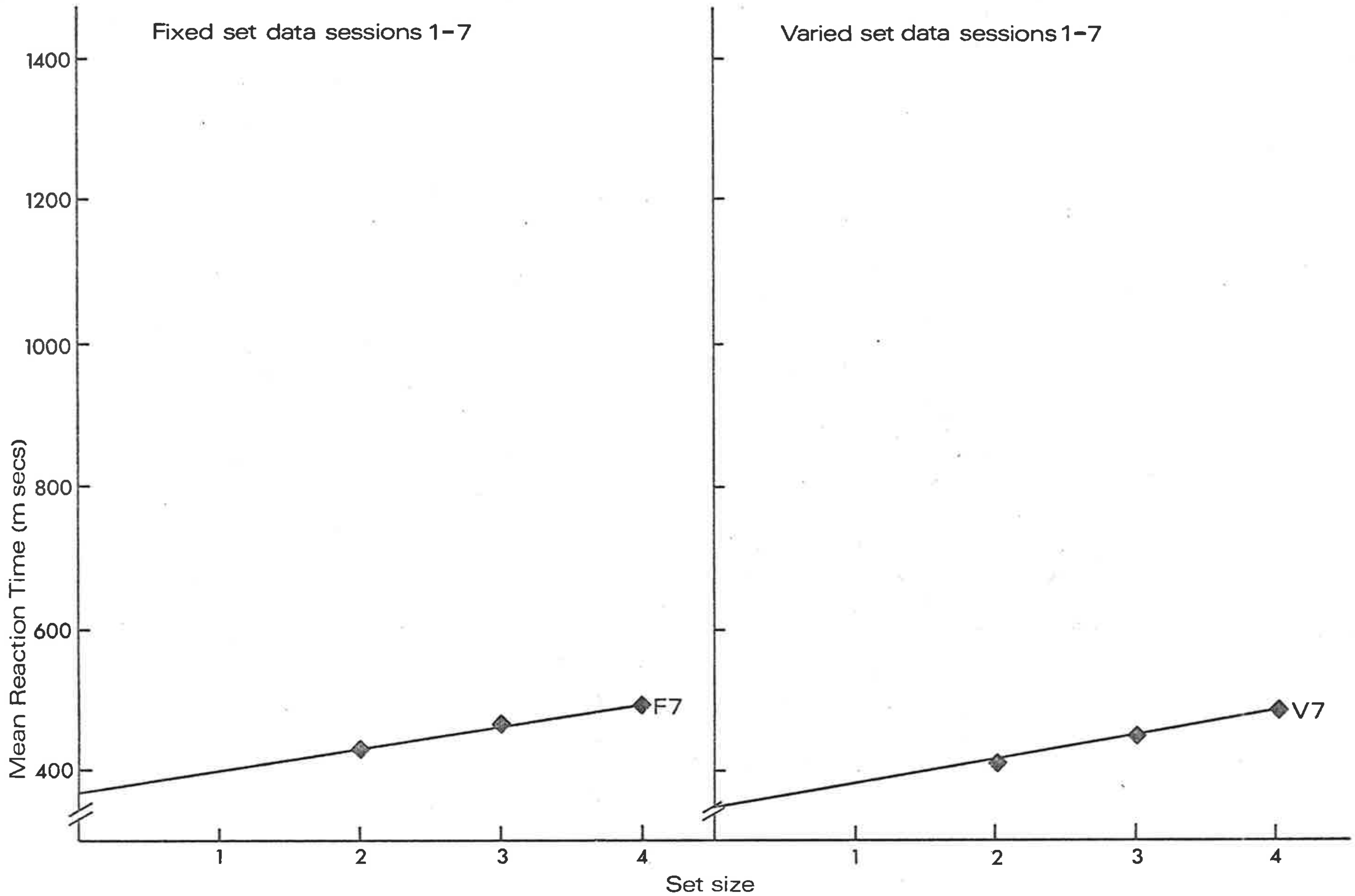
3.3.4 Practice effects on slopes and intercepts

Item recognition functions for each group with 'yes' and 'no' responses combined are presented in Figures 3.4, 3.5 and 3.6. These figures illustrate changes in the slopes and intercepts of item recognition functions across sessions of practice. Corresponding equations for best fitting straight lines are included in Appendix 3.6. From Figure 3.4, it may be seen that the slight improvement with practice in RT among nonretarded adults was centred in the zero intercept rather than the slope of the item recognition function. Even the effect on intercept was small, although there was some variation in the data, due to inconsistent responding among one or two subjects, as will be discussed below. For the nonretarded adults, there was little difference between the two procedures.

Among nonretarded children, intercepts for fixed set item recognition functions decreased with practice, as may be seen in Figure 3.5. In Sessions 3 and 4, these subjects appeared to trade off slope and intercept, so that

FIGURE 3.4

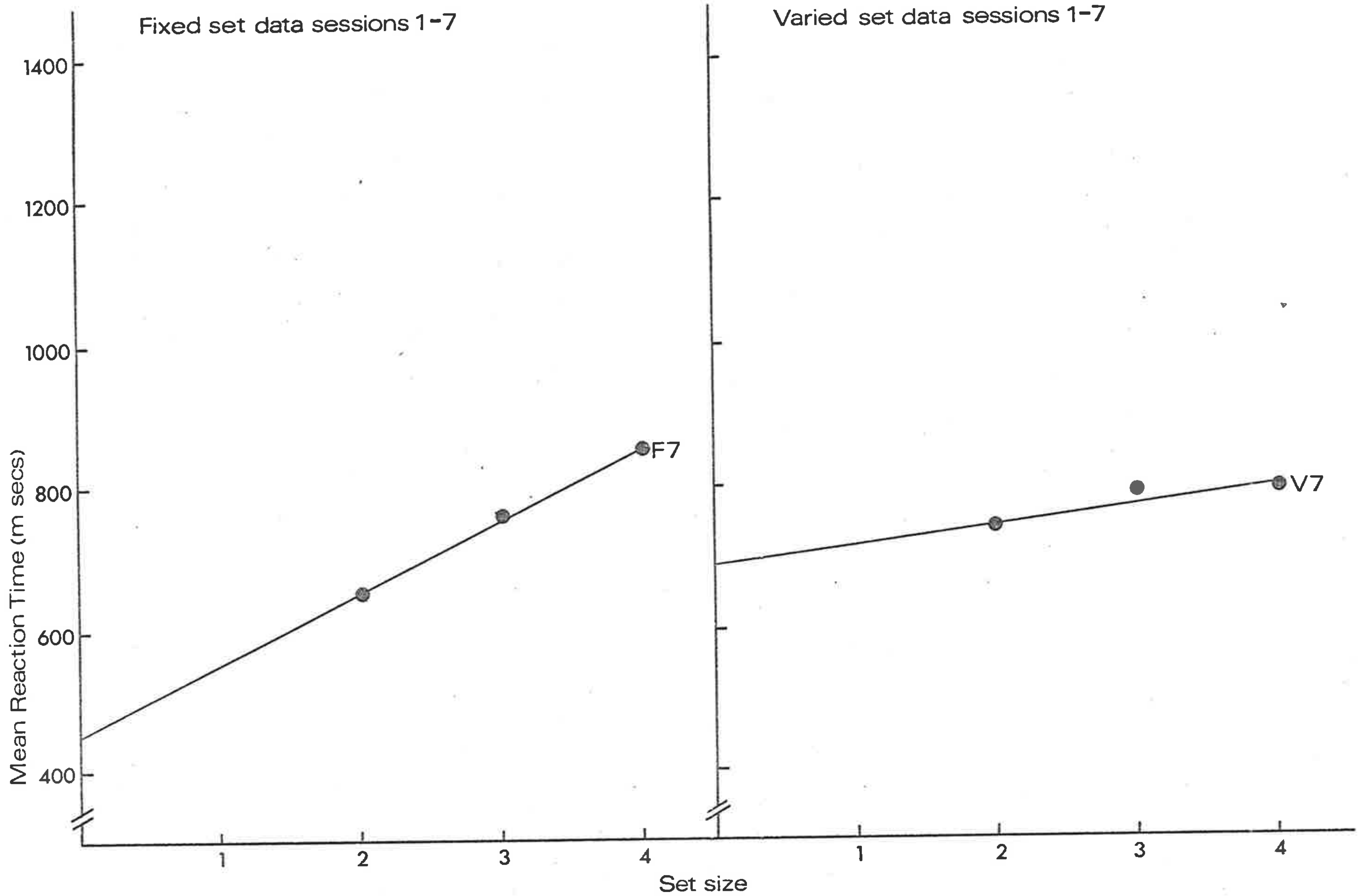
Experiment 3: Item recognition functions for each session of practice given to nonretarded adults, showing 'yes' and 'no' responses combined for fixed set and varied set procedures. Appendix 3.5 contains equations corresponding to the lines of best fit shown here.



Fixed set data sessions 1-7
Varied set data sessions 1-7
1400
1200
1000
800
600
400
Mean Reaction Time (m secs)
F7
V7
1
2
3
4
Set size

FIGURE 3.5

Experiment 3: Item recognition functions for each session of practice given to nonretarded children, showing 'yes' and 'no' responses combined for fixed set and varied set procedures. Appendix 3.6 contains equations corresponding to the lines of best fit shown here.


Fixed set data sessions 1-7
Varied set data sessions 1-7
1400
1200
1000
800
600
400
Mean Reaction Time (m secs)
F7
V7
1
2
3
4
1
2
3
4
Set size

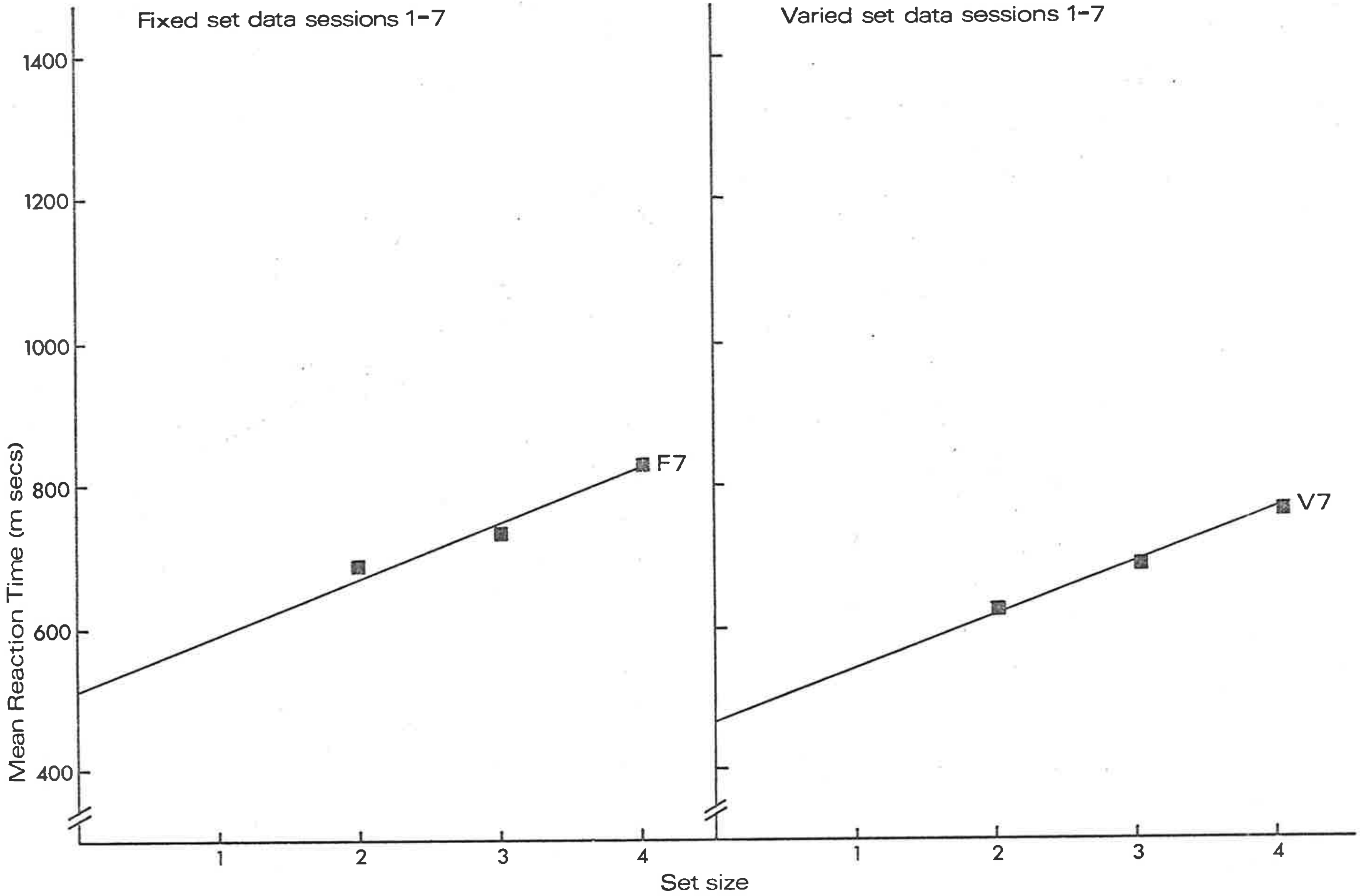
intercepts were higher than expected from other days but slopes were flatter. Under the varied set procedure for this group, there was some flattening of slope from Session 1 to Session 2, as well as a substantial reduction in intercept. Further practice produced smaller reductions in intercept. On the whole, intercepts were higher and slopes lower under the varied set procedure than under the fixed set procedure.

Inspection of functions for the retarded group in Figure 3.6 show that these subjects were obviously more affected by practice than subjects in either of the two control groups. There was a dramatic decrease in intercept under both fixed and varied set procedures. Although slope values were more variable across sessions than was found for the two control groups, a trend towards decreasing slope across sessions can be seen for both procedures. This variability among mean slope values was no doubt affected by the inconsistent relation between 'yes' and 'no' responses found for retarded subjects in Session 1 and Session 2, and also in the two earlier experiments, as described in Chapter 2. Nevertheless, the extent of the improvement found for this group can be seen by comparing their performance with that of the nonretarded children. Whereas the performance of retarded subjects under the varied set procedure began with a higher zero intercept than was found for nonretarded children, by Session 7 the intercept for the retarded group was reduced to below that found for the nonretarded children following the same amount of practice. However, the retarded group performance was similar to that of the mental age controls, in that slopes under the varied set procedure were slightly flatter than in the fixed set procedure, while zero intercepts were higher.

Straight lines were fitted to each subject's item recognition function for 'yes' and 'no' responses. When performance was without error, each mean RT point was based on 15 trials. Twenty-eight values of slope and intercept were calculated for each subject - 'yes' and 'no' responses for each of two

FIGURE 3.6

Experiment 3: Item recognition functions for each session of practice given to retarded adults, showing 'yes' and 'no' responses combined for fixed set and varied set procedures. Appendix 3.5 contains equations corresponding to the lines of best fit shown here.



Fixed set data sessions 1-7
Varied set data sessions 1-7
Mean Reaction Time (m secs)
1400
1200
1000
800
600
400
F7
V7
1
2
3
4
Set size

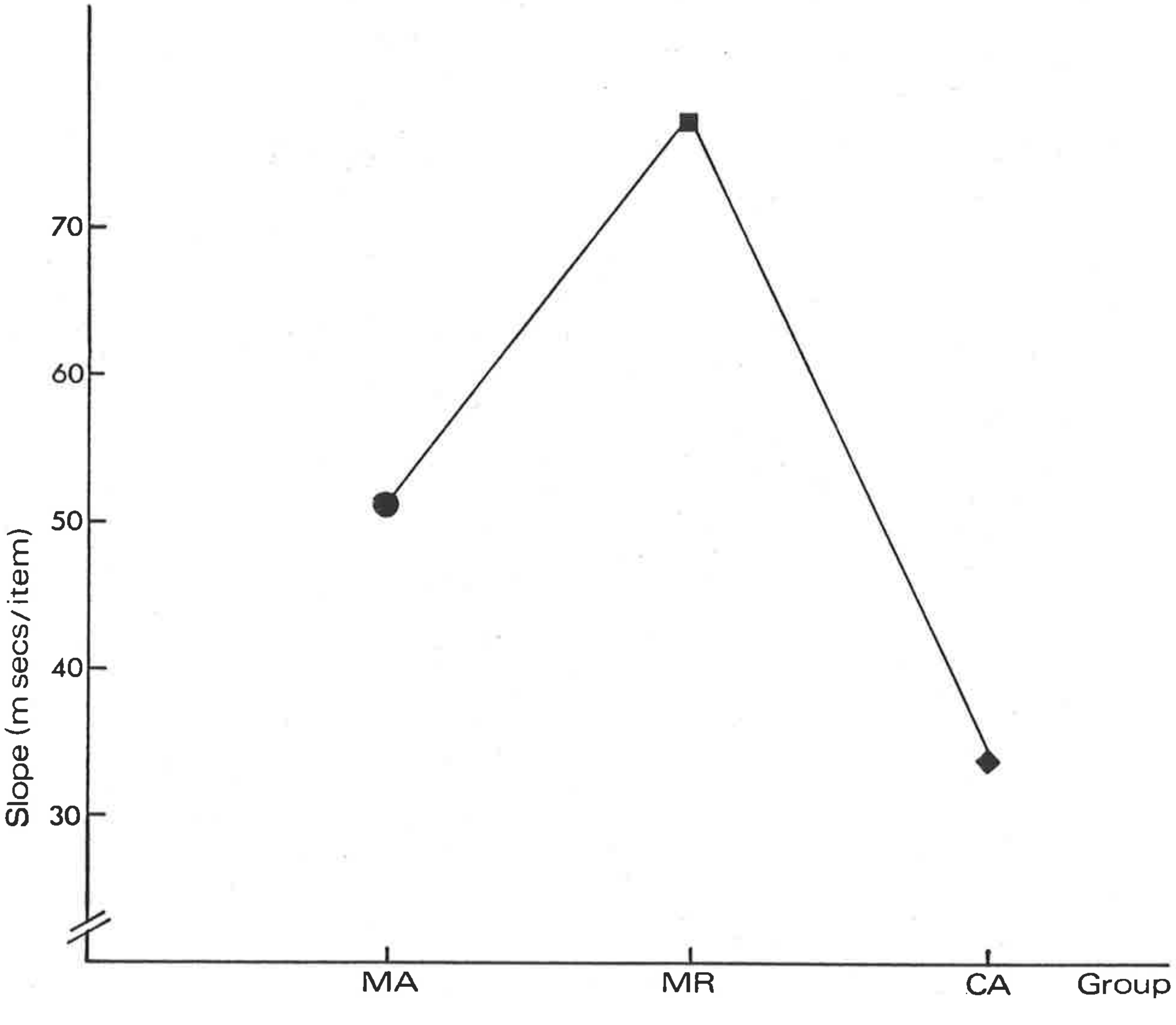
procedures, and for seven sessions of practice. These data were analysed in a Group x Procedure x Response x Practice analysis of variance. In the analysis of slopes, there were significant main effects for Group ($F = 4.60$, 2/21 df, $p < 0.05$) and for Procedure ($F = 7.51$, 1/21 df, $p < 0.05$; see Appendix 3.7). As can be seen in Figure 3.7, the main effect of Group reflected an overall gradation of slopes from nonretarded adults to non-retarded children to retarded adults, as found in the previous two experiments.

Profiles of slope coefficients from the recognition functions averaged across Response for each Group indicated that the fixed set procedure slopes showed no consistent change with practice, while the varied set procedure slopes decreased across sessions of practice in the data of retarded adults and nonretarded children. These results are summarized in Figure 3.8. The difference in slope between the two procedures was also greater in these two groups than in the nonretarded adult group. From the significant interaction between Group, Response and Practice ($F = 2.46$, 12/126 df, $p < 0.01$), there was much more variability in the relation between 'yes' and 'no' slopes for the retarded adults and nonretarded children than was the case among the nonretarded adults (see Figure 3.9). Variability of slope in the retarded group was centred in the 'no' slope, while 'yes' responses showed a steady decline in slope with practice.

In a similar analysis of zero intercepts, all four main effects of Group, Procedure, Response and Practice were significant (Group $F = 5.59$, 2/21 df, $p < 0.05$; Procedure $F = 9.49$, 1/21 df, $p < 0.01$; Response $F = 6.96$, 1/21 df, $p < 0.05$; Practice $F = 5.04$, 6/126 df, $p < 0.01$; see Appendix 3.8). Averaged across sessions, retarded adults and nonretarded children had higher zero intercepts than nonretarded adults, and the varied set procedure led to higher intercepts than the fixed set procedure, especially for 'no' responses (Procedure x Response interaction: $F = 6.71$, 1/21 df, $p < 0.05$) as shown in

FIGURE 3.7

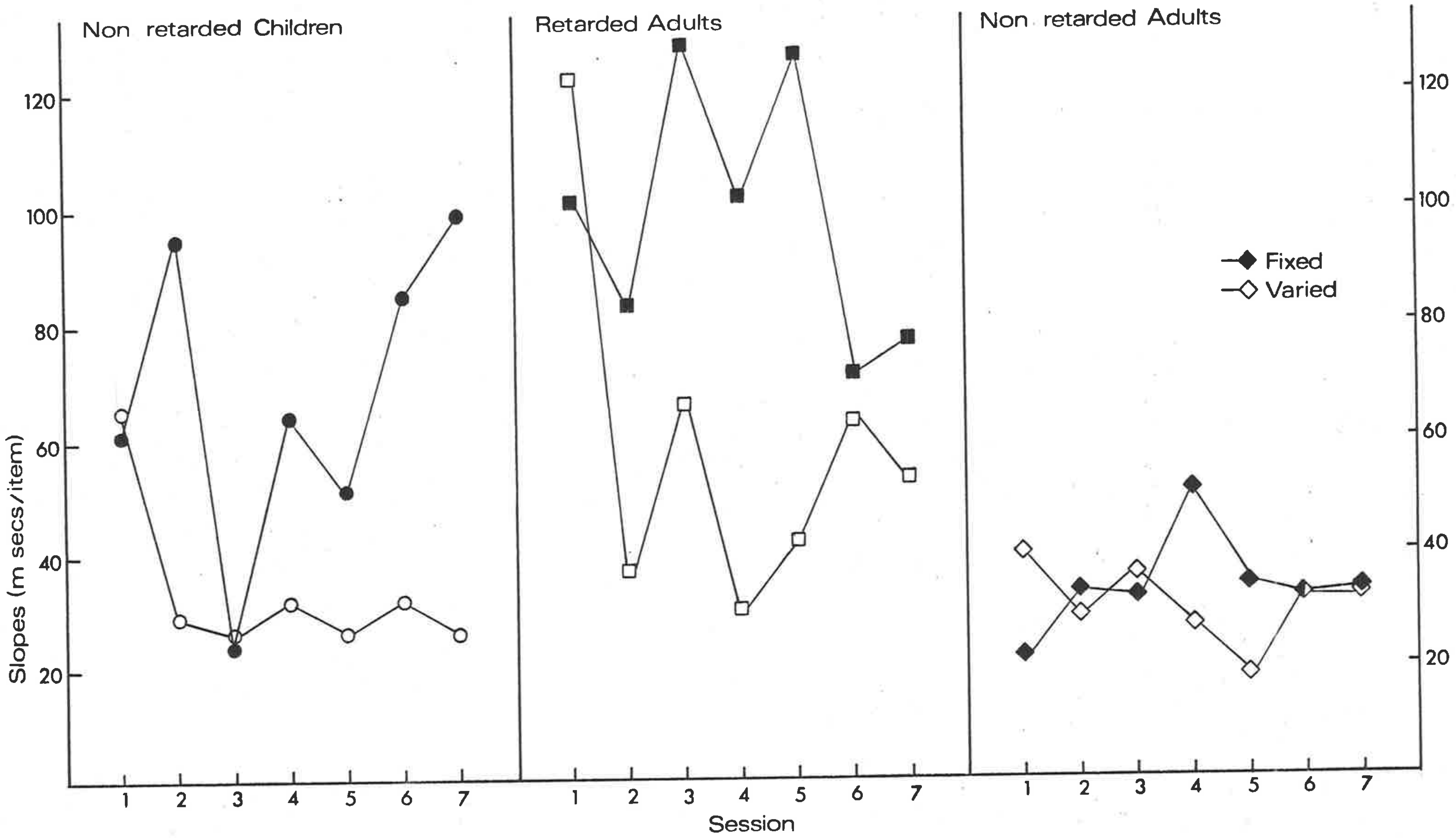
Experiment 3: Slope coefficients from item recognition functions for retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA) showing that, averaged across sessions of practice, there is a gradation of slopes from CA to MR.



Slope (m secs/ item)
70
60
50
40
30
MA
MR
CA
Group

FIGURE 3.8

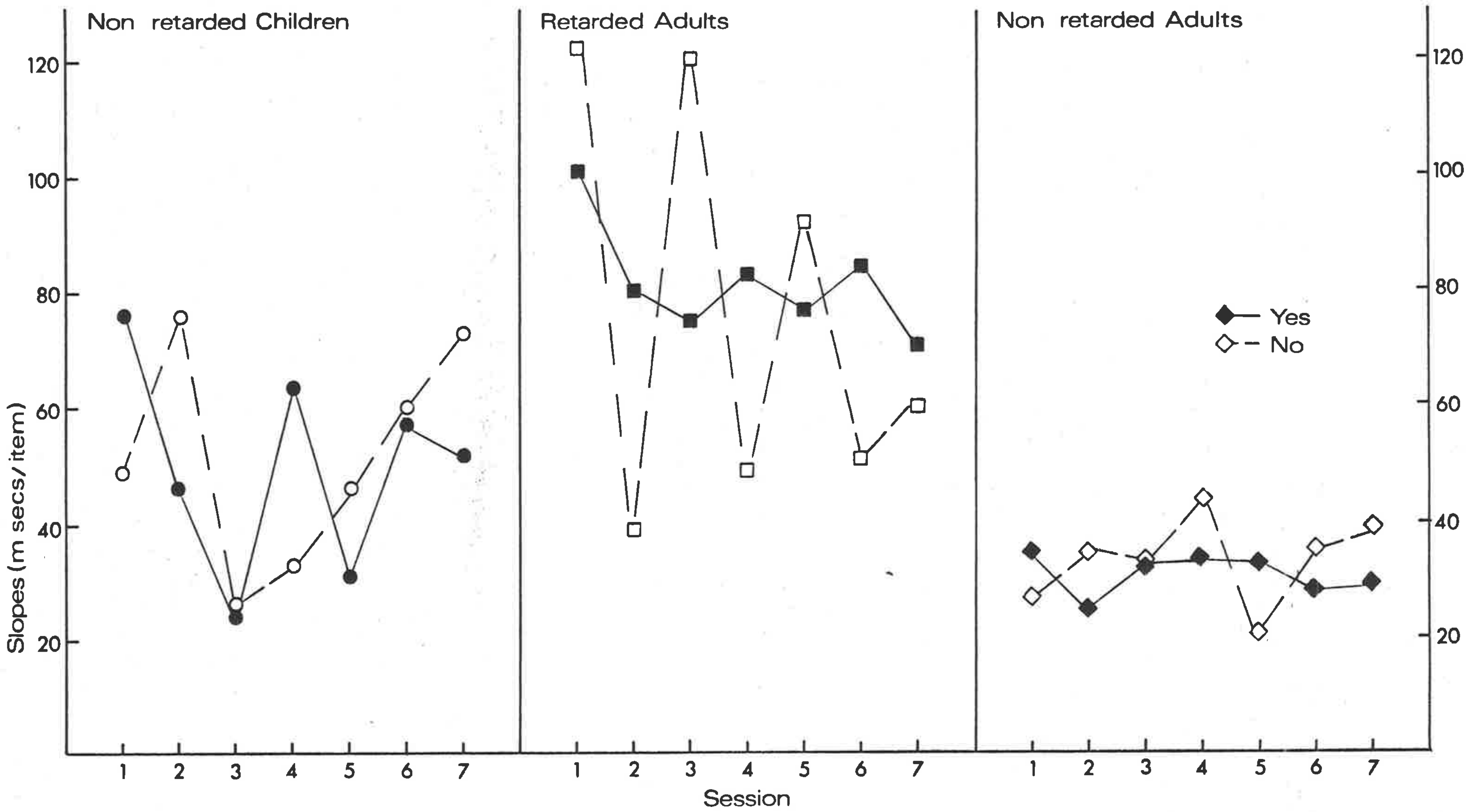
Experiment 3: Slope coefficients from item recognition functions of each session of practice given to retarded adults, nonretarded children and nonretarded adults, showing fixed set and varied set procedures.



Non retarded Children
Retarded Adults
Non retarded Adults
Fixed
Varied
Slopes (m secs/item)
20
40
60
80
100
120
1
2
3
4
5
6
7
Session

FIGURE 3.9

Experiment 3: Slope coefficients from item recognition functions for each session of practice given to retarded adults, nonretarded children and nonretarded adults, showing 'yes' and 'no' responses separately. Each line represents an average of fixed set and varied set procedure data.


Non retarded Children
Retarded Adults
Non retarded Adults
Slopes (m secs/ item)
120
100
80
60
40
20
1
2
3
4
5
6
7
Session
Yes
No

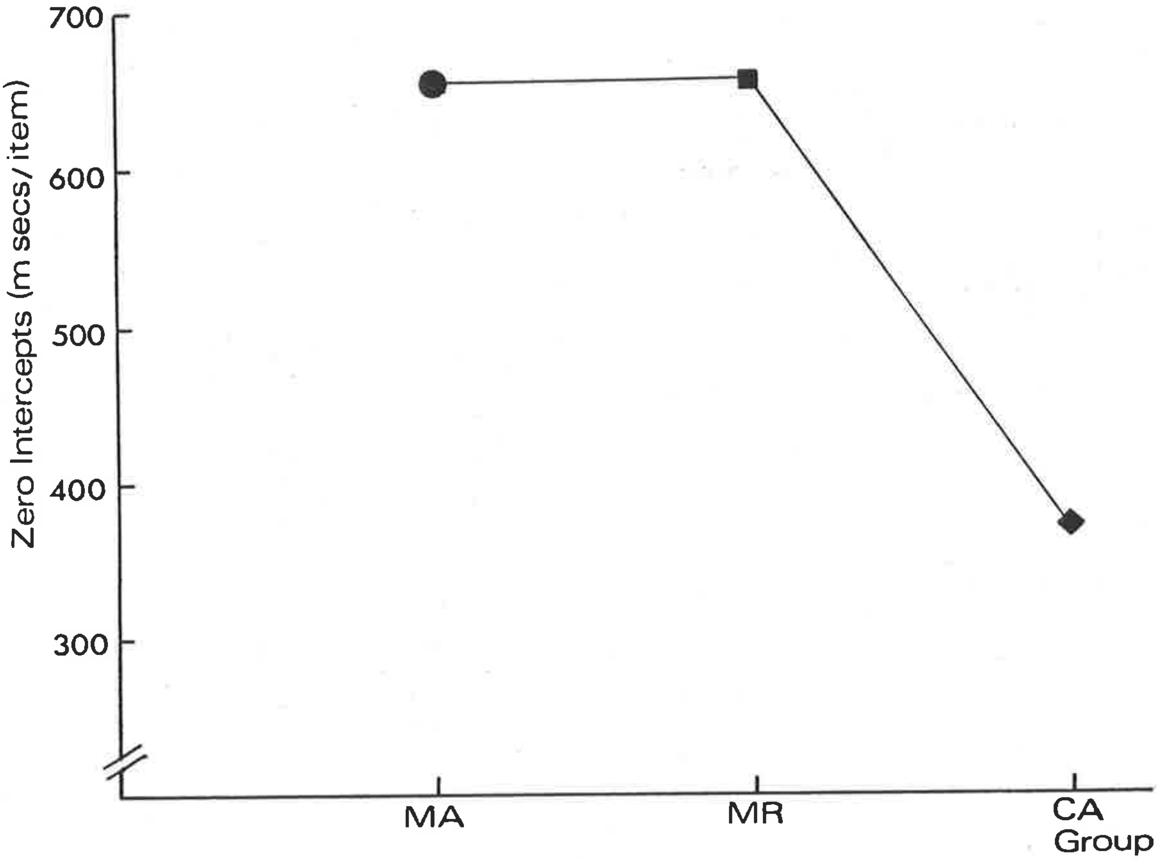
Figures 3.10 and 3.11. Thus, the varied set procedure led to a lower slope, but higher zero intercept than the fixed set procedure. A comparison between Figures 3.8 and 3.12 showed that, for retarded adults and nonretarded children, slope and intercept were not independent so that in sessions for which steep slopes were found, intercepts were relatively low, and vice versa. This trend can also be seen in a comparison of Figures 3.9 and 3.13.

Figure 3.12 illustrates the large decrease in the zero intercept of item recognition functions for the retarded group under the varied set procedure, compared with the less marked decrease in the performance of control groups. The significant interaction between Group, Response and Practice ($F = 2.23$, 2/21 df, $p < 0.05$) in the zero intercept analysis (see Figure 3.13) illustrated the greater variability between 'yes' and 'no' responses in the performance of retarded adults and nonretarded children, when compared with nonretarded adults.

It is possible that the results of the slope and zero intercept analysis were biased by the poor fit of retarded adults' and nonretarded children's data to straight lines. Since slope and intercept analyses were based on straight line fits to only three memory set size points, correct mean RT was also analysed so as to confirm the above findings. Correct mean RT was analysed in a five way, Group x Practice x Procedure x Response x Set Size analysis of variance. Four main effects were significant (Group $F = 10.85$, 2/21 df, $p < 0.01$; Practice $F = 17.80$, 6/126 df, $p < 0.01$; Response $F = 26.92$, 1/21 df, $p < 0.01$; Set Size $F = 70.94$, 2/42 df, $p < 0.01$; see Appendix 3.9), but the main effect for Procedure was not significant. Significant interactions between Group and Practice ($F = 4.22$, 12/126 df, $p < 0.01$) and Group and Set Size ($F = 4.27$, 4/42 df, $p < 0.01$) confirmed conclusions from an examination of the slopes and intercepts of item recognition functions that the main differences between the three subject groups following practice were related

FIGURE 3.10

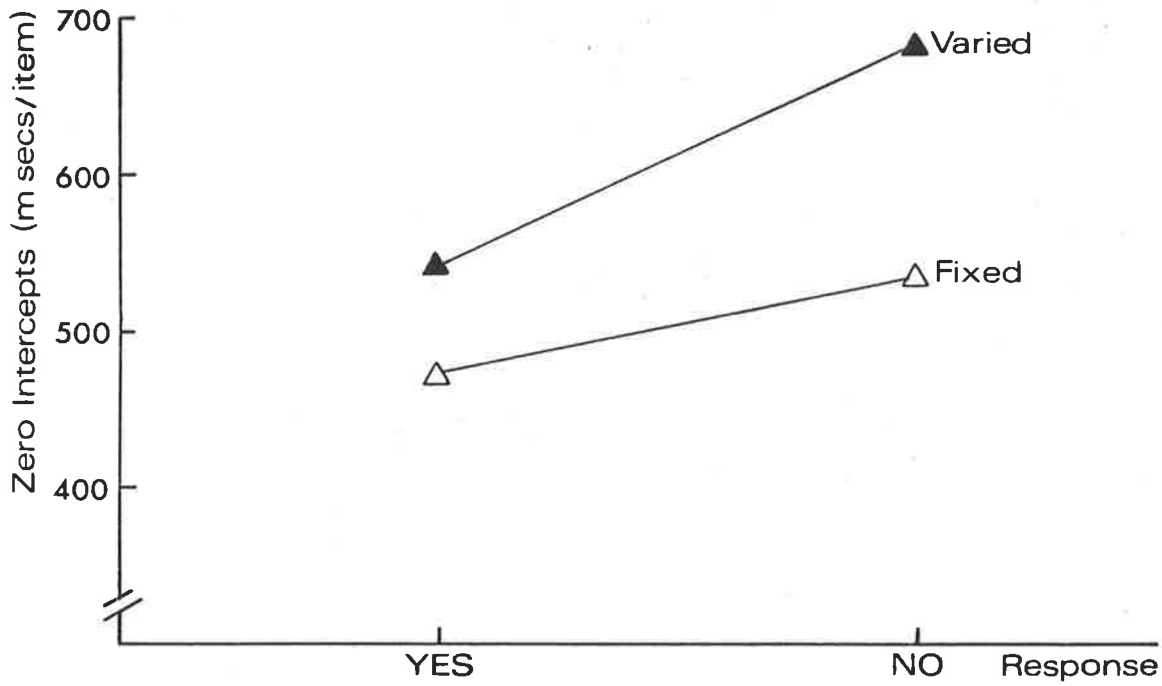
Experiment 3: Zero intercepts from item recognition functions for retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA) showing that, averaged across sessions of practice, retarded adults and nonretarded children had significantly higher zero intercepts than nonretarded adults.



Zero Intercepts (m secs/ item)
700
600
500
400
300
MA
MR
CA
Group

FIGURE 3.11

Experiment 3: The profile of a significant Procedure x Response interaction from a Group x Practice x Procedure x Response analysis of variance in zero intercepts, showing the greater difference between 'yes' and 'no' zero intercepts in the varied set procedure than the fixed set procedure.



Zero Intercepts (m secs/item)
700
600
500
400
Varied
Fixed
YES
NO
Response

FIGURE 3.12

Experiment 3: Zero intercepts from item recognition functions for each session of practice given to retarded adults, nonretarded children and nonretarded adults, showing data for fixed set and varied set procedures.

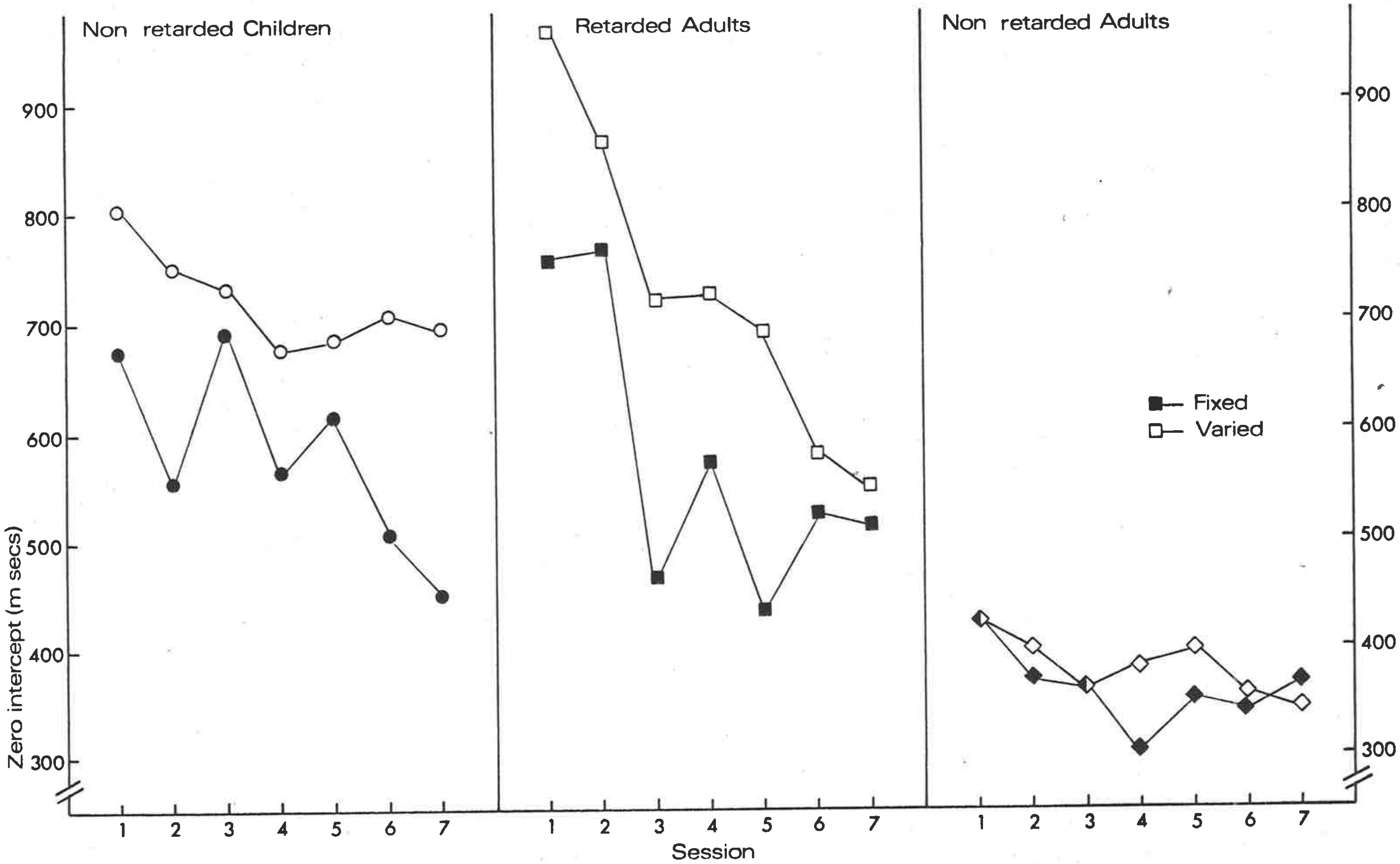
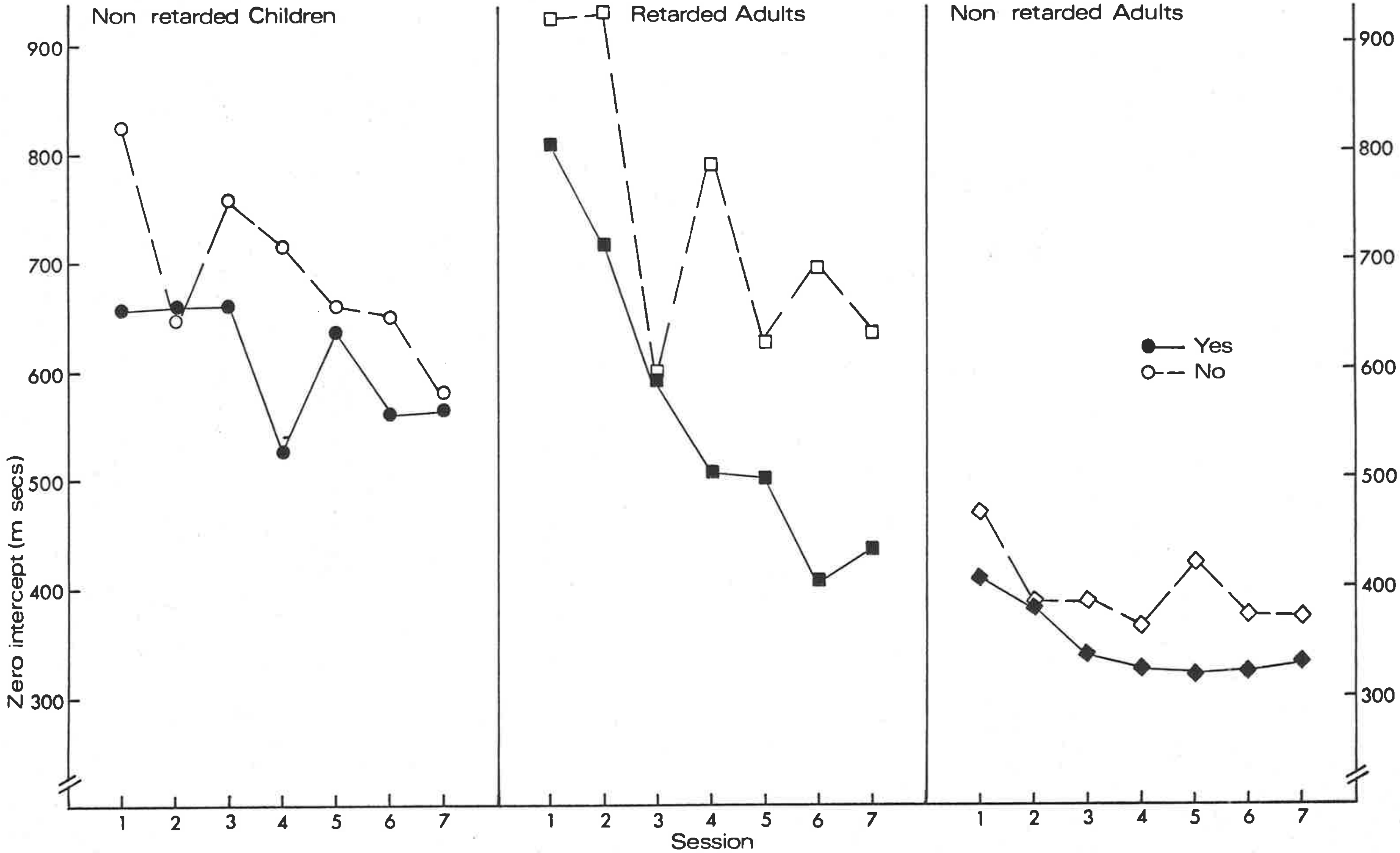

Non retarded Children
Retarded Adults
Non retarded Adults
Zero intercept (m secs)
900
800
700
600
500
400
300
1
2
3
4
5
6
7
Session
Fixed
Varied

FIGURE 3.13

Experiment 3: Zero intercepts from item recognition functions for each session of practice given to retarded adults, nonretarded children and nonretarded adults, showing 'yes' and 'no' responses. Each line represents an average of fixed set and varied set procedure data.


Non retarded Children
Retarded Adults
Non retarded Adults
Zero intercept (m secs)
900
800
700
600
500
400
300
Yes
No
1
2
3
4
5
6
7
Session

to different slopes. Significant interactions between Practice and Procedure ($F = 9.57$, 6/126 df, $p < 0.01$) and Group, Practice and Procedure ($F = 2.31$, 12/126 df, $p < 0.05$) confirmed that the initial difference in mean RT between procedures was reduced with practice, and that the retarded group benefited most from practice under the varied set procedure. Further significant interactions between Procedure and Set Size ($F = 7.44$, 2/42 df, $p < 0.01$) and Practice, Procedure and Set Size ($F = 2.64$, 12/252 df, $p < 0.01$) reflected the differences in slope between procedures and across practice. Finally, differences in variability across practice between the 'yes' and 'no' responses of the retarded and nonretarded younger mental age groups was also shown in significant higher order interactions (see Appendix 3.9).

3.3.5 **Practice effects and the additive factor method**

Three important outcomes from the analyses of the slopes and intercepts of item recognition functions were:

(i) A significant difference between slopes for the three groups;

(ii) Nonretarded adult subjects showed almost no change in slope across sessions of practice, and no difference between the two procedures used. Nonretarded children and the retarded group performed differently under the two procedures and across sessions of practice. The varied set procedure resulted in a more consistent reduction of slope, this trend being most marked for the retarded group;

(iii) The slight decrease in RT found among nonretarded adult subjects was centred in the zero intercept. There was, however, a substantial decrease in intercept values for both the retarded group and nonretarded children having the same mental age.

However, an interpretation of slopes and zero intercepts from average group item recognition functions in terms of the original Sternberg four-stage model of retrieval is not justified, since significant negative correlations were found within all three groups. These are set out in Table 3.5.

Inspection of individual data suggested that a small number of subjects were sometimes not responding in the same way as the rest of the group on particular days. Subjects for whom the item recognition function obtained had a negative slope, or where the function was obviously nonlinear, or where functions had a very steep slope with a very low intercept, have not been included in a follow-up analysis, on the grounds that these data were clearly divergent from the group as a whole, so that a plausible psychological explanation similar to that suggested by other data became impossible. It has been assumed, rather, that these subjects did not follow the instructions for the experiment, and did not respond as quickly as possible at all set sizes.

Among nonretarded adult subjects, correlations between slopes and intercepts were reduced when subjects whose data were considered not representative of the group as a whole were disregarded. Although no varied set procedure correlations were significant after this adjustment, some correlations under the fixed set procedure were still significant, and most remained clearly negative (see Table 3.6). However, a similar examination of individual data from the retarded group indicated that goodness of fit for RT/set size functions was poor compared with that obtained for normal adults, and there were no subjects whose item recognition functions were obvious outliers from the rest of the group.

3.3.6 **Variability of RT**

It is possible that the high correlations found between the slopes and intercepts for item recognition functions in the retarded group reflect to some extent the heterogeneity of group data, since reduction of between-subject variability in the nonretarded adults group was accompanied by a reduction in the size of the correlation. There is evidence that within-subject variability in simple RT decreases with practice (Hoover et al., 1980). Since it is also known that slower RT is more variable than fast RT (e.g.

GROUP: Nonretarded Adults

PROCEDURE:	FIXED		VARIED	
RESPONSE:	NO	YES	NO	YES
SESSION				
1	-0.70	-0.65 (n=6)	-0.61	-0.40
2	-0.85 (n=5)*	-0.69 (n=6)	-0.66 (n=7)	10.52 (n=7)
3	-0.85 (n=6)*	-0.90 (n=7)**	-0.57	-0.48
4	-0.22 (n=7)	-0.93 (n=7)**	-0.60 (n=7)	-0.66 (n=6)
5	-0.66 (n=7)	-0.93 (n=6)**	-0.73 (n=7)	-0.33
6	-0.67	-0.74 (n=7)	-0.32	-0.66 (n=6)
7	-0.89**	-0.85 (n=6)*	-0.63	-0.79 (n=5)

Table 3.6: Experiment 3 within group correlations for nonretarded adults after some atypical subjects were excluded, as described in the text.

** $p < 0.01$ (two tailed)

* $p < 0.05$ (two tailed)

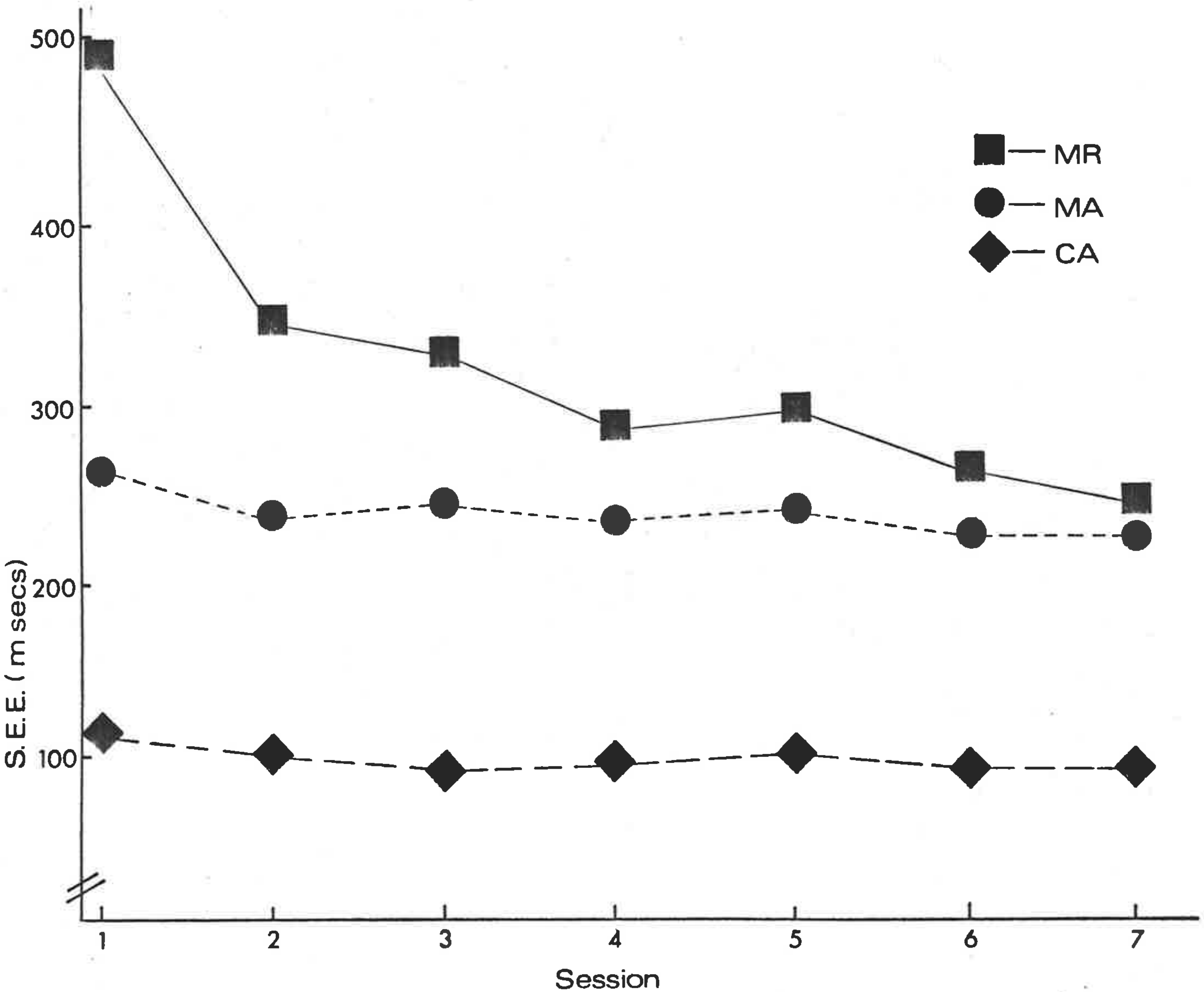
Thomas et al., 1978) and RT decreases with practice (Murrell, 1970), one would expect some reduction in variability with practice.

The standard error of estimate (SEE) of the fit of each subject's data to a straight line was analysed in a Group x Procedure x Response x Practice analysis of variance. Main effects of Group, Practice and Procedure were significant, while the Response main effect was not significant (Group $F = 5.79$, 2/21 df, $p < 0.01$; Practice $F = 10.70$, 6/126 df, $p < 0.01$; Procedure $F = 14.10$, 1/21 df, $p < 0.01$; see Appendix 3.10). There was also a significant linear trend in the Practice factor. The significant interaction between Group and Practice ($F = 5.49$, 12/126 df, $p < 0.01$) indicated that while the two control groups responded with much the same variability across sessions of practice, the retarded group reduced variability, and by the end of seven sessions were responding at a level of variability close to that found among the mental age controls (see Figure 3.14). The interaction between Practice and Procedure ($F = 2.74$, 6/126 df, $p < 0.05$) illustrated the faster reduction in variability under the varied set procedure over the first few sessions of practice (see Figure 3.15). Therefore, from the analysis above, retarded subjects may have moved towards a common, more efficient strategy. As practice continued, individual responding became more like the group average.

Standard deviations were analysed to determine whether the reduction in variability exhibited by the retarded group was general variability, or rather, centred in particular aspects of the situation which subjects found difficult. Thus, practice might reduce the standard deviation for one set size more than for other set sizes, so that a Set Size x Practice interaction would occur. Data were analysed in a five way, Group x Practice x Procedure x Response x Set Size analysis of variance. Main effects for Group, Practice, Procedure and Set Size were significant, while the main effect for Response was not significant (Group $F = 5.66$, 2/21 df, $p < 0.05$; Practice $F = 11.05$,

FIGURE 3.14

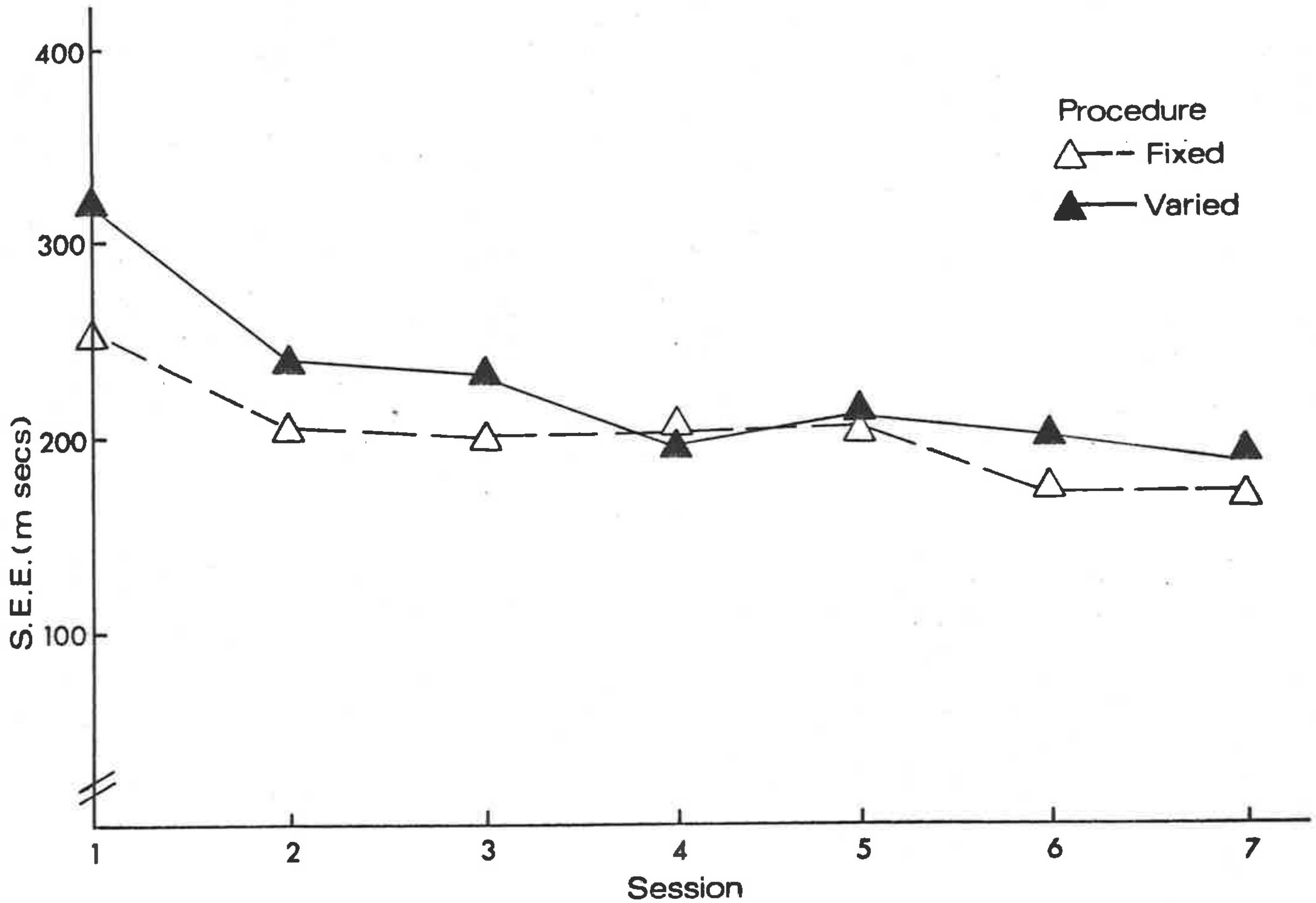
Experiment 3: Standard errors of estimate (SEE), averaged over procedures and responses, at each session of practice given to retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA).



500
400
300
200
100
S.E.E. (m secs)
MR
MA
CA
1
2
3
4
5
6
7
Session

FIGURE 3.15

Experiment 3: Standard errors of estimate (SEE), averaged over groups and responses, at each session of practice under fixed set and varied set procedures.



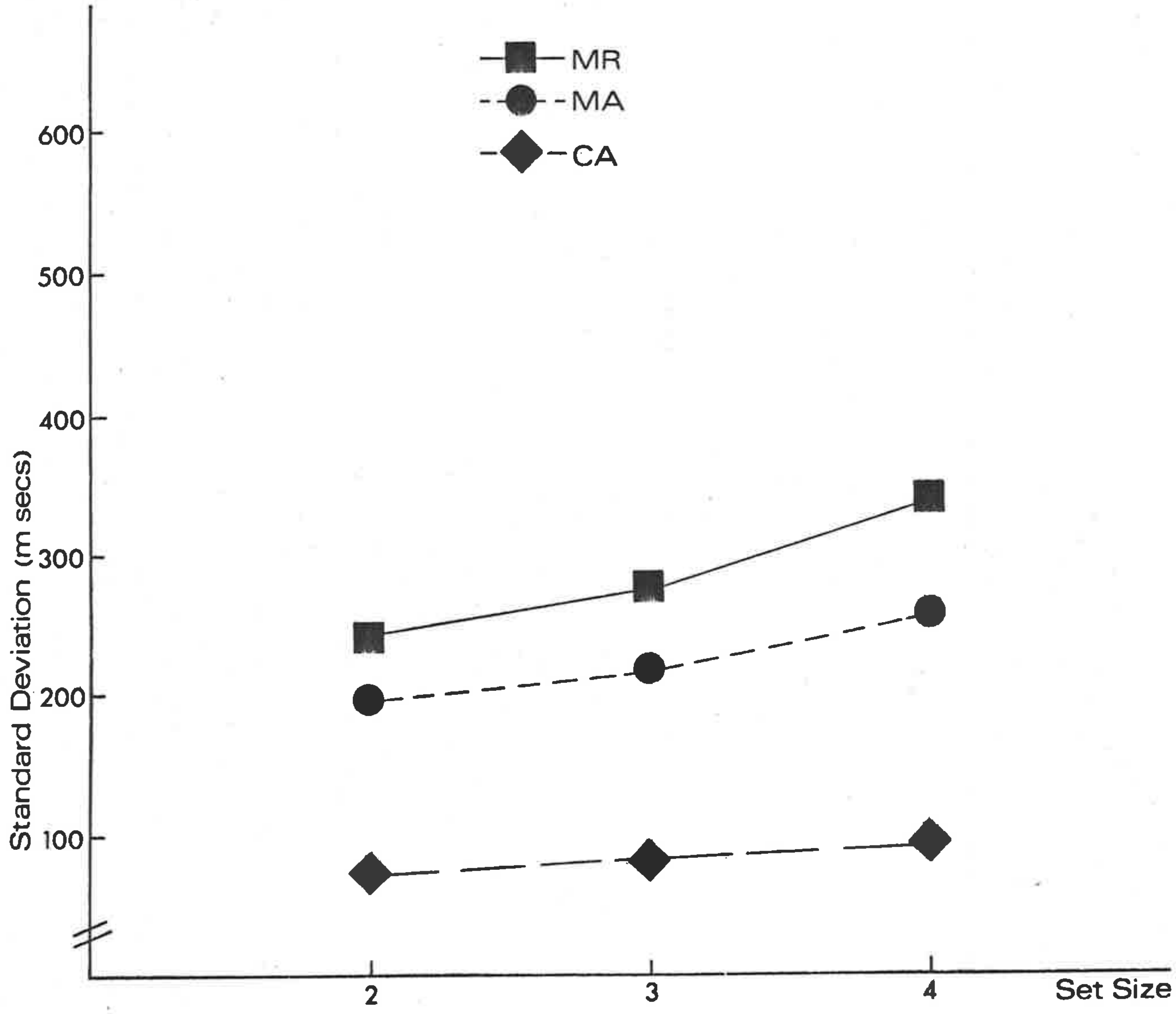
Procedure
Fixed
Varied
400
300
200
100
S.E.E. (m secs)
1
2
3
4
5
6
7
Session

6/126 df, $p < 0.01$; Procedure $F = 18.47$, 1/21 df, $p < 0.01$; Set Size $F = 22.64$, 2/42 df, $p < 0.01$; see Appendix 3.11). There were also significant interactions between Group and Practice ($F = 5.12$, 12/126 df, $p < 0.01$) and Group and Set Size ($F = 3.40$, 4/42 df, $p < 0.05$). As seen in Figure 3.16, variability in RT of the retarded adults and nonretarded children increased across set size, while nonretarded adults were less affected. Other significant interactions between Practice and Procedure ($F = 2.76$, 6/126 df, $p < 0.05$) and Procedure and Set Size ($F = 5.85$, 2/42 df, $p < 0.01$) were due to the greater reduction in variability with practice under the varied set procedure than under the fixed set procedure, with this particularly so at low set sizes. The interactions between Practice and Set Size and between Group, Practice and Set Size were not significant. Thus, the reduction in standard deviation with practice was not located in one set size. Furthermore, the reduction in standard deviation along with a reduction in mean RT was exclusive to the retarded group, as both control groups showed only a slight reduction in variance with practice.

In the analysis of SEE the retarded group was found to become more homogeneous in responding with practice. It may be argued that this reduction in variability was due to fewer outlying RTs as subjects became more accustomed to the experimental situation. Although a reduction in extremely slow responses would be an interesting effect of practice, change in group differences based on such an effect would not be as enlightening as a change in median responses. To control for this possibility, outlying RTs were excluded and data reanalysed, as already described for Experiments 1 and 2 (see Section 2.3.5). Trials were excluded from analysis if RT was greater than 1500 msecs, and of the remaining trials, those further than ± 1.96 standard deviations from the lowered mean were excluded. This procedure, however, led to the exclusion of a considerable percentage of data in the first sessions of practice (see Appendix 3.12). The gradual reduction of percentage

FIGURE 3.16

Experiment 3: Standard deviation of mean RT data for each set size, averaged across 'yes' and 'no' responses and sessions of practice, for retarded adults (MR), nonretarded children (MA) and nonretarded adults (CA).


MR
MA
CA
600
500
400
300
200
100
Standard Deviation (m secs)
2
3
4
Set Size

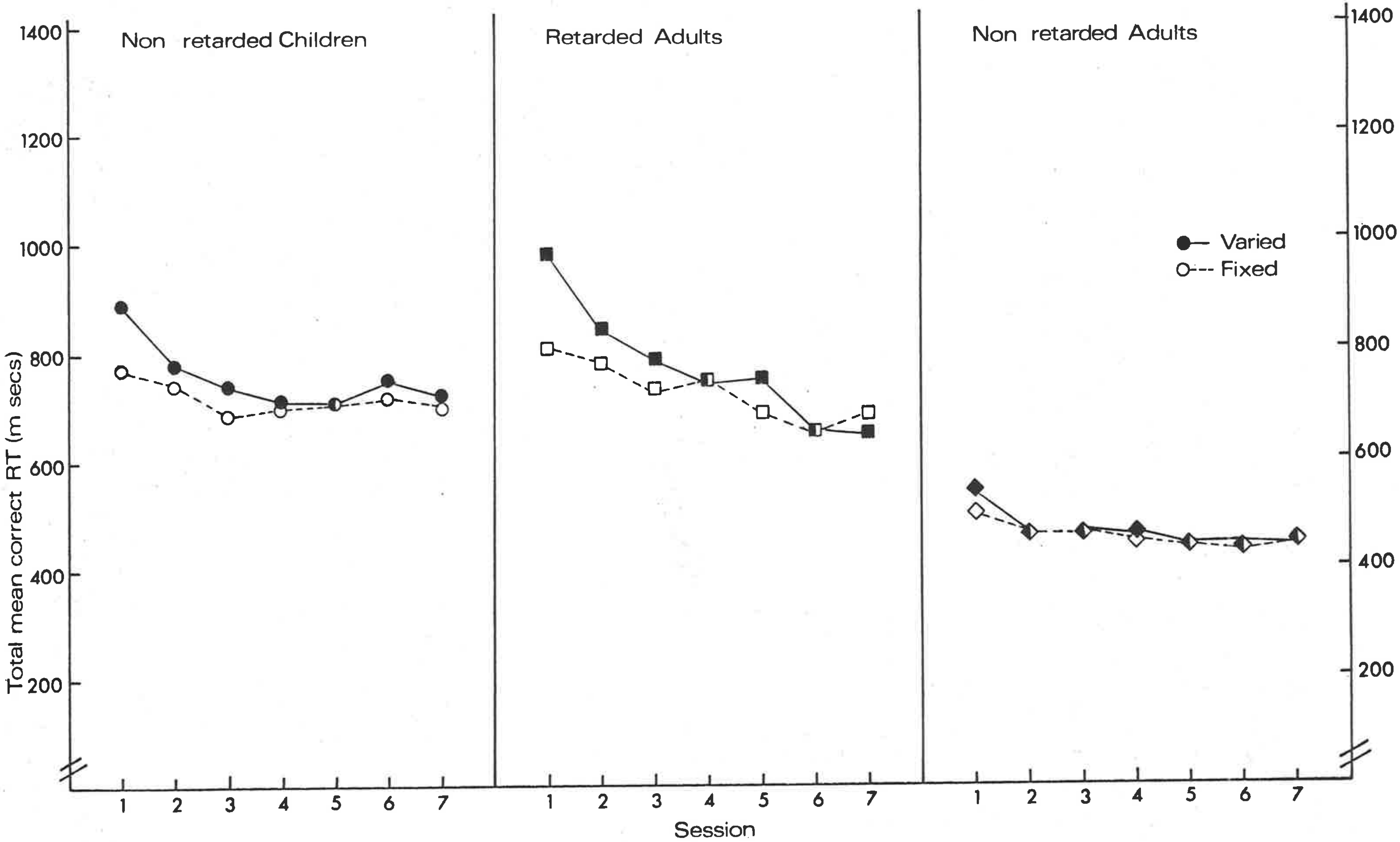
of trials removed by this procedure across practice was another indication of the reduction in variability with practice. With the proviso that among mildly retarded subjects initial sessions of practice do not adequately represent subsequent performance, these data are presented below, since they illustrate that with "noise" removed, performance was distinctly stable, and yet the results found using all data were clearly replicated.

Total mean RT graphed across sessions of practice (Figure 3.17) showed that these reductions did not change the pattern of results obtained, although, as expected, functions were placed further down the ordinate. Comparison of these data with original data shown in Figure 3.3 showed that variability of group distributions was most marked for the retarded group. Nonretarded adults were least affected, and the retarded group functions were brought comparatively closer to nonretarded children's functions. Performances in retarded adults and nonretarded children under the fixed set procedure were similar at the beginning of practice, while performance of the retarded group under the varied set procedure remained poorer than the performance of nonretarded children under this procedure throughout practice. However, there was still clearly a greater reduction in the overall RT of retarded adults than nonretarded controls over the course of practice, whereas the overall RT of nonretarded children reached an asymptote after about three sessions of practice; overall RT of retarded adults showed a clear downward trend which continued to the last session. Analysis of mean RT replicated previous analyses (see Appendix 3.13).

When slopes and intercepts were calculated from reduced data, the same pattern of between group differences was observed, as has been described above for complete data, although because long RTs were excluded, differences were not as marked as in the analysis of all data (see Appendix 3.14). Under the varied set procedure, there was still an initial gradation among the slopes of mean item recognition functions from

FIGURE 3.17

Experiment 3: Total mean correct RT for each session of practice given to retarded adults, nonretarded children and nonretarded adults under fixed set and varied set procedures. Each point has been calculated after very long RTs were excluded from the analysis, as described in the text.



Non retarded Children
Retarded Adults
Non retarded Adults
Varied
Fixed
Total mean correct RT (m secs)
1400
1200
1000
800
600
400
200
1 2 3 4 5 6 7
Session

nonretarded adults (least steep) to nonretarded children to retarded adults (most steep). At the end of seven sessions of practice, the retarded group still had a higher slope than control groups. Reduction of variability reduced slopes and intercepts of item recognition functions for all three groups, but the effect was most marked for the retarded group. Under the fixed set procedure, reduction of variability meant that slopes were reduced, but intercepts increased, indicating that RTs at larger set sizes were reduced more than at smaller ones. The reduction of slopes and intercepts from functions of the retarded group data was most marked under the varied set procedure. These results therefore supported the suggestion that the item recognition functions obtained from retarded subjects may exhibit lower slopes and intercepts when variability of responding is reduced.

Finally, analysis of SEE and standard deviations suggested that there may be significant heterogeneity of variance between groups, violating the analysis of variance assumption of homogeneity of variance. However, Winer (1971) has indicated that the analysis of variance is not greatly affected by departures from normality or homogeneity of variance, and Box (1954) showed that the level of significance is negligibly affected by significantly heterogeneous variance when there are equal n's in all conditions, as was the case in the present data.

3.4 GENERAL DISCUSSION

A number of precautions were taken in Experiment 3 to permit comparison of the retarded group with the two control groups. Information about performance was given following each trial in an attempt to maintain the attention of subjects in younger mental age groups, individual results were displayed and subjects paid to maintain incentive. Although this reward was noncontingent, the reduction in overall RT across seven successive sessions of practice indicated that subjects were motivated and that the conditions as arranged successfully directed subjects' performance towards optimum. Error rates were very low, and there was no evidence of a speed-accuracy tradeoff across sessions of practice. Although RTs of retarded subjects were slower and more variable than those for nonretarded adults, reducing this variability by excluding the longest RTs from analysis did not substantially change the pattern of results obtained. Use of analysis of variance which is robust with regard to heterogeneity of variance enabled group comparisons to be considered within the framework of the additive factor method.

Analysis of mean RT showed that practice did have a differential effect on the three groups. This finding is consistent with evidence that tasks involving strategic behaviour, including RT tasks, are sensitive to developmental change (Brown, 1974; Wickens, 1974). Whereas the reactions of nonretarded adults reached an asymptote early during practice, nonretarded children and retarded adults continued to become faster over a longer period of trials. Children reached an asymptote after three or four sessions, but retarded adults were still becoming faster at the end of seven sessions. This change over substantially longer periods of practice suggests that retarded persons are disadvantaged by comparison with nonretarded persons in tasks of this kind. The slower asymptotic performance found in younger mental age groups indicates that group differences previously reported in the memory scanning literature (e.g. Herman & Landis, 1977) may have been due mainly to insufficient familiarisation with the task among the younger groups.

Although analyses of the slopes and zero intercepts of item recognition functions were based on only three memory set sizes, further analyses of mean RT confirmed that slope and intercept data provided reliable measures of performance. Nonretarded adults showed no systematic change in slope with practice, replicating studies in the literature which have been interpreted as indicating that exhaustive, serial search strategies are employed when particular stimuli are not consistently associated with one response (Kristofferson, 1972). The slight reduction in RT with practice found for the nonretarded adult group was located in the zero intercept of the item recognition function, suggesting an improved efficiency when encoding input, or in response selection processes, or both. Results obtained from fixed and varied set procedures were virtually identical, confirming evidence reviewed in Chapter 1 that normal adults appear to use the same memory search strategies under these different conditions.

Among nonretarded children, mean RT reached an asymptotic level above that found for nonretarded adults, a result consistent with evidence that even when factors of practice and attention are controlled for, there is still some central limitation to children's speed of processing (Wickens, 1974). This difference in speed was located mainly in the zero intercept of the item recognition function, the average performance remaining higher at the end of seven sessions of practice, whereas the slopes of functions under the varied set procedure were much the same among nonretarded children and adults. This finding therefore suggests that studies reporting that speed of memory search increases with increasing mental age have not controlled adequately for differential sensitivity to practice which is age related, at least for children up to about 11 years.

Although the form of item recognition functions for the two control groups was consistent with serial, exhaustive memory scanning, all three groups in the present experiment also exhibited negative, within-group correlations between slopes and intercepts. In the Sternberg model, separate stages are identified when two main requirements are met: firstly, when factors thought to represent separate stages are additive; and secondly, when factors are stochastically independent, or do not correlate. Although stages can be additive without being independent, a tacit assumption of research into the memory scanning of normal subjects has been that if the item recognition function shows the basic characteristics of serial, exhaustive scanning and additive Response and Set Size factors, then the supplementary characteristic of independence has also been found. Tests of independence of stages, either by within-group correlation of slopes and intercepts or additive factor analysis of higher cumulants, are not generally reported in the literature.

The present experiment and those reported in Chapter 2 have shown that even when item recognition functions are similar to those generally found with varied stimulus-response mapping, substantial negative correlations between slope and intercept can occur. However, as yet there is no explanation for the inconsistent appearance of significant correlations. The present experiment found no compelling change in the size of correlations with increasing practice. Maisto (1978) has suggested that negative correlations may occur when there is large between-subject variability. In fact, correlations for the nonretarded adult group were reduced when between-subject variability was reduced in the present experiment. Under this hypothesis, one would not expect correlations for nonretarded adults and nonretarded children in the present experiment to change with practice, since SEEs of control groups were not substantially affected by practice. However, if variability is related to the degree of correlation as Maisto has suggested, then one would expect some group differences in size of correlations, with correlations being strongest in the retarded group. There was, however, no evidence for such group differences in the present experiment. Furthermore, between-subject variability in the retarded group decreased significantly with practice, while negative correlations remained substantial.

Table 3.7 shows correlations found for nonretarded and retarded group data from Experiments 1 and 2, together with correlations available from the literature. Nearly all of the correlations for nonretarded children have been negative, while of the few available for nonretarded adults, two published

NONRETARDED CHILDREN

Study		Response	Age	n	Correlation
Silverman (1974)		Y+N	7.5	12	-0.57
Experiment 1	(fixed proc.)	Y	9.0	10	-0.06
		N	9.0	10	-0.12
	(varied proc.)	Y	9.0	10	0.34
		N	9.0	10	-0.45
Experiment 2	(fixed proc.)	Y	9.8	10	-0.64*
		N	9.8	10	-0.66*
	(varied proc.)	Y	9.8	10	-0.12
		N	9.8	10	-0.62*
Dugas & Kellas (1974)		Y+N	10.5	14	-0.001
Seymour & Moir (1981)		Y	11.0	36	-0.61*
		N	11.0	36	-0.47*
Silverman (1974)		Y+N	11.0	12	-0.53
Maisto & Jerome (1977)		Y+N	13.0	6	-0.11
" "	(degraded probe)	Y+N	13.0	6	-0.48
Silverman (1974)		Y+N	14.0	12	-0.52

NONRETARDED ADULTS

Study		Response	n	Correlation
Chiang & Atkinson (1976)		Y+N	30	0.11
Experiment 1	(fixed proc.)	Y	10	-0.12
		N	10	-0.44
	(varied proc.)	Y	10	-0.03
		N	10	-0.70*
Experiment 2	(fixed proc.)	Y	10	-0.55
		N	10	-0.46
	(varied proc.)	Y	10	0.16
		N	10	0.24
Hunt, Lunneborg & Lewis (1973)		Y+N		-0.38
Warren, Hubbard & Knox (1977)		Y	10	0.47
		N	10	-0.44

RETARDED ADULTS

Study		Response	n	Correlation
Dugas & Kellas (1974)		Y+N	14	-0.53*
Experiment 1	(fixed proc.)	Y	10	-0.68*
		N	10	-0.82*
	(varied proc.)	Y	10	-0.13
		N	10	-0.89*
Experiment 2	(fixed proc.)	Y	10	0.08
		N	10	-0.32
	(varied proc.)	Y	10	-0.31
		N	10	-0.51
Maisto & Jerome (1977)		Y+N	6	-0.80*
" "	(degraded probe)	Y+N	6	-0.97*
Silverman (1974)		Y+N	12	-0.72*

Table 3.7: Within-group correlations between the slope and intercept of item recognition functions from available published studies and from Experiments 1 and 2 in Chapter 2. Correlations are either for 'yes' (Y) or 'no' (N) responses separately, or combined (Y+N). n refers to the number of subjects in each sample.

*$p < 0.05$ (two tailed, n-2 df)

studies found negative correlations, and one, positive. The suggestion has been made* that long RT may lead to greater correlations. There is certainly more evidence for negative correlations among nonretarded children and retarded persons than among nonretarded adults, RTs generally being faster in the latter group. Inspection of Table 3.7 shows that in the studies where separate correlations were available for each response, 'no' responses, which are typically slower than 'yes', have often been associated with greater negative correlations. However, in the present experiment, the large differences in mean RT between groups were not reflected in further differences in correlations.

Therefore, there is as yet no satisfactory explanation for the presence of significant negative correlations in some studies and not others, although reduction of between-subject variability may reduce the size of the correlation under some circumstances. The nonretarded adults in the present experiment may have found the task too simple, so that an additional subject-controlled factor such as attention or motivation may have caused some subjects to use slow scanning while speeding up encoding, and vice versa on some trials. Manipulation of a suitable payoff matrix in future research may result in stricter experimental control.

The reduction in mean RT found for the two younger mental age groups was reflected in a reduction of both the slope and the zero intercept of the item recognition function, suggesting an improved efficiency in processes underlying both these values. This finding is contrary to those studies of varied mapping search strategies among nonretarded adults; changes in speed or strategy of memory search have only been found when stimuli are consistently mapped to the same responses during practice (Nickerson, 1972;

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* I am indebted to Dr A. Maisto (personal communication) for this suggestion.

Shiffrin & Schneider, 1977). Varied stimulus-response mapping from trial to trial led to a more consistent reduction in slope and intercept than the fixed set procedure, possibly due to the different stimulus response mapping characteristics in the two tasks. In the fixed set procedure, positive sets changed at the beginning of each block of thirty experimental trials. The optimal strategy would have been to develop automatic detection by the end of each block of consistent mapping, and then revert to exhaustive search when presented with a new memory set. This requirement may have caused younger mental age groups, with poor attentional and voluntary strategic control, to adopt unfamiliar strategies or to attempt unsuccessful changes in strategy, leading to inconsistent responding. This suggestion rests on the assumption that thirty trials are sufficient to warrant a change in search strategy. An alternative explanation is that the successive presentation of items under the varied set procedure facilitated the adoption of efficient verbal-sequential encoding and rehearsal processes. Such facilitation would not then occur in the fixed set procedure, where simultaneous presentation was used.

In Experiment 3, the slope of the item recognition functions for the retarded group in Session 7 was still higher than that found for either of the two control groups, although slopes may have been reduced further in the retarded group if practice had been extended. That slope was reduced in a varied mapping task suggests that results from studies in which retarded subjects have not had extensive practice, and have been found to have item recognition functions with much higher slopes and intercepts than control groups, may be partly due to the sensitivity of the retarded group to practice, over and above any permanent impairment of memory scanning processes.

Retarded subjects' responding was biased towards a 'no' response but, unlike performance in the control groups, this bias was reflected in widely disparate slopes and intercepts for 'yes' and 'no' functions. Retarded subjects may have been responding more cautiously than controls so as to monitor error rate, although there was no evidence of a speed-accuracy tradeoff within the retarded group, and a nonparametric signal detection theory analysis of errors in each group showed very little difference in caution levels between the three groups. Subjects with very steep slopes may have been using multiple serial checks before responding, although again there was no evidence that these subjects had lower error rates than subjects with flatter slopes. The difference between 'yes' and 'no' functions could, however, be due to failure to identify task demands early in practice. Change by individual subjects to more efficient strategies may have been reflected in the reduction in between-subject variability with practice. Thus, individual strategies may have tended towards a single optimal strategy, since goodness-of-fit to one straight line increased with practice. However, further practice would be necessary to determine whether the performance of retarded subjects stabilised, since by the end of seven sessions of practice, no consistent relation between 'yes' and 'no' responses had yet emerged.

The decrease in RT among retarded subjects seen in the present study is contrary to findings by McCauley et al. (1976), who failed to train less intelligent subjects to use a serial rehearsal strategy and so increase memory search rate. However, results from the present experiment suggest that more than the two days of training used by McCauley et al. (1976) may be necessary in order to produce a change in the search rates of retarded subjects.

Keating et al. (1980) have reported that there is a crucial developmental period during which the efficiency of scanning processes increases, namely between about 9-13 years of age. The practice effect in the present experiment, where children were aged about 11 years, may therefore be restricted to children who are close to this developmental stage. Further experimentation is needed to determine whether younger children could increase their memory scanning speed. The practice literature and recall memory literature provide evidence that children as young as five years can improve memory performance by learning to use rehearsal and other strategies (Hagen, Hargreave & Ross, 1977; Wickens, 1974), so that young children may benefit from practice on a memory scanning task as well.

In summary, practice has been found to be an important variable when considering individual differences in memory search. Slower memory search exhibited by retarded subjects may reflect between-subject variability and sensitivity to practice, in addition to any permanent impairment in memory scanning processes. While retarded persons may have some structural impairment which is related to their performance on this task, such an impairment should be defined in terms of the time taken to become as proficient at the task as normal subjects, rather than in terms of the absolute speed of memory scanning performance early in practice. High between-subject variability early in practice may make any definition of the memory processing speed of retarded persons spurious if this is based on the performance of unpracticed individuals.

Chapter 4

EFFECTS OF FURTHER PRACTICE ON RETARDED MEMORY SCANNING AND MAINTENANCE OF PERFORMANCE

4.1 INTRODUCTION

Thus far, this thesis has shown that the performance of mildly retarded adults in the memory search task is affected by two procedural variables, which apparently do not affect the memory search performance of non-retarded adults. Firstly, performance under a fixed set procedure requiring that items are stored in long term memory is dissimilar to performance under a varied set procedure, where material relevant to any particular trial has to be retained for only a few seconds, subsequently being replaced by new material for a new trial. Secondly, performance improves dramatically with practice. Responding is very variable at first, when compared with the relatively stable performance of nonretarded groups, but variability diminishes with practice. These findings led to the suggestion in Chapter 3 that any conclusions about deficiencies in the memory performance of retarded persons should only be reached after taking into account the level of practice on the task in question.

Experiment 3 demonstrated marked change in the memory search performance of retarded persons under conditions which did not produce significant change in nonretarded adults' performance. Consequently, practice effects are of considerable significance when defining the relationship between nonretarded and retarded performance on the task.

This chapter is concerned firstly with the retention of memory search skills over a period of time, during which the mildly retarded subjects had no opportunity to rehearse those skills previously learnt, and, secondly, with the effects of subsequent extensive practice on speed of memory performance.

In Experiment 3, the continual decrease in the RTs of retarded subjects up to the last session of practice suggested that additional practice may be required before the performance of such subjects reached a level of stability similar to that found among nonretarded control subjects within fewer practice sessions. By using retarded subjects in Experiment 4 who had participated in Experiment 3, it was possible to examine the effects on memory scanning performance of a moderately long period of time between learning the task initially and subsequent extended practice. As will be discussed below, there is evidence in the literature that retarded persons can retain certain cognitive skills for substantial lengths of time, and are capable, furthermore, of restricted generalization to other tasks under certain conditions.

4.1.1 Maintenance of learned memory skills

A review of the training literature in Chapter 3 showed that many cognitive skills can be successfully taught to retarded persons. Investigators using the 'instructional' approach have repeatedly demonstrated that retarded persons can learn to use mnemonic strategies such as rehearsal, organization and the use of cues. There is also evidence that retarded individuals can retain learned strategies over extended periods of time. For example, experimenters have demonstrated retention of a learned rehearsal strategy over periods of two weeks (Reichart, Cody & Borkowski, 1975), six months (Brown, Campione & Murphy, 1974; Kellas, Ashcraft & Johnston, 1974; Turnbull, 1974) and up to one year (Brown, Campione & Barclay, 1979). In general, the 'training' of strategies has involved an initial coaching session, followed by extended experience with the task, during which time the experimenter has prompted the subject into using the learned strategy whenever it was considered necessary.

One factor determining the type of outcome of training is the amount of practice employed during training (Campione & Brown, 1977). The course of maintenance depends on the amount of practice, and very extensive practice can prolong the improvement to performance over time (Reichart et al., 1975).

Although trained strategies can be maintained over time, few data indicate that the strategy will transfer to another problem type, or even across stimulus type, such as from pictures to numbers. Minor changes - such as new pictures where pictures were involved initially - may not result in a performance decrement (Campione & Brown, 1977).

From this evidence, one would expect that retarded individuals participating in Experiment 3 would retain at least some part of the skills which they had acquired by the end of seven sessions of practice. According to Borkowski & Cavanagh (1979), maintenance of performance can often result from no more than two or three training sessions. Thus, since subjects in Experiment 3 had considerable experience with the task, an interval of three to four months between Experiment 3 and Experiment 4 should not result in the complete loss of previously learned skills.

4.2 EXPERIMENT 4

The present experiment aimed to practise retarded individuals sufficiently for them to reach an asymptote in performance. Comparing the stable performance of retarded subjects late in practice with the asymptotic performance of the nonretarded participants in Experiment 3 should provide a more reliable measure of the differences between the memory scanning performance of retarded and nonretarded individuals. Retarded subjects from Experiment 3 therefore continued in this study, thereby shortening the practice period necessary to stabilise performance, as well as providing the opportunity to examine the extent to which memory skills were maintained during a considerable period of time between experiments. Only the varied set procedure was tested, since in Experiment 3 this procedure led to a more consistent reduction in mean RT with practice than did the fixed set procedure. Furthermore, any change in slope under varied stimulus-response mapping conditions is of central interest, since Experiment 3 showed that retarded adults tested under such conditions perform differently to non-retarded adults, whose mean item recognition functions do not show any change in slope during practice. Excluding one procedure meant that more of the subject's time was available and four set sizes were therefore presented instead of three. It is desirable to test linearity of the item recognition function with as many set sizes as possible, and evidence in the literature suggested that subjects would be able to generalize acquired skills to this addition to the previous procedure (Campione & Brown, 1977).

4.2.1 **Method**

Design

Three within-subject variables were manipulated in a 4 x 2 x 18 repeated measures factorial design (Winer, 1971). The variables were memory Set Size (four levels), Response required to a probe item (two alternatives) and Practice (eighteen sessions). The eighteen sessions were spaced over a period of two weeks, each session of practice being separated from the previous session by not less than two hours and not more than forty-eight hours, with the exception of one subject who was absent for four days.

Subjects

Eight mildly retarded participants from Experiment 3, described in Table 4.1, were used in this experiment. All subjects were attending sheltered workshops or their associated assessment and training centres.

Chronological age controls were not included in the present experiment, since Experiment 3 had confirmed the results of other experiments (e.g.

Kristofferson, 1977), clearly showing that memory search under the varied set procedure is very little affected by practice among this group. Mental age controls had achieved memory search rates by the end of Experiment 3 that were similar to those established in normal adults, so that this control was also not necessary in the present study.

GROUP: Retarded adults

CA		MA		IQ	
X	sd	X	sd	X	sd
21-11	4-5	11-4	0-5	71	3

Table 4.1: Experiment 4 subject details, showing mean (X) and standard deviation (sd) in years and months for chronological age (CA) and mental age (MA) of retarded adults, and full scale WAIS IQ (n = 8).

Apparatus

Apparatus was identical to that used for Experiments 1, 2 and 3 (see Section 2.2.1). Auditory feedback about accuracy of responding was provided by a tone generator, as in Experiment 3 (see Section 3.2.1).

Procedure

Subjects used the same hand as in Experiment 3 for a 'yes' or a no' response. A varied set procedure was used. On each trial, a memory set of one, two, three or four digits appeared successively on the display screen at a rate of 1.5 secs/digit. The memory set was followed by a gap of two seconds, followed by a one second visual warning signal, and then the test probe, which remained on the screen until the subject pressed one of the reaction time buttons. The inter-trial interval was four seconds. For each session, 30 test trials at each of four set sizes were presented in five blocks of 24 trials, with a short rest period between successive blocks. The probability of the test item coming from the positive set was 0.5, and the serial position of the test item was distributed as evenly as possible across all set positions.

As noted above, auditory feedback about accuracy of responding was provided by a tone generator. Visual feedback about speed and accuracy of responding was also provided in a procedure which was similar to that described for Experiment 3 (see Section 3.2.1). For each session, a chart showing each individual's mean RT for the session and number of errors made was displayed.

Subjects were instructed to respond as quickly as possible, without making too many errors. Speed and accuracy instructions were repeated at the beginning of each block of 24 trials. The first three trials of each block were for practice only and therefore have not been included in analysis. One session of training and familiarisation preceded the first experimental session.

4.3 RESULTS AND DISCUSSION

4.3.1 Errors

Error rates were low for all subjects, and mean errors never exceeded 5 percent in any one session, as may be seen from Table 4.2. Errors were analysed in a Practice x Response x Set Size analysis of variance (see Appendix 4.1). There were significant effects for Response ($F = 15.29$, 1/7 df, $p < 0.01$), and Set Size ($F = 8.71$, 3/21 df, $p < 0.01$) but not for Practice. Subjects missed identifying items present in the memory set more frequently than they made false positive errors; that is, there was a bias towards responding 'no'. This outcome therefore replicates those from Experiments 1, 2 and 3.

	SESSION	1	2	3	4	5	6
RESPONSE	NO	4.58	3.96	2.08	2.08	2.71	1.46
REQUIRED	YES	2.92	4.58	2.08	3.75	2.50	3.75
	Overall	3.75	4.27	2.08	2.91	2.60	2.60
		7	8	9	10	11	12
RESPONSE	NO	2.08	2.71	2.08	0.83	2.08	1.67
REQUIRED	YES	2.50	2.91	4.17	3.75	3.12	4.38
	Overall	2.29	2.81	3.12	2.29	2.60	3.02
		13	14	15	16	17	18
RESPONSE	NO	1.46	2.71	1.67	1.25	0.62	1.67
REQUIRED	YES	2.29	2.92	3.54	2.92	4.17	4.17
	Overall	1.88	2.82	2.60	2.08	2.39	2.92

Table 4.2: Experiment 4: Mean percentage of errors by retarded adults for responses required at each of 18 sessions of practice. Each figure is calculated on errors per 480 trials, and overall percentage of errors is also shown.

Errors increased with increasing set size, but there was no significant change in the number of errors made with increasing practice. Thus, any reduction in mean RT was not obviously due to a speed/accuracy trade-off. There was also a significant interaction between Set Size and Response ($F = 15.99$, 3/21 df, $p < 0.01$), due to more errors of omission being made to a positive set probe when the set size was larger. However, an examination of error rates suggested that changes in RT were independent of errors made.

Nonparametric signal detection theory analysis of errors indicated that while the number of misses remained constant over practice, false alarms decreased so that in effect caution increased with practice. A measure of sensitivity from the signal detection theory analysis also increased slightly with practice (see Appendix 4.2). These results suggested that the distributions for 'noise' and 'signal + noise' moved apart as subjects became more practiced, while the response criterion remained in the same position relative to the 'signal + noise' distribution.

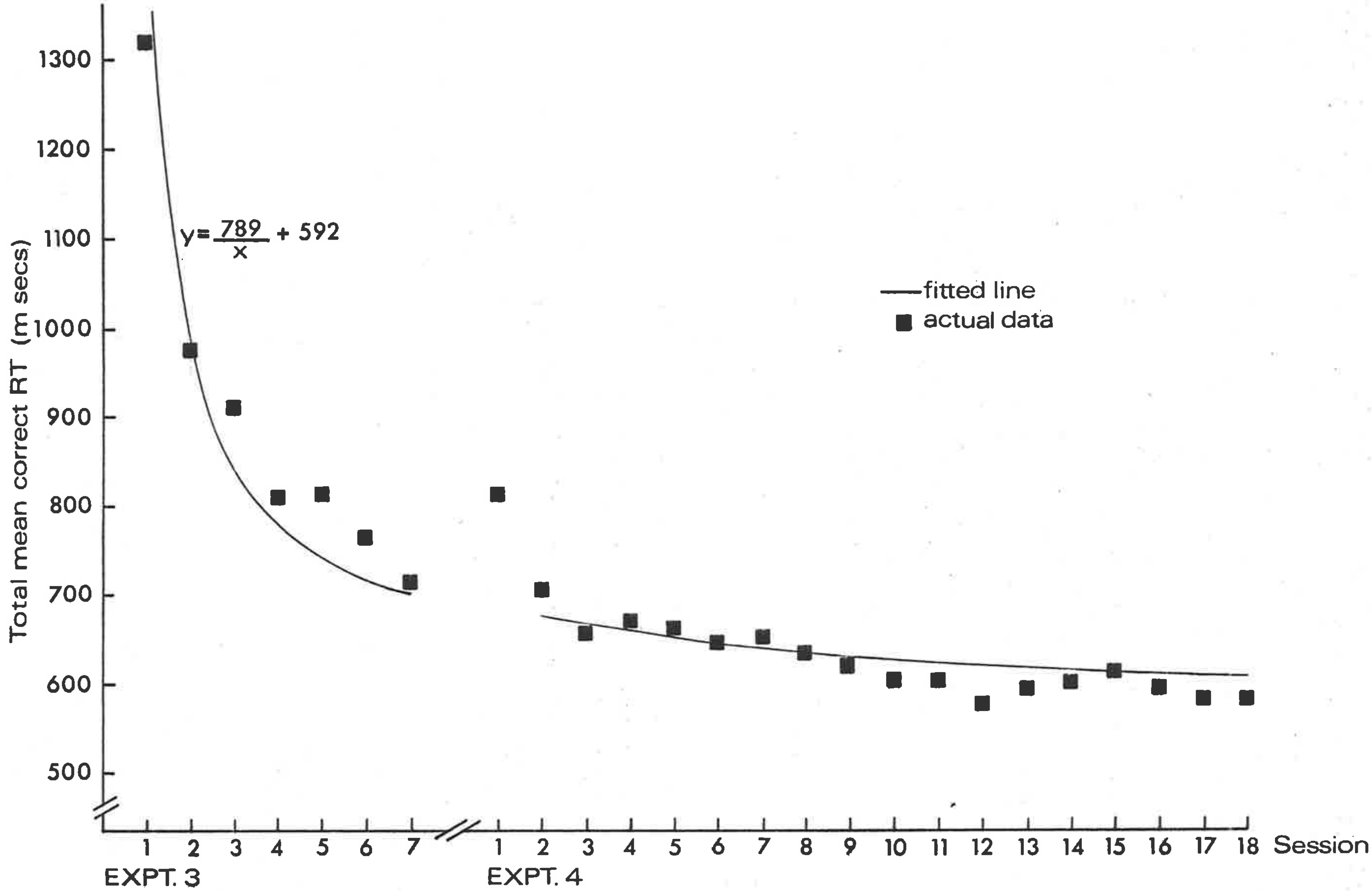
4.3.2 Total mean RT and comparison with results from Experiments 3 and 4

When overall mean RT for all memory set sizes combined is graphed for the seven sessions of practice in Experiment 3 and eighteen sessions in Experiment 4, yielding 25 sessions in all, the asymptote for RT can be seen clearly (refer to Figure 4.1). Correct mean RT is derived from a maximum of 720 trials per point in Experiment 3, and from 960 trials per point for data from Experiment 4. The period of three months' gap between Experiments 3 and 4 resulted in a slowing in RT that was equivalent to a loss of approximately two to three sessions of practice, since data obtained during session 1 of Experiment 4 appear similar in speed to those obtained during sessions 4 and 5 of Experiment 3. However, after only one initial session of practice, subjects had reached the level of performance previously attained at the end of seven sessions of practice. Thus, the skills developed in the memory scanning task were retained reasonably intact over a period of three to four months.

The overall reduction in total correct mean RT across sessions was significant ($F = 3.42$, 17/118 df, $p < 0.01$; see Appendix 4.3). However, it may be seen that RT approached a fairly constant level after approximately eight or nine sessions of practice, and there was very little improvement in RT over the last nine sessions of Experiment 4. Disregarding session 1 of Experiment 4, during which performance was reduced to the level reached at the end of Experiment 3, a steady reduction in overall RT can be seen from session 1 of Experiment 3 to around session 9 of Experiment 4. A hyperbola fitted to 24 data points excluding session 1 of Experiment 4 accounted for 96 per cent of the variance, and the correlation between observed and predicted points was 0.98. Thus, correct mean RT approached an asymptote around 625 msecs, compared with the best performance under the varied set procedure in Experiment 3 for nonretarded adults of about 450 msecs and for

FIGURE 4.1

Total mean correct RT graphed for each session of practice given to retarded adults in a varied set procedure for Experiment 3 (seven sessions) and Experiment 4 (eighteen sessions). The best fitting hyperbola of the form $y = \frac{789}{x} + 592$ is also shown, as calculated with session 1 of Experiment 4 excluded.



Total mean correct RT (m secs)
1300
1200
1100
1000
900
800
700
600
500
$y = \frac{789}{x} + 592$
fitted line
actual data
1 2 3 4 5 6 7
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Session
EXPT. 3
EXPT. 4

nonretarded children of about 770 msecs. This outcome is in agreement with evidence in the literature for a central processing limit in the speed with which information is processed by retarded persons and nonretarded children. In the present experiment retarded subjects required an additional 8,000 trials when compared with nonretarded controls before RT reached a level of stability similar to that for the nonretarded groups. However, without a substantial gap in practice, and with only one type of task to learn from the beginning, it is possible that the amount of practice required by retarded subjects to achieve stable performance would have been reduced.

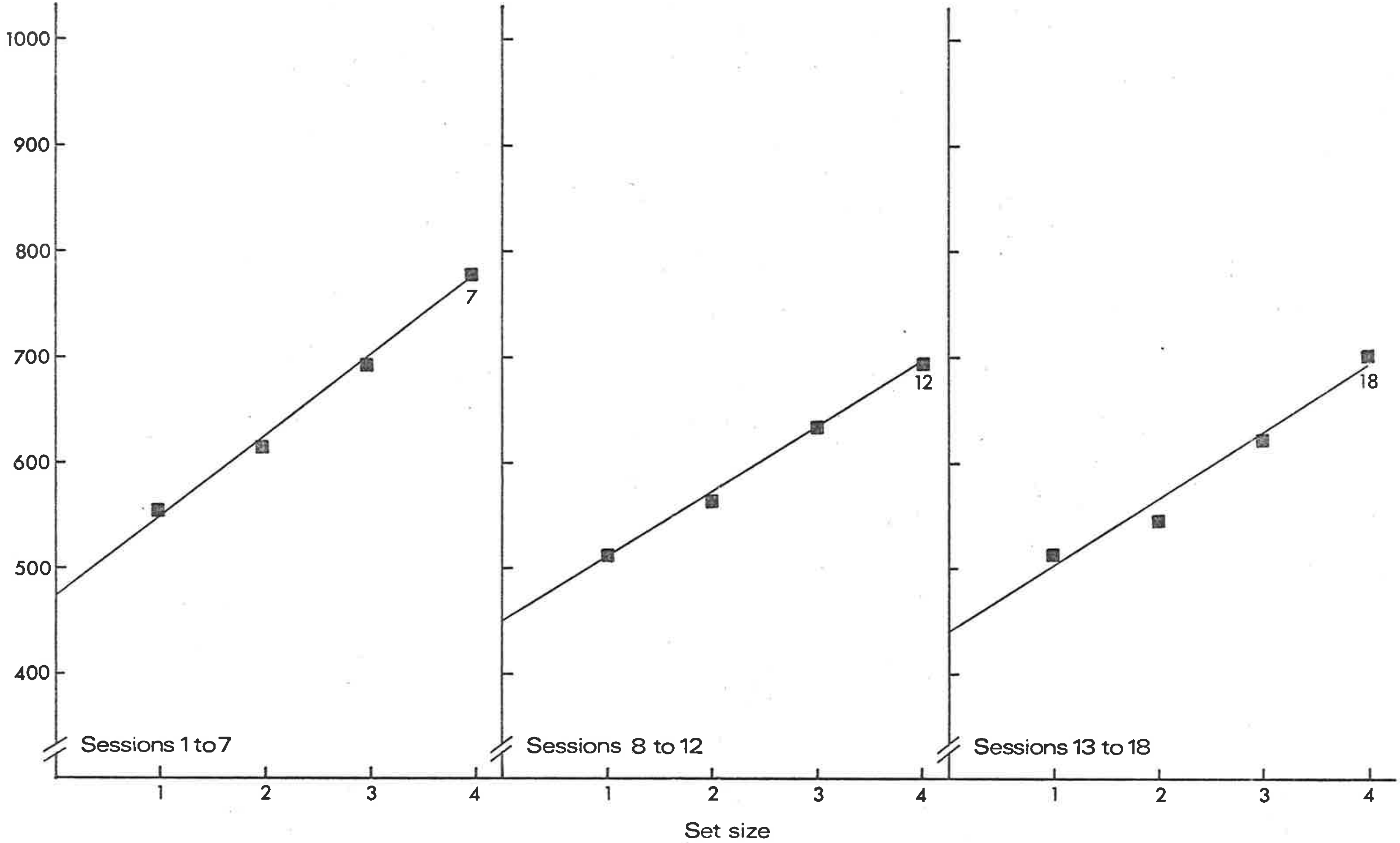
4.3.3 Practice and memory scanning

Item recognition functions for each session, with 'yes' and 'no' responses combined, are presented in Figure 4.2, which illustrates the effects of practice on memory scanning. Corresponding equations for best fitting straight lines are set out in Appendix 4.4. From Figure 4.2, it may be seen that the main reduction in mean RT is due to the reduction in the zero intercept for the function, without a similar reduction in slope. To some extent, RT to smaller set sizes decreased, larger set sizes not benefiting equally from practice, so that the group slope appeared to increase, although there is no clear pattern across sessions of practice.

Straight lines were fitted to each subject's correct mean RT per set size, for 'yes' and 'no' responses separately. In a Practice x Response analysis of variance in slopes, the main effect of practice was just statistically significant ($F = 1.77$, 17/119 df, $p < 0.05$; see Appendix 4.5). Slopes over the first seven sessions were variable and tended to increase across sessions. In the latter eleven sessions, slopes remained relatively stable between 40 msecs/item and 60 msecs/item. The main effect for Response was not significant, and as may be seen from Figure 4.3, the relation between 'yes' and 'no' responses stabilised after some practice. Thus, the interaction

FIGURE 4.2

Experiment 4: Item recognition functions for each session of practice given to retarded adults under a varied set procedure, showing 'yes' and 'no' responses combined, and Appendix 4.4 contains equations corresponding to the lines of best fit shown here.



1000
900
800
700
600
500
400
7
12
18
Sessions 1 to 7
Sessions 8 to 12
Sessions 13 to 18
1
2
3
4
Set size

between Practice and Response was not significant. For sessions 6 to 15, the pattern for 'yes' and 'no' functions remained the same. The less stable data obtained during sessions 17 and 18 may have been due to poorer concentration, since subjects knew that they were near the end of the experiment.

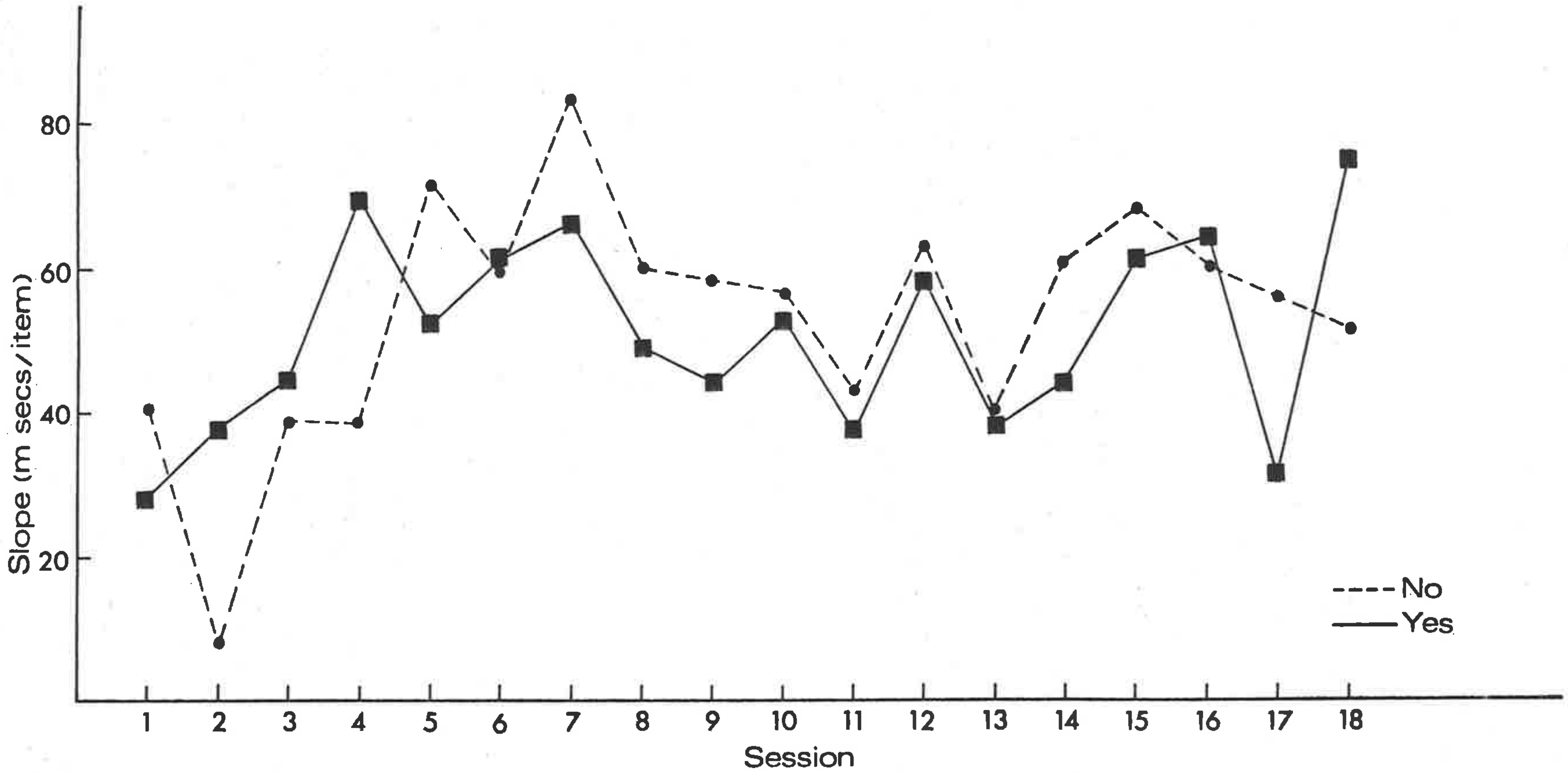
These results indicate that the pattern of RT performance under the varied set procedure among retarded adults changes with practice. Initial performance, characterised by considerable differences in slope between 'yes' and 'no' responses, is later replaced by a pattern similar to that found among nonretarded subjects.

In an analysis of the zero intercepts for item recognition functions, main effects of Practice and Response were significant (Practice $F = 3.53$, 17/119 df, $p < 0.01$; Response $F = 14.70$, 1/7 df, $p < 0.01$; see Appendix 4.6). Figure 4.4 shows that practice resulted in a steady reduction in zero intercepts, the level stabilizing after session 5 at about 480 msecs. This value is therefore considerably higher than the 350 msecs found late in practice among chronological age controls in Experiment 3 under the varied set procedure. Comparison between Figures 4.3 and 4.4 shows that the increase in slope of average item recognition functions early in practice was accompanied by a decrease in the zero intercept, so that subjects appeared to be trading off slope for zero intercept as practice progressed. Later in practice, after about seven sessions, intercepts remained steady at around 480 msecs, while slopes fluctuated between 40 and 60 msecs/item. The significant effect of Response in the analysis of intercepts was due to 'no' responses being consistently slower than 'yes' responses.

Analysis of correct mean RT per set size supported the above analysis. In a Practice x Response x Set Size analysis of variance, all three main effects were significant (Practice $F = 3.56$, 17/119 df, $p < 0.01$; Response $F = 24.10$, 1/7 df, $p < 0.01$; Set Size $F = 21.27$, 3/21 df, $p < 0.01$; see Appendix 4.7). Thus, the reduction in RT with practice, the slower 'no'

FIGURE 4.3

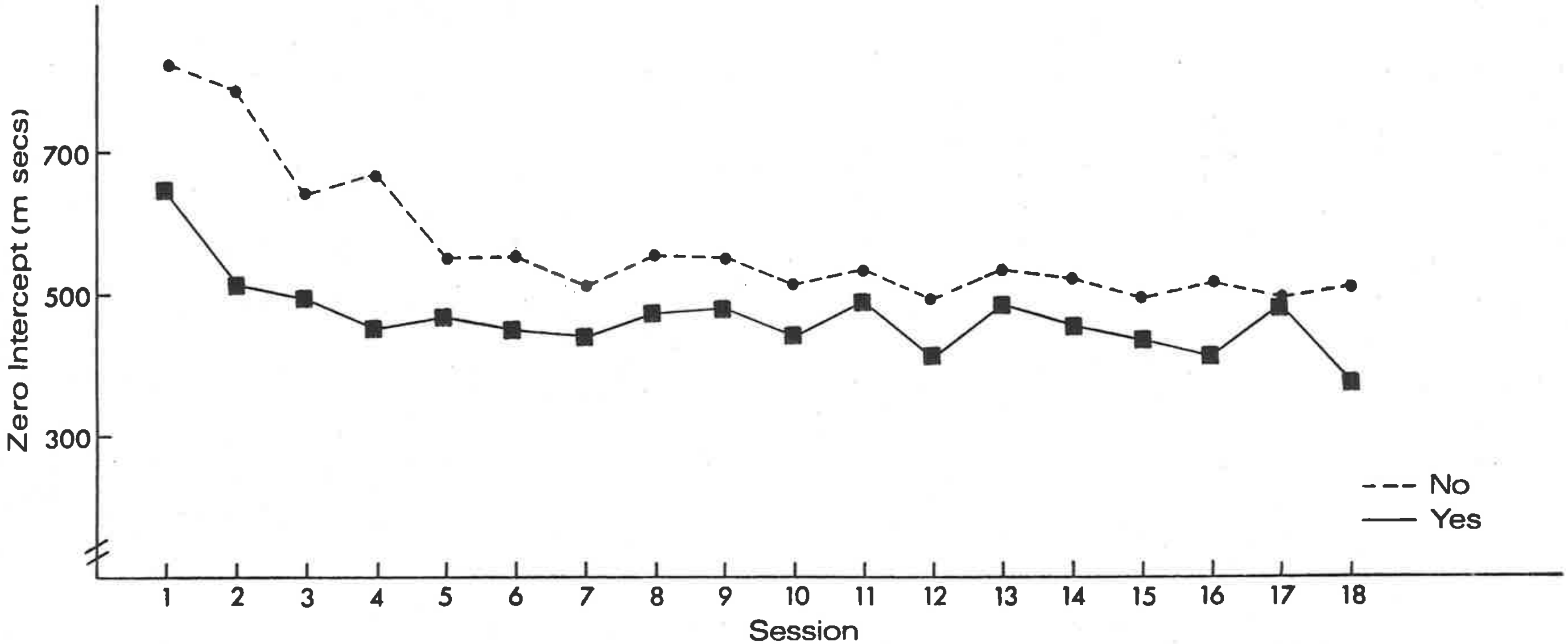
Experiment 4: Slopes from item recognition functions for each session of practice given to retarded adults under a varied set procedure, showing 'yes' and 'no' responses separately.



80
60
40
20
Slope (m secs/item)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Session
No
Yes

FIGURE 4.4

Experiment 4: Zero intercepts from item recognition functions for each session of practice given to retarded adults under a varied set procedure, showing 'yes' and 'no' responses separately.



Zero Intercept (m secs)
700
500
300
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Session
No
Yes

responses than 'yes' responses, and an increase in RT with set size were all significant. There was a significant interaction between Practice and Response ($F = 2.01$, 17/119 df, $p < 0.05$) due to the diminishing difference between 'yes' and 'no' responses with practice. The Practice x Set Size interaction was also significant ($F = 1.46$, 51/357 df, $p < 0.05$), reflecting changes in the slope of item recognition functions across sessions. Analyses of linear trend in item recognition functions for 'yes' and 'no' responses separately at each session indicated that there were significant linear trends in every function, with the exceptions of 'no' responses during the first two sessions.

In summary, the analysis of slopes and intercepts of item recognition functions suggested that practice had two main effects on the RT performance of the retarded subjects. Firstly, the tradeoff between slope and intercept subsided when intercepts reduced to a stable level following considerable practice. Secondly, the large differences early in practice between functions describing 'yes' and 'no' responses were reduced appreciably, so that functions became similar for the two responses. This is illustrated in Figures 4.3 and 4.4 where slopes and intercepts of 'yes' and 'no' functions can be seen to draw closer with practice.

4.3.4 Practice effects and the additive factor method

In Experiment 3, significant negative correlations between the slopes and intercepts of item recognition functions led to the conclusion that these two measures should not be regarded as representing independent parameters of memory scanning and other mental operations, since the Sternberg model requires independence as well as additivity of factors before separate stages can be identified. Table 4.3 sets out correlations between slopes and intercepts in this study, for both 'yes' and 'no' responses separately, and for 'yes' and 'no' responses combined, since there was no main effect of Response

	RESPONSE		
	NO	YES	YES + NO
SESSION			
1	-0.53	-0.85**	-0.61
2	-0.43	-0.82**	-0.92**
3	-0.71*	-0.94**	-0.86**
4	-0.90**	-0.86**	-0.49
5	-0.62	-0.82**	-0.62
6	-0.15	-0.70*	-0.36
7	-0.30	-0.65*	-0.45
8	-0.45	-0.73*	-0.63*
9	-0.18	-0.63*	-0.25
10	-0.27	-0.60*	-0.38
11	-0.73*	-0.80**	-0.69*
12	-0.68*	-0.88**	-0.80**
13	-0.79**	-0.75*	-0.78*
14	-0.77*	-0.70*	-0.68*
15	-0.66*	-0.65*	-0.64*
16	-0.61	-0.82**	-0.70*
17	-0.60	-0.79**	-0.59
18	-0.26	-0.76*	-0.52

Table 4.3: Experiment 4: within-group correlations (n = 8) from each subject's item recognition function for each session of practice showing 'yes' and 'no' responses separately and combined.

** $p < 0.01$ (one tailed)

* $p < 0.05$ (one tailed)

in the analysis of slopes. Given that negative correlations have been found consistently in the results of retarded adults, a one-tailed test of significance has been used. As may be seen from Table 4.3, most correlations were high and negative, all 'yes' responses and 9 out of 18 combined responses being significant at the 5 per cent level or higher. This outcome is particularly compelling, given the small sample of 8 subjects involved.

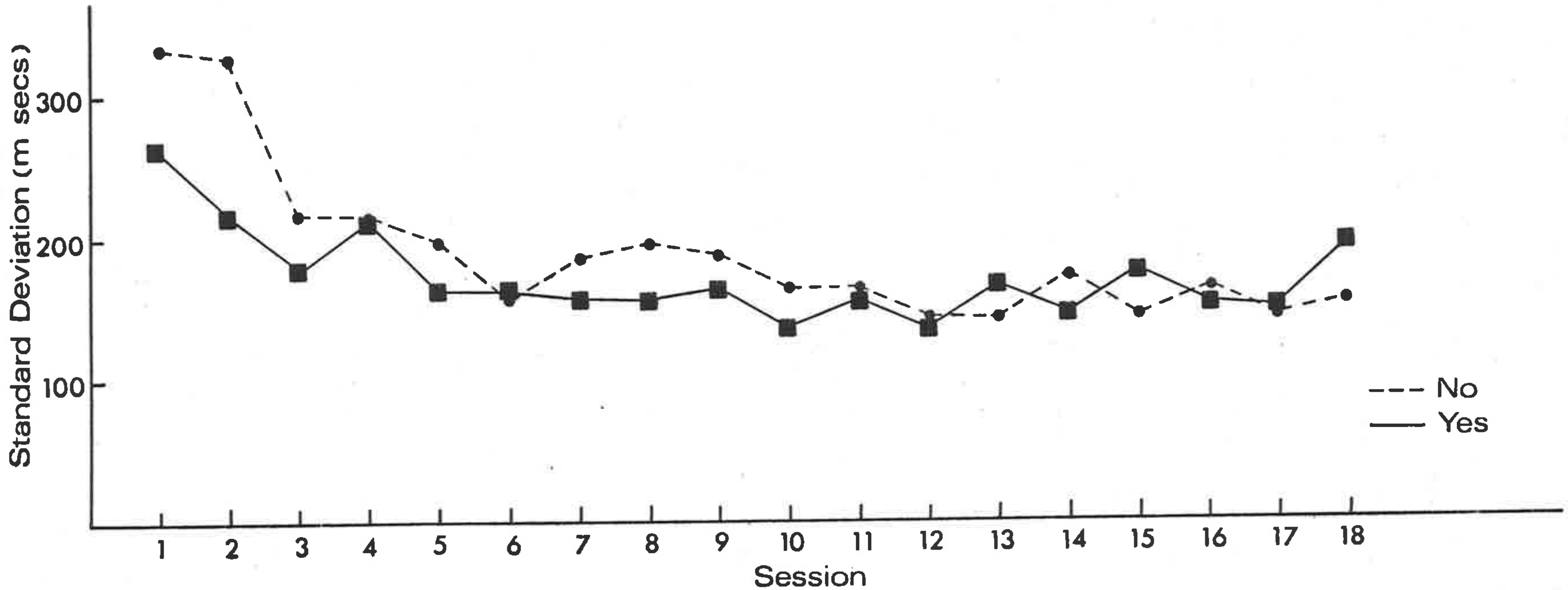
Although these correlations were somewhat reduced when compared with those found in Experiment 3, all correlations at each session of practice were still negative and the average correlation of -0.61 across sessions and alternative responses was still high ($p < 0.5$, 6 df). Thus, although retarded subjects appeared to be responding similarly to nonretarded adults late in practice, as seen in the reduced slopes of item recognition functions with 'yes' and 'no' slopes parallel, significant negative correlations indicate that hypothesized stages of processing were not independent, even following extensive practice.

4.3.5 **Variability of RT**

Standard deviations of 'yes' and 'no' responses for each set size were analysed in a Practice x Response x Set Size analysis of variance. Main effects of Practice and Set Size were significant (Practice $F = 2.39$, 17/119 df, $p < 0.01$; Set Size $F = 4.57$, 3/21 df, $p < 0.05$; see Appendix 4.8), and there was a significant interaction of Practice and Response ($F = 1.91$, 17/119 df, $p < 0.05$). As may be seen in Figure 4.5, the main effect of Practice was mainly due to a reduction in variance over the first six sessions, variance remaining stable after that. The interaction between Practice and Response (refer to Figure 4.5) was due to more variability among 'no' responses early in practice, the difference between responses coarctating with practice. Thus, variability was reduced to a constant value of approximately 150 msecs after about six sessions of practice. This figure is

FIGURE 4.5

Experiment 4: Average standard deviation of correct RT for each session of practice given to retarded adults under a varied set procedure, showing 'yes' and 'no' responses.


Standard Deviation (m secs)
300
200
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Session
No
Yes

close to the average standard deviation of 135 msecs found among nonretarded adults in Experiment 2, where the same number of set sizes were presented within a varied set procedure.

Thus, when retarded subjects are given sufficient practice, they appear to respond similarly to nonretarded controls. Late in practice, performance reached a stable limit, shown by the asymptote in mean RT, zero intercept and standard deviation. However, fluctuation in slopes of the item recognition functions for the retarded group, even late in practice, suggested that performance at larger set sizes, particularly at a set size of four elements, was still not stable. With zero intercepts constant, changes in RT to probe stimuli from relatively large set sizes would lead to changes in slope. If variability in slope was mainly due to outlying RTs at large set sizes, then reduction of variability would also reduce the slope. Thus suggestion is supported by the significant main effect for Set Size in the analysis of standard deviations, which showed that standard deviations for set sizes of three and four were larger than those for sets of one and two items (refer to Figure 4.6a).

Similar reanalyses to those described in Chapters 2 and 3 were done to examine the effect of reducing within-subject variability caused by outlying very slow RTs. Trials on which RT was greater than 1500 msecs were excluded, and then further trials on which RT was more than 1.96 standard deviations from the mean were also discarded. This procedure resulted in an average of 7 per cent of trials being discarded (see Appendix 4.9), so that reanalysis still included the majority of data.

Figure 4.7 shows reduced mean RT for Experiments 3 and 4. The pattern of improvement in mean RT remains basically the same as that seen in Figure 4.1 and the reduction in overall mean RT was still significant ($F = 3.19$, 17/118 df, $p < 0.01$; see Appendix 4.10). When the slopes and intercepts of item recognition functions were recalculated, variability in

FIGURE 4.6

Experiment 4: Standard deviation at each set size, averaged across 'yes' and 'no' responses and sessions of practice, for retarded adults. (A) shows the increase in standard deviation with increasing set size when all data are considered. (B) shows that there is relatively little effect of increasing set size on standard deviation when very long RTs are excluded from analysis.

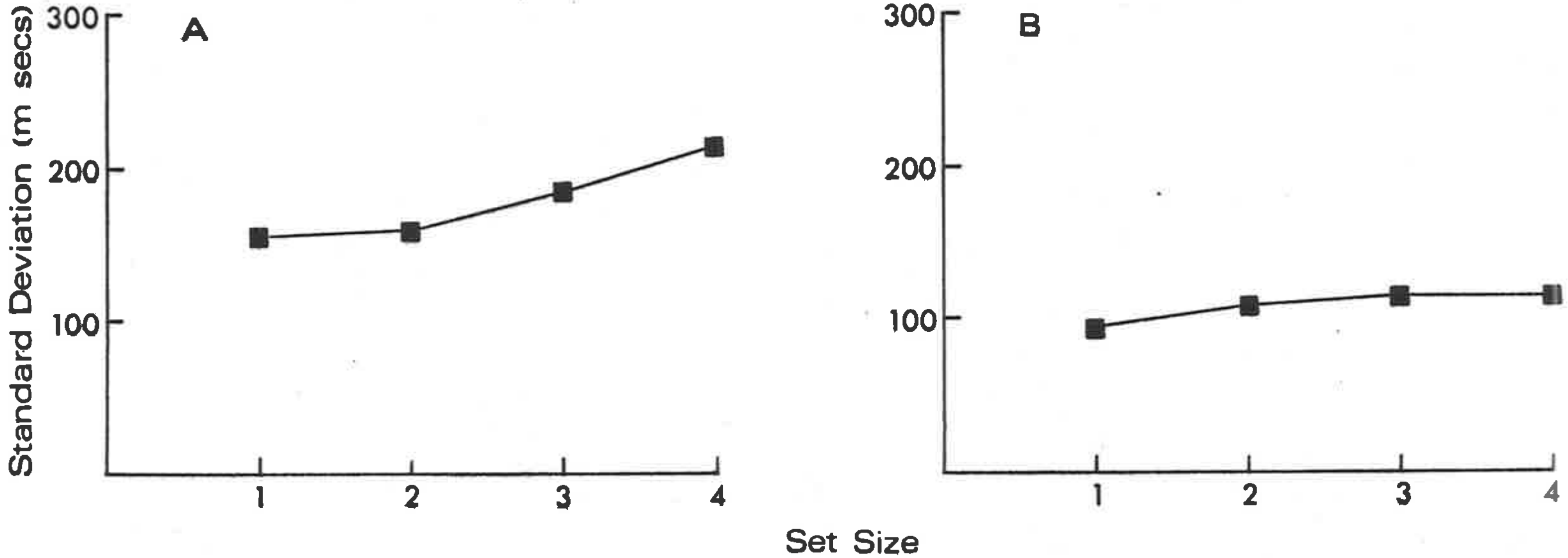
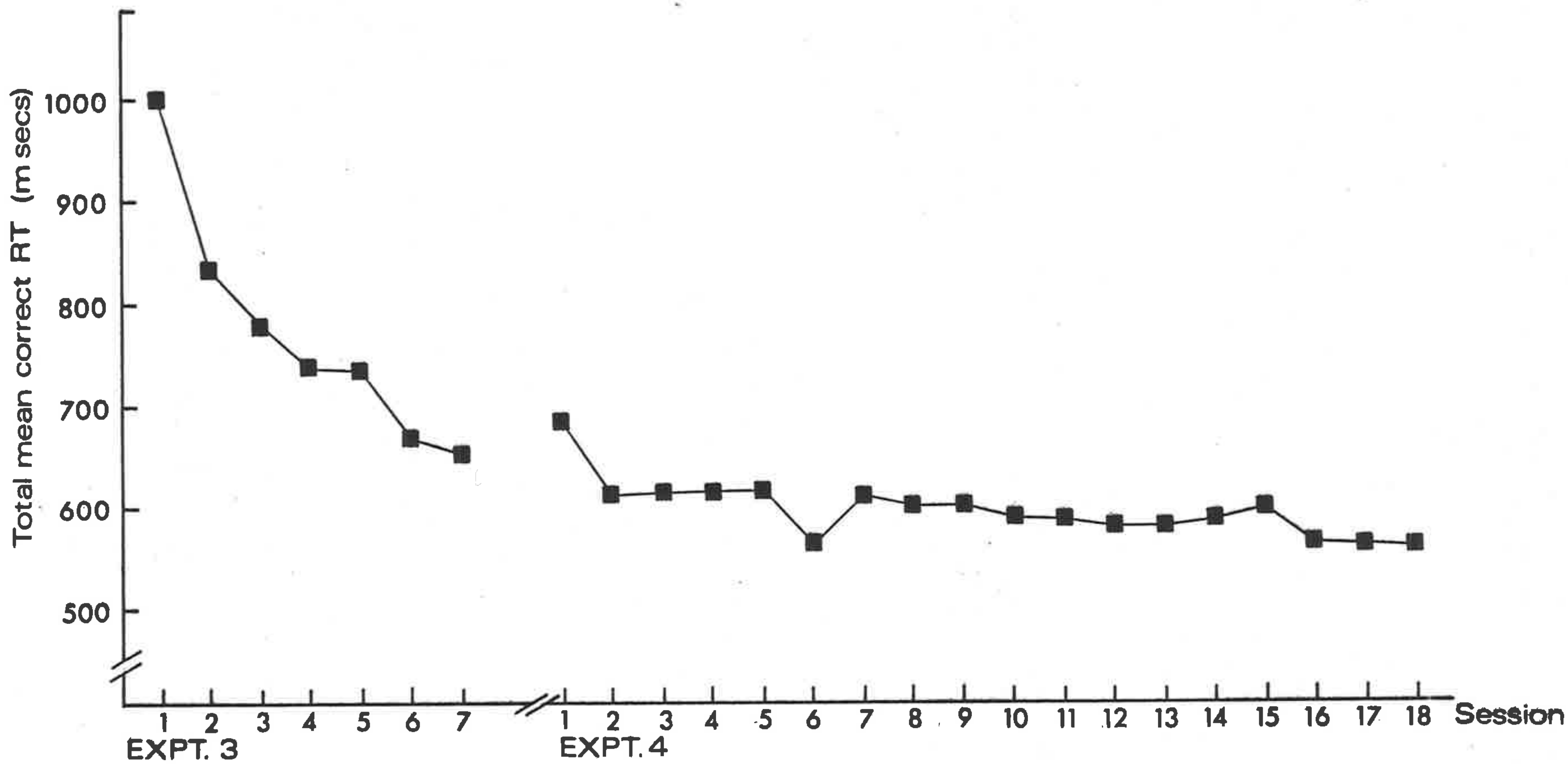

Standard Deviation (m secs)
300
200
100
A
1
2
3
4
300
200
100
B
1
2
3
4
Set Size

FIGURE 4.7

Total mean correct RT graphed for each session of practice given to retarded adults under a varied set procedure for Experiment 3 (seven sessions) and Experiment 4 (eighteen sessions). Each point has been calculated after very long RTs were excluded from analysis, as described in the text.


Total mean correct RT (m secs)
1000
900
800
700
600
500
1 2 3 4 5 6 7
EXPT. 3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
EXPT. 4
Session

slope was reduced, but without any absolute reduction in intercept. Zero intercepts still approached an asymptote at approximately 480 msecs. However, the fluctuations in slope shown in Figure 4.3 were reduced, and the overall slope approached an asymptote at around 40 msecs/item (refer to Figures 4.8a and 4.8b).

Examination of reduced standard deviations showed that the reduction in slope was due to greater reduction of variability at larger set sizes than at smaller set sizes. Comparing Figures 4.6a and 4.6b, the difference in standard deviation between sizes 1 and 4 was greater when all data were included in analysis than when very long RTs were disregarded. Table 4.4 shows that correlations between slopes and intercepts were reduced when variability was reduced, so that fewer were statistically significant. However, all remained negative, with an average correlation of -0.55, and those which were significant were not limited to earlier sessions.

In summary, the present experiment had four main outcomes:

(i) Following the seven sessions in Experiment 3, retarded subjects retained skills necessary for the memory scanning task over a period of three to four months with further practice in the task.

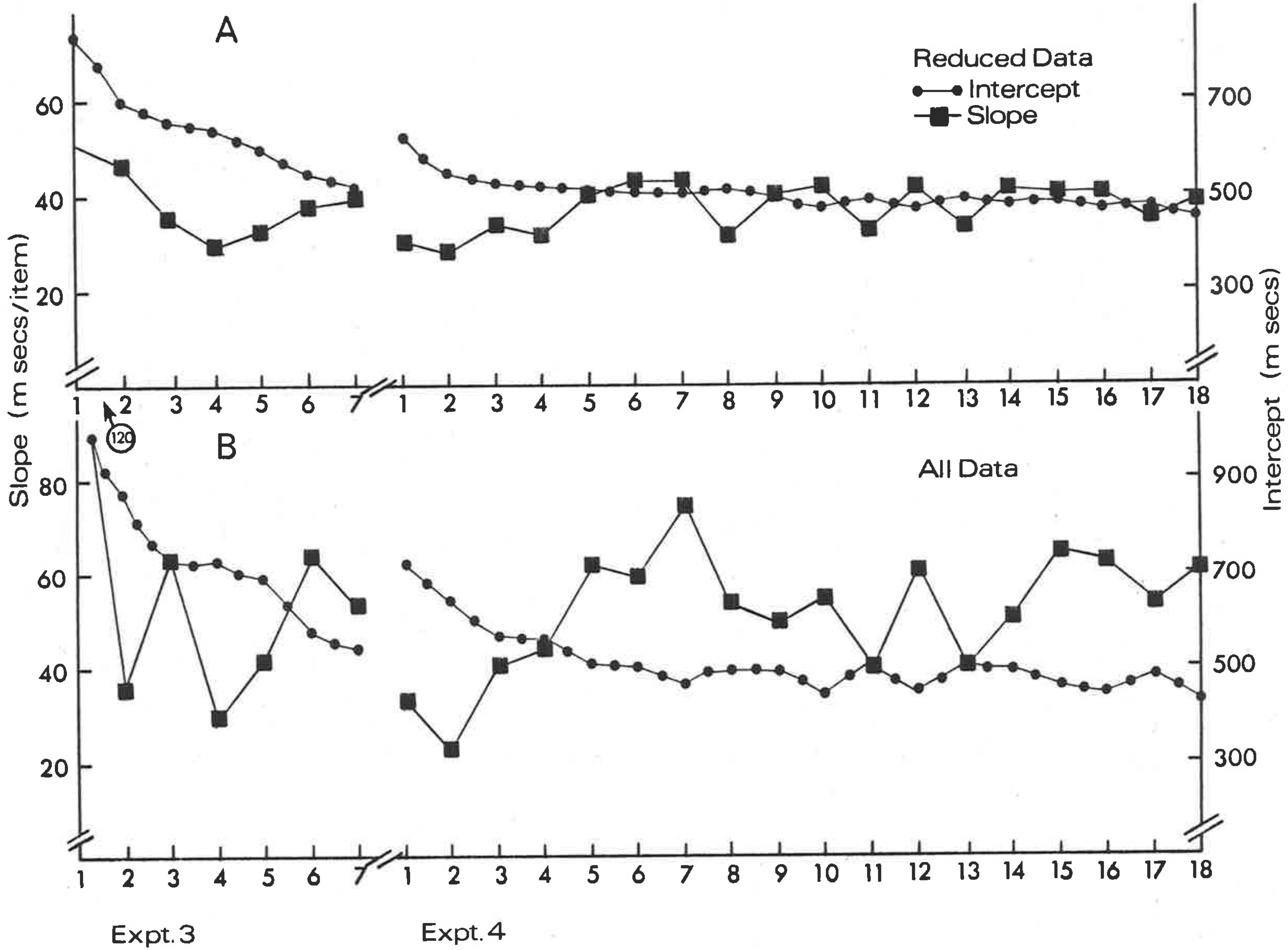
(ii) Early in practice, there were large differences in the slopes and intercepts of item recognition functions for 'yes' and 'no' responses among retarded subjects. However, late in practice, item recognition functions for the two levels of response were parallel.

(iii) Following extensive practice, slopes among retarded subjects were reduced to a level similar to that found in Experiments 1, 2 and 3 for nonretarded adults. Zero intercepts were reduced as well, but they approached an asymptote at a speed slower than that found among nonretarded adults in the earlier experiments.

(iv) Negative correlations between the slopes and intercepts of item recognition functions of retarded adults were reduced somewhat by practice,

FIGURE 4.8

Slopes (msecs/item) and zero intercepts (msecs), averaged across 'yes' and 'no' responses, for each session of practice given to retarded adults under a varied set procedure in Experiment 3 (seven sessions) and Experiment 4 (eighteen sessions). (A) shows data calculated after very long RTs were excluded from analysis, and by way of comparison, (B) shows data with all RTs included.


A
Reduced Data
Intercept
Slope
B
All Data
Slope (m secs/item)
Intercept (m secs)
120
Expt. 3
Expt. 4

	RESPONSE		
	NO	YES	YES + NO
SESSION			
1	-0.82*	-0.46	-0.85**
2	-0.54	-0.82**	-0.67*
3	-0.58	-0.94**	-0.88**
4	-0.70*	-0.84**	-0.78*
5	-0.23	-0.78*	-0.33
6	-0.52	-0.61	-0.56
7	-0.24	-0.55	-0.48
8	-0.46	-0.62	-0.52
9	-0.14	-0.70*	-0.28
10	-0.43	-0.63*	-0.53
11	-0.66*	-0.78*	-0.13
12	-0.49	-0.76*	-0.57
13	-0.49	-0.86**	-0.65*
14	-0.52	-0.79**	-0.57
15	-0.31	-0.76*	-0.53
16	-0.48	-0.81**	-0.63*
17	-0.32	-0.84**	-0.54
18	-0.29	-0.41	-0.31

Table 4.4: Experiment 4: within-group correlations ($n = 8$) of slopes and intercepts from each subject's item recognition function from reduced data from each session of practice showing 'yes' and 'no' responses separately and combined.

** $p < 0.01$ (one tailed)

* $p < 0.05$ (one tailed)

when performance was relatively stable and within-subject variability low. However, correlations remained high and negative throughout practice.

4.4 GENERAL DISCUSSION

Literature reviewed in Chapter 3, together with results from Experiment 3, showed that the effect of practice on memory search performance among nonretarded adults is dependent on stimulus-response mapping characteristics of the task. When a memory item is not consistently associated with one type of response, as in the varied set procedure, practice only reduces the zero intercept of the item recognition function, the slope remaining unchanged (Kristofferson, 1977). In terms of Sternberg's model, this outcome is interpreted to mean an increase with practice in the efficiency of processes reflected in the zero intercept, with the rate of exhaustive scanning of memory being already maximally efficient at the beginning of training.

The present experiment has found that practice within a varied set procedure improves both the slope and the zero intercept of item recognition functions among retarded adults. Extensive practice was needed to bring retarded subjects' performance close to the level of efficiency easily attained by normal subjects after very little practice, but the mean value for slopes of item recognition functions eventually reached by retarded subjects in the present experiment was similar to that obtained in previous studies of normal memory search. This finding contradicts those experiments, reviewed in Section 1.4, which have found that the slopes of functions among retarded subjects are more steep when compared with functions for normal controls. The suggestion that retarded memory search performance is due to some permanent deficiency in speed of memory scanning (Harris & Fleer, 1974) was therefore premature, since the present experiment has shown that the slopes of mean item recognition functions can be reduced with practice. The slower initial speed of processes reflected in the slope of the mean item recognition function for this group is therefore interpretable as being the consequence of a control or production deficiency.

Processing limitations resistant to practice were, however, exhibited in processes reflected in the zero intercept of item recognition functions for the retarded subjects, intercepts remaining higher than those of chronological age controls even after extensive practice.

Although normal controls were not included in the present experiment, examination of Experiment 3 data suggested that nonretarded subjects would not have improved greatly with further practice. Extrapolating from the improvement in mean RT among chronological age controls in Experiment 3, a further eighteen sessions of practice would have produced a decrease in RT of only 20 msecs for this group (percentage of variance accounted for by fitted curve = 99.06%). With a predicted mean RT at session 25 of 438 msecs, and a slope of 34 msecs/item (assuming no change in slope with practice), the predicted zero intercept would be 332 msecs - 150 msecs faster than the final zero intercept of 480 msecs among retarded subjects. This predicted asymptote is similar to that obtained in previous studies. Kristofferson (1972) found that the mean zero intercept was reduced over 30 sessions from 350 msecs to 300 msecs among her normal subjects. Sternberg (1967) found a shift over two sessions from 372 msecs to 332 msecs. Corballis, Roldan & Zbrodoff (1974) obtained a shift from approximately 370 msecs to 320 msecs over 18 sessions of practice. The slightly lower intercepts among these previous studies is probably due to the fixed set procedure being used within each session, since the fixed set procedure generally leads to intercepts in the order of 30 msecs lower than those found under varied set procedure (Sternberg, 1969). Furthermore, Kristofferson (1972) and Corballis et al. (1974) presented probe test stimuli for very short exposures (44 msecs and 150 msecs respectively), a procedure which may have biased subjects towards responding more quickly.

It is clear from this evidence that while retarded subjects may have reached a level of efficiency for processes associated with the slope of the item recognition function that was close to that found among nonretarded subjects, other processes reflected in the zero intercept remained less efficient after extensive practice. Three previous studies have reported values for zero intercepts that were substantially the same for retarded subjects and their chronological age controls, but steeper slopes among retarded subjects (Harris & Fleer, 1974; Maisto & Jerome, 1977; Silverman, 1974). It is interesting to note that retarded subjects from these studies have had no more than preliminary training in the experimental task. In Experiments 3 and 4, however, where practice has been extensive, slopes are eventually about the same for retarded and nonretarded adults, but intercepts are higher for the retarded group. It is possible that, early in practice, subjects trade off slope and intercept, as will be discussed below, so that the relationship of the performance of retarded subjects to that of chronological age controls appears to be the opposite to that found late in practice.

The present data are in agreement with previous studies which have concluded that retarded subjects' encoding or response selection processes are quicker than those of mental age controls (Harris & Fleer, 1974; Silverman, 1974). This finding apparently applies both early and late in practice. Extrapolating from a curve fitted to mental age controls' mean RT per session in Experiment 3 (percentage of variance accounted for by fitted curve = 93.02%), mean RT after 25 sessions of practice would be approximately 739 msecs. Given the mean slope of 25 msecs/item calculated after seven sessions' practice, the zero intercept after a further 18 sessions would be around 662 msecs. Experiment 3 data suggest that mental age controls would not have benefited from further extensive practice as much as did the retarded subjects participating in Experiment 4.

As was shown from the data of Experiments 3 and 4, retarded subjects' responding not only became faster with practice, but item recognition functions more closely resembled those found among nonretarded adults. Thus, the inconsistencies in reported relationships between retarded and nonretarded responding may be due in part to the level of practice at which performance was examined, it being shown here that responding is very slow and variable in the early stages of practice. However, the fact that negative within-group correlations between the slopes and intercepts of item recognition functions remain substantial during the course of practice indicates that the independence of stages commonly assumed to characterize memory processing among nonretarded adults does not hold for retarded adults' performance. The negative correlations were somewhat reduced, but certainly not abolished, by extensive practice. If independence is required for identification of separate processing stages, then, in this task, retarded subjects cannot be said to process information in distinct mental operations.

The stronger negative correlations early in practice than later may be related to the greater variability in responding to probe stimuli from 'large' set sizes. The very slow responses early in practice may have been due to subjects attempting to maintain accuracy by being very cautious. However, a nonparametric signal detection theory analysis of errors made indicated that while the number of misses remained constant over practice, false alarms decreased, so that in effect caution increased with practice. As was noted above in the analysis of errors made (section 4.3.1), the distributions for 'noise' and 'signal + noise' appeared to move apart as subjects became more practiced, while the response criterion remained in the same position relative to the 'signal + noise' distribution. This increase in sensitivity could have reflected more effective attention after some practice with the task.

Thus, early in practice, subjects may have been hampered by poor attentional control which made storage of items inaccurate when set size was large and when the time taken for the successive presentation of the memory set was relatively long. If this problem was handled by responding after some subjectively fixed time, any increase in the time taken by one mental operation would reduce the amount of time available for all other stages. Later in practice, subjects may have attended to the presentation of large set sizes more efficiently, so that the proportion of very long RTs, as well as the negative correlation between speed of mental operations, decreased.

Crossman (1959) has suggested that early in practice, a number of different methods of responding, corresponding to the repertoire of strategies available to be applied, are used with equal probability. Some methods are slower than others, so that variance will be high and mean RT slow. The poor appreciation of retarded subjects for task demands may mean that they begin with a wide repertoire of inefficient strategies, and continue to use inappropriate strategies of responding when normal subjects have already discovered the most efficient method of performance. Again according to Crossman (1959), more efficient methods are developed later in practice, so that mean RT and variance are reduced. While Crossman's (1959) suggestion predicts the change to RT distributions found between Experiments 3 and 4, it cannot explain how retarded subjects change from responding characterized by nonlinear functions to linear ones, or from nonparallel to parallel 'yes' and 'no' functions. As Rabbitt (1981) has pointed out, with extensive practice subjects do not simply carry out the same processes faster and more accurately, but rather find new and more efficient ways to complete the task.

Chapter 5

CRITICISMS, DIRECTIONS FOR FURTHER RESEARCH, AND CONCLUSION

5.1 INTRODUCTION

While the process of recognition can be analysed into a series of discrete mental operations carried out by normal adults, this thesis has shown that a similar analysis of the recognition memory performance of mildly retarded adults is hampered by their sensitivity to procedural variables. Such sensitivity may place serious limitations on the usefulness of the Sternberg recognition memory paradigm as a technique for exploring the cognitive processes of retarded persons.

This chapter considers the potential of the Sternberg paradigm for discovering more about the way retarded persons recognize stimuli. Firstly, experimental results presented in Chapters 2, 3 and 4 are summarized, so as to define the limits of the four stage model in describing retarded performance. Secondly, some alternative models are examined in order to explore the possibility that modifications of, or extensions to, the Sternberg paradigm concomitant with these models provide a more refined description of the recognition memory performance of mildly retarded persons.

5.2 THE STERNBERG MODEL AND MENTAL RETARDATION

A review of the literature in Chapter 1 showed that the Sternberg four-stage model of memory processing (Sternberg, 1969) can describe the memory retrieval performance of normal adults, but only under limited conditions. When small positive sets, up to approximately the memory span of the subject, are presented slowly so that errors are at a minimum and responses are not consistently associated with particular stimuli, the recognition strategy adopted by normal adults is generally well described as a serial, exhaustive memory scanning process within a series of discrete mental operations, each of which is apparently completed before the next begins. The performance of nonretarded children and retarded adults can also be described in terms of a progression through a series of mental operations, as inferred from the additive factors manipulated in Experiments 1 to 4, but the independence of operations is more difficult to demonstrate within these two groups. Thus, important aspects of the present data, as well as aspects of previous studies, are not easily fitted into the original framework outlined by Sternberg (1969).

A number of findings reviewed in Chapters 1 and 3 were either at variance with or not included within the scope of the model. The main discrepancies were:

(i) Nonlinear functions, and in particular negatively accelerating functions; studies reviewed in Chapter 3 showed that when stimulus-response mapping is consistent across trials, linear functions generally assumed to reflect serial, exhaustive memory scanning are not found.

(ii) Item recognition functions that do not change with increasing set size, as when very long, well learned lists are presented.

(iii) Category and familiarity effects; when items can be organized in some way, such as being grouped into a set number of categories, or some items are more familiar than others, the slope of the item recognition function is reduced.

(iv) Serial position effects; Chapter 1, Section 1.7 and Experiments 1 and 2 provided evidence that serial position effects can occur even when data are well described by parallel 'yes' and 'no' item recognition functions.

(v) Stimulus set effects; when some items occur more than once in the positive set list, or when certain items are presented as probes more often than other items, RTs to these items are on average faster than those to less frequent items.

Certain aspects of the performance of mildly retarded adults and of nonretarded children investigated in this thesis have also raised difficulties for the Sternberg model. The main issues addressed in this thesis have been:

(a) The effects of a fixed set and a varied set procedure, assumed respectively to reflect long-term and short-term storage, on performance in Sternberg's memory retrieval task.

(b) The effects of practice on performance in the memory retrieval task.

(c) The independence of processing stages postulated by Sternberg.

(d) The effects of individual differences, between retarded and nonretarded groups, and within groups, on performance in the memory retrieval task.

These issues are summarized in the sections that follow, evaluating the relevance of the Sternberg model to recognition memory in mild mental retardation.

5.2.1 Effects of procedure on memory scanning in mental retardation

Sternberg (1969) found similar results among normal adults tested under either a fixed set or a varied set procedure, the only difference being that, under the varied set procedure, item recognition functions had slightly slower intercept values, this outcome presumably being related to slower encoding or response selection processes. Data presented in this thesis have suggested that both encoding or response selection and memory scanning processes may differ between procedures when retarded adults are tested under both conditions, since both slopes and intercepts of item recognition functions for this group of subjects are affected by this procedure.

Sternberg has suggested that the same short-term memory store may be searched in the two procedures, and has described the short-term store as a "temporary active memory of small capacity from which information is rapidly lost unless an active retention process is operating" (Sternberg, 1969, p.430). He has concluded that under the fixed set procedure, material is apparently maintained in short-term memory by rehearsal as well as being stored in long-term memory. Under the varied set procedure, however, the progression of material is too rapid for registration in a long-term store, so that a serial, exhaustive scan of material that is held only in short-term memory is required.

In Experiment 1, data for mildly retarded subjects were consistent with serial, exhaustive memory scanning of up to six items when a fixed set procedure was used. Thus, under this condition, in which material is assumed to be stored in both long-term and short-term memory, a similar retrieval strategy to that typically used by nonretarded subjects may have been employed. However, retarded subjects may have employed different strategies when the varied set procedure was involved, as suggested by the different form of the mean item recognition function to that for the fixed set procedure, the greater number of errors and the different kinds of serial position effects. The greater number of misses registered by retarded subjects under the varied set procedure in Experiments 1, 2 and 3 suggests that stimulus items may not have been stored as accurately as under fixed set conditions. Furthermore, serial position effects found under the varied set procedure in Experiment 2 suggest that retarded subjects may have stored the last items presented, but that items presented first were likely to be lost. The finding of recency effects in the varied set procedure and primacy effects in the fixed set procedure suggests differences in the amount of rehearsal used by retarded subjects under the two procedures. These results are therefore contrary to Sternberg's (1969) proposal, which implied that the same 'active retention process' would be used in the two procedures.

This finding of significant serial position effects poses another problem for the Sternberg model, which holds that all positive set items in memory are searched on every trial. This strategy would not result in serial position effects, so that even though item recognition functions are consistent with exhaustive memory scanning, the presence of significant serial position effects in the same data is incompatible with Sternberg's model. The serial position effects found in Experiment 2 may have been due to the particular sample of subjects used, since statistically significant serial position effects were not found in other experiments presented here. However, previous studies have also found similar results which have contradicted the Sternberg model, as has been reviewed in Chapter 1.

Previous evidence in the literature has suggested that serial position effects may occur when storage of information is unstable, as may be the case when the presentation rate for the memory set is fast. However, the low error rates found in Experiment 2 indicated that the storage of items in memory should have been reasonably stable. An alternative suggestion is that serial position effects may occur when subjects decide to respond on the basis of some process other than a serial scan of memory items. Results from Experiments 3 and 4 showed that early in practice, retarded subjects under the varied set procedure responded very slowly, making more errors than under fixed set conditions. Thus, the successive presentation of material in the varied set procedure may have exacerbated subjects' poor attentional control and made it difficult for them to hold all items in memory. It has also been suggested in Chapter 2 that retarded subjects may have been hampered by their inability to use a verbal-sequential coding system. Under these conditions, when memory storage may have been poor, items presented late in the list, and thus relatively close in time to the probe item, may have been stored with a stronger memory trace than items presented earlier. Thus, subjects may have responded on the basis of strength of a memory trace, items with weak memory traces being responded to very slowly. When subjects' attention was more controlled, all items stored may have resulted in a memory trace of similar strength, and a serial scan of memory may have been employed. Similar theories, which suppose that there may be some mechanism of direct access to memory which can be used as an alternative to serial search, will be discussed below. It should be noted, however, that the Sternberg model has no provision for such alternatives.

Another aspect of the difference in performance found between procedures in the systematically greater number of errors made by retarded subjects under the varied set procedure compared with the fixed set procedure. There were also consistent increases in errors with increasing set size in data from all experiments reported here, an effect which has been supported by evidence from studies with nonretarded children and adults (e.g. Naus & Ornstein, 1977). Although these effects were small and overall error rates quite low, they cannot be accounted for by the Sternberg model, which assumes that errors do not affect RT and are invariant across levels of factor tested. Furthermore, there is evidence from other RT tasks that very small changes in error rate can lead to large changes in RT (Pachella, 1974; Rabbitt, 1981). Thus it is possible that when retarded subjects are required to respond very accurately, they may attempt to maintain accuracy by responding very slowly so that RT is sometimes beyond the upper asymptote of an ogival speed/accuracy function, and is very variable.

Similarly, the Sternberg model cannot account for data where moderately large numbers of errors occur, since scanning under these conditions is generally not serial or exhaustive. Data from Experiment 1 showed that when error rate among retarded subjects was high, some strategy other than serial, exhaustive scanning may have been adopted, as suggested by faster than expected RT to negative probes when large positive set sizes were presented under the varied set procedure. NcNicol & Stewart (1981) attempted to incorporate the number of errors made into the serial exhaustive scanning model, but they concluded that such a model can only easily account for error-free performance. This could be a significant limitation to a model of memory for mental retardation, since, as was shown in Chapter 2, the circumstances under which retarded subjects respond with similar error rates to those found among nonretarded subjects are quite restricted.

Thus, the effect of speed/accuracy set on retarded performance needs to be investigated more fully, since although the Sternberg paradigm requires close to error-free performance, errors may be an important source of information about the memory processing strategies of retarded persons. Manipulating the speed/accuracy trade-off adopted by retarded subjects may reveal a systematic trend in the response strategy applied early in practice.

5.2.2 Effects of practice on memory scanning in mental retardation

Changes in the slopes of mean item recognition functions under a varied set procedure cannot be accommodated by a serial, stage model of recognition, regardless of whether the stronger supplementary assumption of independence of stages is included or not. Models such as the Sternberg model of recognition memory do not attempt to explain a control process which may regulate the speed of each stage of recognition, but some such explanation is necessary to account for change in cognitive performance. A model which accommodates practice effects may also need to explain the process of making a choice between alternative strategies such as serial scanning and automatic detection. Again, this concept is beyond the scope of the Sternberg model.

The results from retarded adults and nonretarded children reported in Chapters 3 and 4 therefore cannot be explained by the Sternberg model, which does not consider the individual subject's ability to increase his speed or efficiency of recognition. However, the model is not unique in this shortcoming. Rabbitt (1981) has argued that the majority of current information processing models are 'static', in that they cannot describe systems which are subject to any change, such as that brought about by practice.

Experiment 3 showed that retarded subjects' performance benefited most from practice when compared with the performance of nonretarded adults and children. The difference in speed between fixed set and varied set procedures was reduced after one or two sessions of practice, indicating that retarded subjects required more practice with the varied set procedure than the fixed set procedure, compared with nonretarded control subjects. Thus, practice led to different effects on the performance of retarded subjects under the two procedures, in that the decrease in slope and intercept values from mean item recognition functions was more consistent during practice under the varied set procedure than the fixed set procedure. This result suggests that the varied set procedure facilitated whatever process regulates efficiency of memory processing.

One aspect of the varied set procedure which may have encouraged more efficient memory processing during practice was the successive presentation of memory set items. As noted in Chapter 2, this presentation may have led to the use of an auditory-verbal memory code of material (as suggested by the work of O'Connor & Hermelin, 1971) and verbal rehearsal, while the simultaneous presentation used under the fixed set procedure may have led to the use of visual, spatial coding of material and so less verbalization.

Thus the reduction in zero intercepts of mean item recognition functions from the varied set procedure may have been due in part to more effective rehearsal with practice, as retarded subjects gradually learned to use the successive-presentation cue to rehearse verbally. Studies of the effect of interpolated tasks on memory scanning performance, reviewed in Chapter 1, indicated that prevention of rehearsal leads to an increase in the zero intercept of the item recognition function. Thus, the high zero intercept for retarded subjects under the varied set procedure early in practice may have been due in part to insufficient rehearsal. One could test this by interpolating an extra task between presentation of the memory set and the probe after retarded subjects have been well practiced, to determine whether performance reverts back to levels established early in practice. Alternatively, items in the varied set procedure could be presented either simultaneously or successively, the former hypothetically leading to visual spatial coding of material than the latter. The number of trials of practice necessary to bring the performance of retarded subjects to an asymptote under these two conditions could then be compared.

5.2.3 Independence of processing stages

Early in practice, the performance of retarded subjects was characterised by negative correlations between slopes and intercepts of item recognition functions, suggesting that underlying processing stages were not independent. Significant negative correlations have been reported in other studies of retarded persons' performance in the memory retrieval task (Silverman, 1978), and have also been found in studies of normal children. For example, Seymour & Moir (1980) found negative correlations between slopes and intercepts when testing ten year old children. Their data also appeared to demonstrate considerable individual differences, since they reported instances of certain individuals' data with negative slope values for the item recognition function, even though the average slope values were positive and reasonably high. The results from studies reported in this thesis suggest that this pattern of results will be found early in practice when testing groups of a young mental age, but that when sufficient practice is given, the correlation between slope and intercept diminishes.

It has been suggested in Chapter 4 that some subjects may adopt a strategy of deadline responding early in practice, so that additional time spent in processing at one stage reduces the time remaining for processing at the next stage. This hypothesis could be tested by manipulating a deadline by which subjects should respond, to see whether such a restriction increased the negative correlation between slope and intercept, compared with when no deadline was imposed.

That negative correlations between the slope and intercept of functions were also found among nonretarded adults in Experiment 3, when results were virtually identical to those generally assumed to mean serial, exhaustive scanning, raises the possibility that the original assumption of independence as well as the additivity may not have been met in other studies which have produced similar results. Furthermore it seems possible that a broader range of performance may be explained by an additive factor model which excludes the assumption of independence from a definition of separate processing stages, such as that proposed by Stanovich & Pachella (1977).

5.2.4 Memory scanning and individual differences

Practice led to increasing efficiency of retarded performance, visible in the reduction of mean RT, and of both zero intercept and slope of the item recognition function and of between-subject variability. These results have important consequences for those studies in the literature which have attempted to link slow, variable memory search with some organic impairment in memory processing. Several of the studies reporting slower memory search in pathological groups such as brain damaged alcoholics (Naus et al., 1977), aphasic patients (Warren et al., 1977) and schizophrenic patients (Wishner et al., 1977) found considerable individual differences within groups categorized according to pathology. However, between-subject variability among retarded subjects participating in Experiment 4 subsided to a level near that found among nonretarded adults. This finding may be relevant to the performance of other pathological groups if they were permitted similar levels of practice to those applied here.

Thus, other groups who have exhibited steep slopes for average item recognition functions and variable performance may benefit from similar conditions to those which enabled a stable level of performance to be reached by retarded persons.

The finding of slower memory search in some groups with an established memory deficit may reflect a structural deficiency, but contrary to the suggestion of Harris & Fleer (1974) the deficiency attributed to retarded persons' memory search does not appear to be permanent, since the results from Experiments 3 and 4 have shown that a sufficient amount of practice can mitigate this deficiency. Thus an alternative explanation to that suggested by a 'static' model of the performance of retarded persons in the memory retrieval task is that the mechanism of memory search is intact in retarded persons, since they are able to perform in a similar manner to chronological age controls, but the control process which regulates speed of processing or choice of retrieval strategy is retarded, this retarded control process presumably being a permanent deficiency*. As was noted in Chapter 3, an appropriate measure of the efficiency of memory retrieval performance of retarded persons may be the amount of practice required before performance reaches a level of stability near that of nonretarded controls, rather than the speed of mental operations early in practice. Unfortunately, the Sternberg model throws no light on the control process which prevents retarded adults from responding in a stable manner until they have had considerable experience with the memory retrieval task.

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* I am indebted to Dr T. Nettlebeck (personal communication) for this suggestion.

5.3 ALTERNATIVE MODELS OF RECOGNITION MEMORY IN MENTAL RETARDATION

Overall, the concept of a serial, exhaustive memory scanning process has limited usefulness, expecially when considering memory processes in mentally retarded persons. Some of the findings from previous studies as well as aspects of some data presented here contribute to the generality of the Sternberg model. For example, stimulus probability appears to affect only the encoding stage of recognition memory (Miller & Pachella, 1973); response set effects may only occur under stimulus conditions which are not usually associated with serial, exhaustive scanning (Kristofferson, 1973). However, those effects associated with changes in the slope of the item recognition function (e.g. the effects of certain items in the memory set being more familiar than other items or the effects of practice) require more drastic changes to the Sternberg model. Sternberg (1975) has conceded this, and others (e.g. Corballis, 1975) have noted that serial, exhaustive scanning must be only one of a repertoire of retrieval strategies available in the recognition process.

For the memory scanning modèl to account for a wider range of recognition memory performance, it should therefore be modified. Several models have been generated to account for data that are either contradictory or not encompassed by the four stage model of recognition memory. A number of models have also presented alternative, equally credible explanations of typical findings. Since this thesis attempts no direct test of the predictions generated by alternative models, they will not be examined in detail. However, in light of the restricted applicability of the Sternberg model to the data obtained for mentally retarded adults, some alternative models of recognition memory will be considered as possibly providing a more satisfactory framework for the present data.

Huesmann & Woocher (1976) referred to four main classes of recognition memory models:

(a) Extensions to the concept of exhaustive memory search.

(b) Limited capacity, parallel processing models.

(c) Self-terminating memory search models.

(d) Trace strength and direct access models.

5.3.1 Extensions to the concept of exhaustive memory scanning

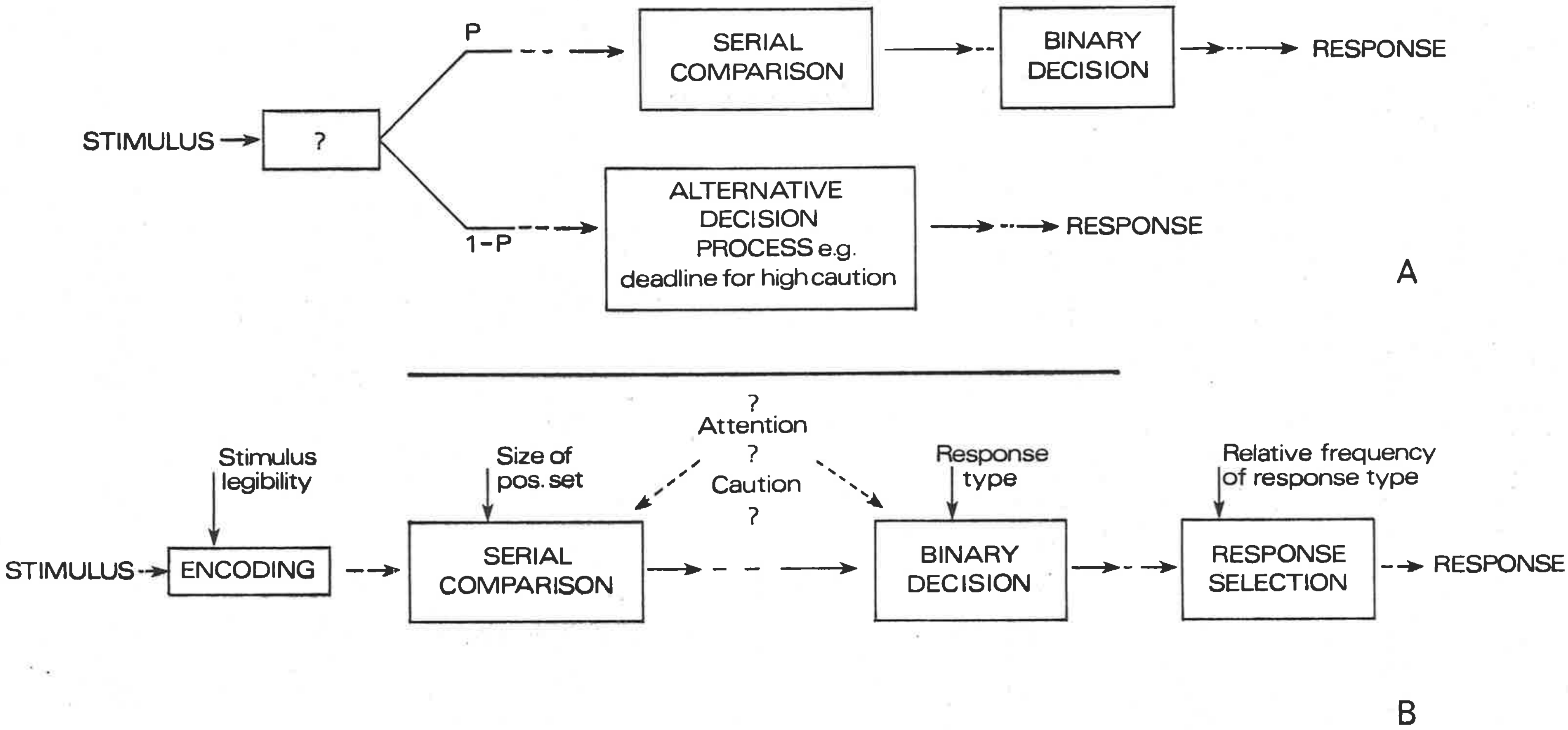
Included in Huesmann & Woocher's (1976) first class of models would be Sternberg's (1975) suggestion that performance may be a probabilistic mixture of serial comparison and an alternative decision process. This suggestion could account for the alternative strategies adopted by retarded adults and nonretarded children early in practice, the alternative decision being conceptualised as, for example, a very slow, subjectively fixed, deadline response. Here the alternative decision process could be considered to have a high probability of use early in practice, but a low probability of being used later in practice. This suggestion is illustrated in Figure 5.1(A). The proportion of trials on which subjects choose the serial comparison strategy may increase with practice, and this would explain the reduction in variability of RT over practice.

However, this suggestion would not explain the process by which subjects change the probability of using one decision strategy or the other. Why would subjects prefer one decision strategy early in practice and another later? Without specifying the process by which a particular decision strategy is chosen from trial to trial (beyond the "early analysis of the stimulus" (Sternberg, 1975, p.12)), changes in probability remain unexplained.

An alternative model to the above conception would be one in which the second decision strategy is assumed to be an extra factor which influences more than one stage of the recognition process. Figure 5.1(B) illustrates a situation where some factor, such as attention or caution, is assumed to vary from trial to trial in such a way that processing times for all stages are

FIGURE 5.1

Two conceptions of the recognition process which attempt to account for the proportion of very slow RTs seen early in practice in the performance of retarded adults (adapted from Sternberg, 1975).


P
SERIAL COMPARISON
BINARY DECISION
RESPONSE
STIMULUS
?
ALTERNATIVE DECISION PROCESS e.g. deadline for high caution
1-P
RESPONSE
A
?
Attention
?
Caution
?
Stimulus legibility
Size of pos. set
Response type
Relative frequency of response type
STIMULUS
ENCODING
SERIAL COMPARISON
BINARY DECISION
RESPONSE SELECTION
RESPONSE
B

affected together. The result, as explained by Chase (1978), would be that the component times for the various stages were substantially correlated. If the influence of the extra factor made subjects use a deadline response on some trials, the negative correlations between slope and zero intercept of item recognition functions for retarded subjects could be explained, although change with practice would remain outside the scope of the model.

Other models have added a process for fast retrieval in order to account for change in slopes of item recognition functions. Juola, Fischler, Wood & Atkinson (1971) added a process for retrieval from long-term memory; Naus, Glucksberg & Ornstein (1971) added a self-terminating scan for categories within the positive set and Burrows & Okada (1971) added a 'priority of access hierarchy' within the positive set. However, while these models may account for a change from serial, exhaustive scanning to a faster strategy, which may be used when some order can be imposed on the memory set or when the memory set is very well learned, the move from inefficient, slow responding to serial, exhaustive scanning found among retarded subjects is not as readily explained. Nor do these models account for the greater number of errors made by retarded subjects when relatively large memory sets are presented, as in Experiment 1.

5.3.2 Parallel processing models

Limited capacity, parallel processing models assume that items in the positive set are compared in parallel with the test item, but by a process within which comparison speed is limited by the number of items in the positive set - the more items, the slower the speed (Murdock, 1971; Townsend, 1971). The question of parallel versus sequential processing has received a great deal of attention but little resolution. Some experimenters have questioned the identity of underlying processes, and so the usefulness of the distinction (Eysenck, 1977; Townsend, 1971). Nickerson (1972) has suggested a system where parallel and sequential operations are interchangeable, so that some, but not all, processes may overlap in time. Stanovich & Pachella (1977) conjected that instead of a factor that speeds up some stages but slows down others to account for negative correlations between stages, an underadditive interaction* could be accommodated by assuming that stages may overlap in time. The extent of overlap is determined by the efficiency of each stage, so that as each stage becomes more efficient, it also becomes more independent. This conception assumes that the same processes occur at all levels of practice, the processes becoming faster with practice. However, Experiments 3 and 4 have indicated that qualitatively different responses are adopted by retarded persons as practice with the task progresses, as evidenced by the change from nonparallel to parallel 'yes' and 'no' item recognition functions and reduction in the between-subject variability. These results thus suggest that retarded persons may use different processes late in practice, rather than speeding up processes used earlier.

McClelland (1979) has presented a 'cascade model' in which all the subprocesses postulated by Sternberg operate simultaneously. Processing at one level is contingent on processing at other levels, even though they occur simultaneously. The model successfully predicts data found in the typical memory scanning paradigm. However, the derivation of the model is complicated. McClelland (1979) has admitted that it is impractical to collect the amount of data necessary for a proper test of cascade predictions and that many of the underlying assumptions of the model are oversimplifications. Furthermore, the model's inability to "distinguish

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* The concept of underadditivity refers to a situation where, for example, the difference in RT between 'yes' and 'no' responses is greater at small set sizes than at large set sizes. Overadditivity would occur when the difference between RTs for 'yes' and 'no' responses was greater at large set sizes than at small set sizes (Stanovich & Pachella, 1977).

between a manipulation that inserts a process and one that alters the rate of a process" (McClelland, 1979, p.319) suggests that it has a similar fault to the subtractive method of Donders (1968) in that the assumption of pure insertion of stages is difficult to justify.

5.3.3 Self-terminating memory scanning models

The third class of models that Huesmann & Woocher (1976) have considered are theories of self-terminating memory scanning (e.g. Anders, 1973; Snodgrass, 1972; Theios, 1973). According to the model of Theios (1973), the whole ensemble of positive and negative stimuli is searched, rather than just the positive set. When a match with the probe occurs, memory search stops. Each item in the list has a code attached which indicates the correct response for that item, and the list acts as a 'push down stack', with more recent and more frequent stimuli located near the beginning of the list. If the two responses are required with equal frequency, the average amount of search required for each response will be the same, so parallel 'yes' and 'no' functions should occur. However, this model has been criticized on several grounds (Pachella, 1974; Shiffrin & Schneider, 1974; Sternberg, 1975). For example, the unparsimonious method of accounting for the varied set procedure, where the negative set is known only by default, suggests that it is an unacceptable model for either retarded or nonretarded performance.

An alternative proposal is that of Ratcliff (1978), whose 'random walk' model is based on a comparison between probe and memory items by way of a diffusion process towards either a 'match' or 'non-match' boundary. He proposed parallel, self-terminating comparisons between probe and items in memory. The model uses RT distributions and speed/accuracy functions rather than mean RT as the dependent variable. This would be an advantage when considering retarded memory performance, where variability is a compelling characteristic of performance early in practice. The model accounts for serial position effects, repetition effects and effects of very long memory lists. However, it does not made a clear prediction regarding linearity of the latency function, even though it has sixteen parameters to fit mean RT to positive set size. Serial position effects and repetition effects can occur at the encoding stage rather than the serial comparison stage of the Sternberg model (Juola, 1973; Sternberg, 1975), so Ratcliff's (1978) claim that these effects are incompatible with Sternberg's (1975) scheme was misleading. Furthermore, the fit of Radcliff's (1978) model to data from very long lists was unremarkable, so that the advantages of the more complicated model as far as accommodating data not encompassed by the Sternberg (1975) model are not as marked as supposed by Ratcliff. Corballis (1979) has suggested that if the serial process involved in recognition was conceived as 'evocation' (Ratcliff, 1978) or 'decoding' (Newell, 1973) of the search set followed by a non-serial comparison with the probe, then the two approaches of Sternberg (1975) and Ratcliff (1978) would be resolved. However, he also noted that "it is difficult to distinguish empirically between a serial process that involves comparison and one that does not" (Corballis, 1979).

5.3.4 Trace strength and direct access models

In the typical trace strength model, the subject consults a memory location corresponding to the probe item, basing his decision on the strength or familiarity of the trace that is stored there (e.g. Pike, 1973). If the familiarity is greater than an adopted criterion, the subject decides that he does recognize the presented item. Thus, the serial position effects found in Experiment 2 could be explained by assuming that the familiarity value is highest for more recently presented items or perhaps more recently rehearsed items.

However, again there is no reason to expect RT to decrease with practice in this model, since in the varied set procedure, familiarity would always be the same, regardless of the level of practice. The model also does not predict the shape of the item recognition function; only that it should increase monotonically.

The notion of direct access can, however, be adapted to explain a wide range of cognitive processes when it is combined with alternative modes of processing. For example, the model proposed by Atkinson & Juola (1972) is a dual process model in which the subject has two alternative strategies available: one, a direct access strategy, and the other, a serial search strategy. It has been described in detail by Corballis (1975), Eysenck (1977) and Sternberg (1975). The subject is held to base his decision on familiarity alone if the probe item has either a very low or very high familiarity value. For intermediate values, however, an exhaustive serial search is undertaken. This model can account for functions where RT is independent of the number of items memorized, and for serial position effects.

However, this model also implies a bimodal distribution of RT, with longer RTs for serial search and shorter RTs for direct judgments of familiarity. Application of the model to data from mentally retarded subjects may require the addition of a third, optional strategy which produces very long RTs, since RT data for such subjects early in practice is typically positively skewed rather than bimodally distributed. With this addition, it is possible that a model similar to that proposed by Atkinson & Juola (1972) could explain the performance of retarded subjects in tasks presented here.

Since the two strategies suggested by Atkinson & Juola (1972) are mutually exclusive, the proportion of trials on which subjects use each strategy can be expressed as a probability. This concept was illustrated in Figure 5.1(A), and is now considered in the context of the dual process model, in which the alternative to serial search is direct access based on a familiarity value. Figure 5.2(A) shows a hypothetical item recognition function, with the linear, increasing function generally assumed to signify serial search, and the flat function which would occur when subjects used a direct access strategy because of very high familiarity. If subjects used the two strategies equally often at every memory set size, so that the probability of using serial search was 0.5 at each set size, then the average item recognition function would be that illustrated in Figure 5.2(A). In this figure, the probability of a particular strategy being used does not vary systematically with the number of positive set items stored in memory.

However, this concept poses some difficulty for the interpretation of data from retarded subjects. The large number of errors made to probe items from positive set sizes of five and six items in Experiment 1, and the greater variability in RT to probe items from large set sizes in Experiments 3 and 4 suggest that retarded subjects may not have used the same response strategy to all set sizes. There is evidence in the literature that serial, exhaustive memory scanning does not occur when error rates are moderate (e.g. Aube & Murdock, 1974). Given that errors increase with increasing set size, especially in the data of retarded adults, it appears reasonable to suggest that the probability of serial search strategy being used may decrease with increasing positive memory set size. Thus, although the Atkinson & Juola (1972) model (illustrated rudimentarily in Figure 5.2(A)) accounted well for the performance of normal adults who were presented with very long, well learned memory lists, such a conception in which the probability of each strategy being used is independent of memory set size, may not be as satisfactory when considering the performance of retarded subjects presented with short memory lists.

If one could assume that the probability of responding on the basis of the alternative strategy to serial search increased with positive memory set size in a dual process model, then the performance of retarded subjects may be accommodated more satisfactorily. This hypothetical situation is illustrated in Figure 5.2(B), where the probability of using serial search is high (>0.5) for a small set size, but decreases as set size becomes larger. The average function would have a flatter slope and higher zero intercept than the average function illustrated in Figure.5.2(A). However, as was noted above, the RT data of retarded subjects is typically positively skewed due to a proportion of very long RTs, so that a more appropriate dual process model for recognition memory in mental retardation may be one in which the second process is very slow. The possibility that more than two alternative processes are available at any one time cannot of course be excluded.

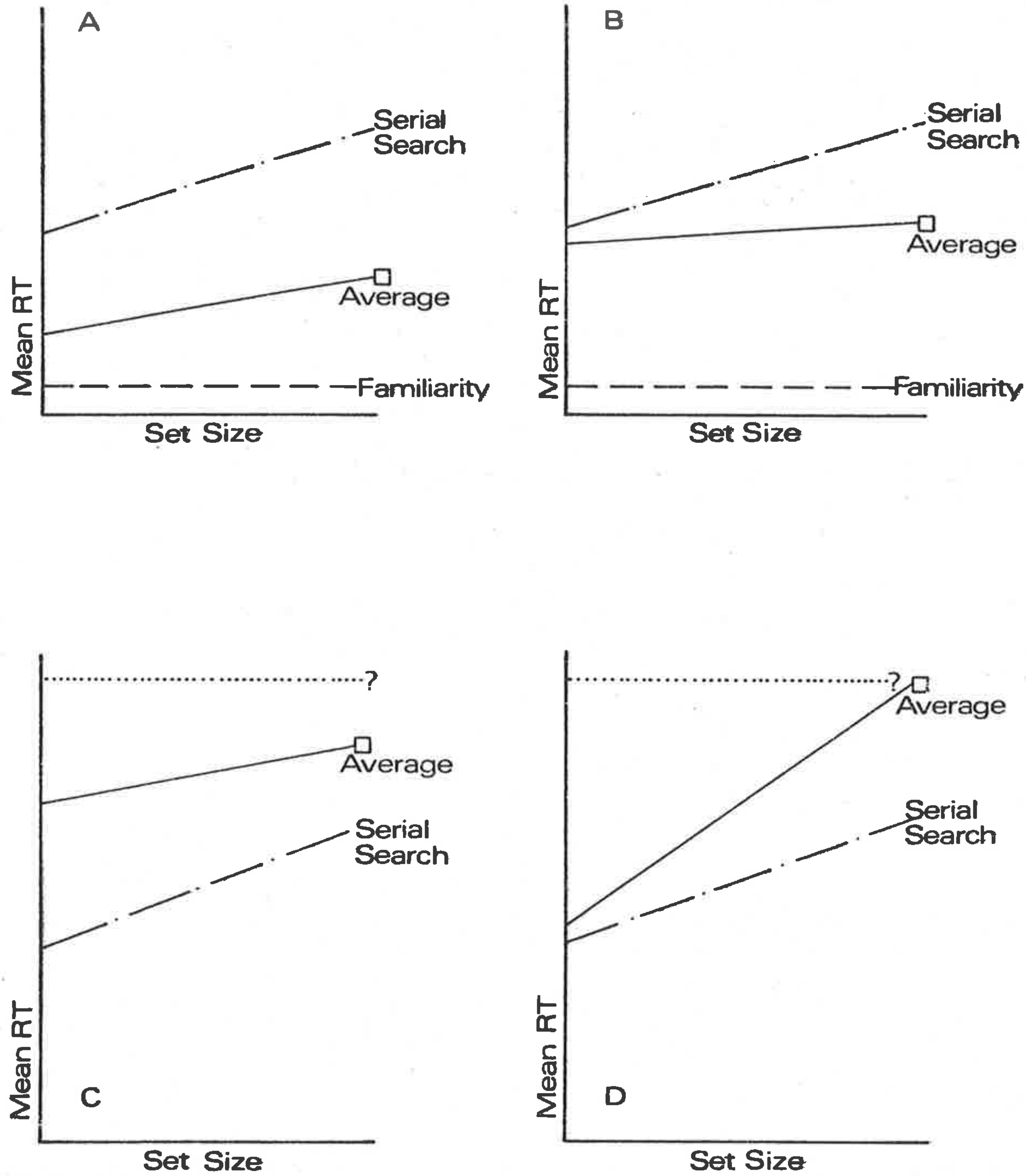
Figure 5.2(C) illustrates a novel dual process model of recognition memory in mental retardation, based on the model of Atkinson & Juola (1972). Here, mean performance at each memory set size is the result of a mixture of two mutually exclusive strategies, one of which is serial search through memory, the other strategy some process which is independent of the memory set size and very slow. The alternative strategy could be a deadline response which is reverted to on those trials when attention to trial events is poor. If subjects used the two strategies equally often at every memory set size, so that the probability of using serial search was 0.5 at each set size, then the average item recognition function would be the hypothetical function illustrated in Figure 5.2(C). This average function would be characterized by a flatter slope and higher zero intercept than a function representing the situation where all responses were based on serial search (i.e. p(search) = 1).

However, if one assumed that the probability of responding on the basis of the alternative strategy to serial search increased with increasing positive memory set size, then the average item recognition function would be that illustrated in Figure 5.2(D). Here, the proportion of trials in which memory is searched serially is high when the set size is small; the alternative strategy

FIGURE 5.2

Various predictions from probabilistic mixture models of recognition memory. (A) is adapted from Sternberg (1975), depicting the model of Atkinson & Juola (1972). In (A) and (C), the probability of each strategy being chosen is independent of set size. In (B) and (D), the probability of the serial search strategy being chosen decreases with increasing set size.

The alternative strategy to serial search is a direct access strategy based on a very high or very low familiarity value of the probe item. (C) and (D) consider an alternative strategy to serial search which is very slow and is independent of memory set size. It may be a response based on some subjectively fixed, temporal deadline which retarded subjects use when attention to the trial events is poor.


A
Serial Search
Average
Familiarity
Mean RT
Set Size
B
Serial Search
Average
Familiarity
Mean RT
Set Size
?
Average
Serial Search
Mean RT
C
Set Size
?
Average
Serial Search
Mean RT
D
Set Size

to serial search is rarely used when the positive memory set size is small. As memory set size increases, the proportion of trials on which serial search is used decreases, while the alternative strategy is more likely to be used. Thus the average item recognition function would have a slightly higher zero intercept than the function for serial search, but a steeper slope. This hypothetical function therefore appears to correspond well with the pattern of data found for retarded subjects early in practice - that is, in Experiments 1 and 2 and in initial sessions for Experiment 3. The average zero intercept is similar and the average slope more steep when compared with functions for normal adults, who are assumed to search memory serially.

Later in practice, the flatter slope of mean item recognition functions for retarded subjects may be due to a lower probability of an alternative strategy to serial search being used at large memory set sizes. In this model, practice increases the probability of serial search being used when subjects are presented with large set sizes, so that during practice, the hypothetical average item recognition function would become flatter.

Thus, although this model is only a rudimentary sketch of the possible processing involved in the recognition memory of retarded persons, it demonstrates that a multi-process model may be a more fruitful theoretical approach than models based on a single process, which have difficulty in accounting for changes in cognitive performance. Huesmann & Woocher (1976) discuss other models which attempt to account for the reduced slopes of item recognition functions found when stimuli are able to be categorized, or are of increased familiarity. Such models (e.g. Lively & Sanford, 1972) are characterized by an additional preliminary stage which determines whether to use a serial search strategy or not. This decision is regulated by alternative fast checks which are carried out first, so that a serial search of memory is only instigated if a decision cannot be made on the basis of familiarity or category. Future research into recognition memory in mental retardation should perhaps concentrate on the processing which occurs at this preliminary stage. The suggestion has been made that retarded subjects are deficient in assessing task demands (Brown, 1975) which presumably would affect the decision to use a certain strategy. These multi-process models have the disadvantage of being based on RT measurements only. Errors may be an important source of information about the cognitive processing of retarded persons. Certainly the approach of the Atkinson & Juola (1972) model, in which it was assumed that serial search would be error free, could not be adopted in a model of recognition memory in mental retardation.

In summary, none of the models reviewed here can explain all the changes in processing which have been suggested by the results of Experiments 1 to 4. All of the models would encounter difficulties where subjects could be shown to have modified the strategy employed as may happen during the course of experience gained through extensive practice.

With some modification or extension, the Sternberg model can accommodate findings related to procedural changes such as stimulus probability and rate of presentation of stimuli. The concept of a series of mental operations appears to be as successful as the alternatives put forward by other theorists, and none of the models reviewed here has sufficient scope to account for all the effects reported in the literature.

No current model clearly predicts the effect of practice on children's or mentally retarded adults' memory performance, but models that consider more than one strategy of responding, such as the modification of Atkinson & Juola's (1972) model as presented here, may be more promising for further development than non-adaptive models.

5.4 CONCLUSION

Given the sensitivity of the RT performance of retarded persons to procedural changes and the effects of practice, is the memory scanning paradigm a viable tool for research into the recognition memory processes of this group? Because of the vast amount of practice necessary for the mentally retarded group in the present experiments to reach a level of stability similar to nonretarded controls, such a paradigm may not be a practicable method of research into individual differences in memory performance. The finding of negative correlations in the data of nonretarded adults in Experiment 3 suggests that further investigation into the conditions under which this result occurs may throw some light onto the performance of other groups in which similar correlations are often found. However, the demonstrated increase in efficiency within the retarded group's performance with practice is as yet without a theoretical framework, which means that future experiments would remain at the same level of testing basic hypotheses without a clear explanation of the most fundamental aspect of performance.

Nevertheless, given that change in performance with practice is of immediate concern to an understanding of the development of cognitive skills of retarded persons, further experimentation could concentrate on manipulating conditions which effect a change in memory retrieval strategies, for example by increasing error rates or by the intensive training of strategies such as rehearsal. The present data suggest that the efforts of McCauley et al. (1976) in training retarded persons to rehearse may have been successful if the procedures used had permitted additional practice. Further research could also investigate the locus of the slower processing of retarded subjects shown in higher zero intercepts of the item recognition function. Deficiencies in encoding, response selection and binary decision processes may be differentiated by testing the additivity of factors that have been found to affect these processes in nonretarded subjects. The development of an automatic attention-directing strategy as described by Shiffrin & Schneider (1977) could be examined in retarded persons by providing them with extended practice with response-consistent memory set items.

However, there is no evidence that improvement in cognitive skills required for the memory scanning task would generalize to other tasks. While such skills can be maintained over time, evidence from training on other tasks such as recall of pictures (Brown, Campione & Barclay, 1979) have indicated that improvement does not generalize (Kramer et al., 1980). Thus, the direct practical ramifications of the present research are unpromising.

From the present data, there is no reason to abandon the additive factor method completely. However, a model of performance derived from this method has to be tailored to fit the characteristics of retarded performance, and requires provision for adaptive cognitive behaviour.

APPENDICES

Details of analyses referred to in Chapters 2, 3 and 4

The following abbreviations have been used in analyses of variance presented in these appendices:

SS	Sum of Squares
MS	Mean Square
df	degrees of freedom
MV	missing values
F	F ratio
p	significance value for F-test
NS	Not Significant

Analyses of variance were calculated using Genstat V Statistical Packages Mark 4.01-4.03 (1977, 1978, 1979, 1980). In those analyses with missing values, iterated values were substituted by Genstat. Degrees of freedom were reduced by the number shown in brackets (mv) beside the df column, to compensate for inflated treatment sum of squares. This procedure produced an appropriate, though conservative, analysis.

Appendix 2.1

Experiment 1: Group x Procedure x Response x Set Size:

Analyses of variance of errors made

Source	SS	MS	df	F	p
Group	28.0361	14.0180	2	12.05	<0.01
Residual	31.4208	1.1637	27		
Procedure	19.6680	19.6680	1	18.94	<0.01
Group x Procedure	5.7528	2.8764	2	2.77	NS
Residual	28.0375	1.0384	27		
Response	36.9104	36.9014	1	25.08	<0.01
Group x Response	7.5028	3.7514	2	2.55	NS
Residual	39.7208	1.4711	27		
Set Size	118.2735	23.6547	5	28.36	<0.01
Group x Set Size	35.4138	3.5414	10	4.25	<0.01
Residual	112.6040	0.8341	135		
Procedure x Response	2.3347	2.3347	1	2.17	NS
Group x Procedure x Response	1.1194	0.5597	2	0.52	NS
Residual	29.0041	1.0742	27		
Procedure x Set Size	5.4069	1.0814	5	1.19	NS
Group x Procedure x Set Size	8.9972	0.8997	10	0.99	NS
Residual	122.8872	0.9103	135		
Response x Set Size	20.1402	4.0280	5	3.81	<0.05
Group x Response x Set Size	17.8805	1.7881	10	1.69	NS
Residual	142.6038	1.0563	135		
Procedure x Response x Set Size	5.3736	1.0747	5	1.82	NS
Group x Procedure x Response x Set Size	6.2972	0.6297	10	1.07	NS
Residual	79.6207	0.5898	135		
Grand Total	904.9966		719		

Appendix 2.2

Experiment 1: Group x Procedure x Response x Set Size

Analysis of variance in correct mean RT (msecs)

Source	SS	MS	df	F	p
Group	40405888	20202944	2	13.49	<0.01
Residual	40435040	1497594	27		
Procedure	1493128	1493128	1	9.40	<0.01
Group x Procedure	1376201	688101	2	4.33	<0.05
Residual	4287003	158778	27		
Response	765447	765447	1	8.85	<0.01
Group x Response	77077	38538	2	0.44	NS
Residual	2336308	86530	27		
Set Size	7405198	1481039	5	38.78	<0.01
Group x Set Size	664838	66484	10	1.74	NS*
Residual	5155338	38188	135		
Procedure x Response	6183	6183	1	0.40	NS
Group x Procedure x Response	24505	12253	2	0.78	NS
Residual	423070	15669	27		
Procedure x Set Size	776064	155213	5	4.00	<0.01
Group x Procedure x Set Size	667158	66716	10	1.72	NS*
Residual	5242556	38834	135		
Response x Set Size	370454	74091	5	3.60	<0.01
Group x Response x Set Size	309116	30912	10	1.50	NS*
Residual	2774807	20554	135		
Procedure x Response x Set Size	93211	18642	5	0.83	NS
Group x Procedure x Response x Set Size	120506	12051	10	0.54	NS
Residual	3020997	22378	135		
Grand Total	118230032		719		

* Critical F = 1.90

Appendix 2.3

Experiment 1: Procedure x Response x Set Size analysis of variance in correct mean RT (msecs) for Retarded Group, with test for linear trend in Set Size factor

Source	SS	ms	df	F	p
Subjects	19979152	2219905	9		
Procedure	61632	61632	1	0.44	NS
Residual	1257415	139713	9		
Response	348538	348538	1	1.50	NS
Residual	2094382	232709	9		
Set Size	3741770	748354	5	8.59	<0.01
Linear	3626927	3626927	1	41.62	<0.01
Deviations	114848	28712	4	0.33	NS
Residual	3921162	87137	45		
Procedure x Response	2007	2007	1	0.07	NS
Residual	265280	29476	9		
Procedure x Set Size	1114031	222806	5	2.39	NS
Deviations x Linear	923181	923181	1	9.89	<0.01
Deviations	190852	47713	4	0.51	NS
Residual	4200479	93344	45		
Response x Set Size	535719	107144	5	2.25	NS
Deviations x Linear	507441	507441	1	10.66	<0.01
Deviations	28279	7070	4	0.15	NS
Residual	2141426	47587	45		
Procedure x Response x Set Size	162928	32586	5	0.63	NS
Deviations x Deviations x Linear	138013	138013	1	2.67	NS
Deviations	24915	6229	4	0.12	NS
Residual	2329751	51772	45		
Grand Total	42155616		239		

Appendix 2.4

Experiment 1: Procedure x Response x Set Size analysis of variance in correct mean RT (msecs) for nonretarded children group, with test for linear trend in Set Size factor

Source	SS	MS	df	F	p
Subjects	15691553	1743505	9		
Procedure	1222509	1222509	1	6.71	<0.05
Residual	1640324	182258	9		
Response	415251	415251	1	19.71	<0.01
Residual	189650	21072	9		
Set Size	3407931	681586	5	37.42	<0.01
Linear	3379717	3379717	1	185.55	<0.01
Deviations	28218	7055	4	0.39	NS
Residual	819672	18215	45		
Procedure x Response	28536	28536	1	2.09	NS
Residual	122857	13651	9		
Procedure x Set Size	256904	51381	5	3.02	<0.05
Deviations x Linear	228007	228007	1	13.38	<0.01
Deviations	28896	7224	4	0.42	NS
Residual	766629	17036	45		
Response x Set Size	115676	23135	5	2.51	<0.05
Deviations x Linear	58085	58085	1	6.31	<0.05
Deviations	57591	14398	4	1.56	NS
Residual	414449	9210	45		
Procedure x Response x Set Size	21146	4229	5	0.37	NS
Deviations x Deviations x Linear	3199	3199	1	0.28	NS
Deviations	17947	4487	4	0.39	NS
Residual	519139	11536	45		
Grand Total	25632176		239		

Appendix 2.5

Experiment 1: Procedure x Response x Set Size analysis of variance in correct mean RT (msecs) for nonretarded adults group, with test for linear trend in Set Size factor

Source	SS	MS	df	F	p
Subjects	4764373	529375	9		
Procedure	1585187	1585187	1	10.27	<0.05
Residual	1389264	154363	9		
Response	78735	78735	1	13.56	<0.01
Residual	52275	5808	9		
Set Size	920335	184067	5	19.98	<0.01
Linear	899262	899262	1	97.63	<0.01
Deviations	21074	5268	4	0.57	NS
Residual	414506	9211	45		
Procedure x Response	146	146	1	0.04	NS
Residual	34933	3881	9		
Procedure x Set Size	72286	14457	5	2.36	NS
Deviations x Linear	1832	1832	1	0.30	NS
Deviations	70454	17614	4	2.88	<0.05
Residual	275449	6121	45		
Response x Set Size	28174	5635	5	1.16	NS
Deviations x Linear	846	846	1	0.17	NS
Deviations	27329	6832	4	1.40	NS
Residual	218932	4865	45		
Procedure x Response x Set Size	29643	5929	5	1.55	NS
Deviations x Deviations x Linear	9271	9271	1	2.42	NS
Deviations	20372	5093	4	1.33	NS
Residual	172107	3825	45		
Grand Total	10036343		239		

Appendix 2.6

Test of linear trend in Set Size factor for each group's separate 'yes' and 'no' correct mean RT:

MR = Retarded adults; CA = Nonretarded adults;

MA = Nonretarded children

(i) MR - Fixed Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	5271153	585684	9		
Set Size	1646713	329343	5	3.56	<0.01
Linear	1593180	1593180	1	17.24	<0.01
Deviations	53533	13383	4	0.14	NS
Residual	4159147	92425	45		
Grand Total	11077013		59		

(ii) MR - Fixed Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	5006319	556258	9		
Set Size	2670331	534066	5	8.86	<0.01
Linear	2569804	2569804	1	42.18	<0.01
Deviations	100527	25132	4	0.41	NS
Residual	2741867	60930	45		
Grand Total	10418517		59		

(iii) MA - Fixed Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	2800744	311194	9		
Set Size	1054781	210956	5	18.45	<0.01
Linear	1018414	1018414	1	89.06	<0.01
Deviations	36367	9092	4	0.80	NS
Residual	514556	11435	45		
Grand Total	4370081		59		

Appendix 2.6

(continued)

(iv) MA - Fixed Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	3508023	389780	9		
Set Size	1748210	349642	5	13.08	<0.01
Linear	1707560	1707560	1	63.90	<0.01
Deviations	40650	10162	4	0.38	NS
Residual	1202506	26722	45		
Grand Total	6458739		59		

(v) CA - Fixed Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	401599	44622	9		
Set Size	316097	63219	5	13.04	<0.01
Linear	280000	280000	1	57.56	<0.01
Deviations	36097	9024	4	1.86	NS
Residual	218153	4848	45		
Grand Total	935849		59		

(vi) CĀ - Fixed Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	587712	65301	9		
Set Size	259972	51994	5	9.15	<0.01
Linear	213396	213396	1	37.57	<0.01
Deviations	46576	11644	4	2.05	NS
Residual	255587	5680	45		
Grand Total	1103271		59		

Appendix 2.6

(continued)

(vii) MR - Varied Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	5174913	574990	9		
Set Size	168485	33697	5	0.34	NS
Linear	4916	4916	1	0.05	NS
Deviations	163569	40892	4	0.41	NS
Residual	4519257	100428	45		
Grand Total	9862656		59		

(viii) MR - Varied Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	8143857	904873	9		
Set Size	1068931	213786	5	8.20	<0.01
Linear	1027666	1027666	1	39.44	<0.01
Deviations	41265	10312	4	0.58	NS
Residual	1172574	26057	45		
Grand Total	10385362		59		

(ix) MA - Varied Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	6127169	680797	9		
Set Size	382273	76455	5	7.81	<0.01
Linear	346010	346010	1	35.33	<0.01
Deviations	36263	9066	4	0.93	NS
Residual	440733	9794	45		
Grand Total	6950175		59		

Appendix 2.6

(continued)

(x) MA - Varied Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	5208451	578717	9		
Set Size	616397	123279	5	15.32	<0.01
Linear	597023	597023	1	74.20	<0.01
Deviations	19374	4844	4	0.60	NS
Residual	362097	8047	45		
Grand Total	6186945		59		

(xi) CA - Varied Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	2817890	313099	9		
Set Size	176076	35215	5	4.03	<0.01
Linear	152146	152146	1	17.42	<0.01
Deviations	23930	5982	4	0.68	NS
Residual	392979	8733	45		
Grand Total	3386945		59		

(xii) CA - Varied Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	2433646	270405	9		
Set Size	298295	59659	5	12.53	<0.01
Linear	265668	265668	1	55.79	<0.01
Deviations	32627	8157	4	1.71	NS
Residual	214276	4762	45		
Grand Total	2946217		59		

Appendix **2.7**

Experiment 1: Group x Procedure x Response analysis of variance in slopes of the item recognition functions for nonretarded adults and children

Source	SS	MS	df	F	p
Group	22683.9	22683.9	1	17.05	<0.01
Residual	23946.9	1330.4	18		
Procedure	7762.4	7762.4	1	6.92	<0.05
Group x Procedure	5421.8	5421.8	1	4.83	<0.05
Residual	20188.0	1121.6	18		
Response	2098.5	2098.5	1	3.65	NS
Group x Response	1294.3	1294.3	1	2.25	NS
Residual	10335.9	574.2	18		
Procedure x Response	43.0	43.0	1	0.08	NS
Group x Procedure x Response	675.5	675.5	1	1.24	NS
Residual	9834.3	546.4	18		
Grand Total	104284.6		79		

Appendix 2.8

Experiment 1: Group x Procedure x Response analysis of variance in intercepts for the item recognition functions for nonretarded adults and children

Source	SS	MS	df	F	p
Group	616147	616147	1	4.35	<0.05
Residual	2549393	141633	18		
Procedure	972530	972530	1	23.74	<0.01
Group x Procedure	43521	43521	1	1.06	NS
Residual	737278	40960	18		
Response	178456	178456	1	19.22	<0.01
Group x Response	51087	51087	1	5.50	<0.05
Residual	167153	9286	18		
Procedure x Response	5194	5194	1	0.81	NS
Group x Procedure x Response	2385	2385	1	0.37	NS
Residual	115341	6408	18		
Grand Total	5438485		79		

Appendix 2.9

Experiment 1: Group x Response analysis of slopes

for all three groups in fixed set procedure

Source	SS	MS	df	F	p
Group	53069	26535	2	4.06	<0.05
Residual	176559	6539	27		
Response	3128	3128	1	1.97	NS
Group x Response	2882	1441	2	0.91	NS
Residual	42956	1591	27		
Grand Total	278594		59		

Appendix 2.10

Experiment 1: Group x Response analysis of intercepts

for all three groups in Fixed Set procedure

Source	SS	MS	df	F	p
Group	1944318	972159	2	6.11	<0.01
Residual	4296348	159124	27		
Response	180248	180248	1	8.60	<0.01
Group x Response	67115	33557	2	1.60	NS
Residual	565918	20960	27		
Grand Total	7053946		59		

Appendix 2.11

Experiment 1: Analysis of serial position effects in each group -

MR = Retarded adults; MA = Nonretarded children; CA = Nonretarded adults

Ser = Serial Position of Probed Item

(i) MR - Fixed Procedure

Source	SS	MS	df (MV)	F	p
Subjects	25223760	3152970	8(1)		
Ser	2730298	546060	5	1.39	NS
Residual	13345702	392521	34(11)		
Grand Total	41299760		47		

(ii) MA - Fixed Procedure

Source	SS	MS	df (MV)	F	p
Subjects	6935871	770652	9		
Ser	577456	115491	5	1.35	NS
Residual	3680706	85598	43(2)		
Grand Total	11194032		57		

(iii) CA - Fixed Procedure

Source	SS	MS	df	F	p
Subjects	459807	51090	9		
Ser	89605	17921	5	1.56	NS
Residual	516686	11482	45		
Grand Total	1066097		59		

(iv) MR - Varied Procedure

Source	SS	MS	df (MV)	F	p
Subjects	32850384	3650042	9		
Ser	2147022	429404	5	1.71	NS
Residual	9529625	250780	38(7)		
Grand Total	44527024		52		

(v) MA - Varied Procedure

Source	SS	MS	df (MV)	F	p
Subjects	9111527	1138940	8(1)		
Ser	1623029	324606	5	4.02	< 0.01
Residual	3151350	80804	39(6)		
Grand Total	13885906		52		

(vi) CA - Varied Procedure

Source	SS	MS	df (MV)	F	p
Subjects	2821062	313451	9		
Ser	135779	27156	5	0.895	NS
Residual	1335449	30351	44(1)		
Grand Total	4292289		58		

Appendix 2.12

Experiment 1: Analysis of standard deviations in each Procedure;

Group x Procedure x Response x Set Size analysis of variance

Source	SS	MS	df(MV)	F	p
Group	11429440	5714720	2	16.08	<0.01
Residual	9597463	355462	27		
Procedure	257024	257024	1	4.75	<0.05
Group x Procedure	1005746	502873	2	9.29	<0.01
Residual	1353501	54140	25(2)		
Response	40505	40505	1	1.76	NS
Group x Response	10248	5124	2	0.22	NS
Residual	619512	22945	27		
Set Size	1366657	273331	5	11.05	<0.01
Group x Set Size	723425	72343	10	2.92	<0.01
Residual	3338703	24731	135		
Procedure x Response	12994	12294	1	0.62	NS
Group x Procedure x Response	8303	4151	2	0.20	NS
Residual	525616	21025	25(2)		
Procedure x Set Size	703459	140692	5	4.90	<0.01
Group x Procedure x Set Size	384092	38409	10	1.34	NS
Residual	3589178	28713	125(10)		
Response x Set Size	99308	19862	5	1.20	NS
Group x Response x Set Size	290028	29003	10	1.75	NS
Residual	2236571	16567	135		
Procedure x Response x Set Size	111717	22343	5	1.45	NS
Group x Procedure x Response x Set Size	119924	11992	10	0.78	NS
Residual	1920882	15367	125(10)		
Grand Total	39744240		695		

Appendix 2.13

Experiment 1: Analysis of reduced data:

RT > 1500 msecs and ± 1.96 standard deviations from

lowered mean excluded from Group x Procedure

x Response x Set Size analysis of variance

(a)

Source	SS	MS	df(MV)	F	p
Group	14955825	7477912	2	11.78	<0.01
Residual	16506639	634871	26(1)		
Procedure	1251275	1251275	1	15.94	<0.01
Group x Procedure	395446	197723	2	2.52	NS
Residual	1726880	78495	22(5)		
Response	604816	604816	1	41.31	<0.01
Group x Response	92734	46367	2	3.17	NS
Residual	336774	14642	23(4)		
Set Size	2921963	584393	5	69.94	<0.01
Group x Set Size	100183	10018	10	1.20	NS
Residual	1086218	8356	130(5)		
Procedure x Response	3092	3092	1	0.58	NS
Group x Procedure x Response	24275	12138	2	2.28	NS
Residual	106419	5321	20(7)		
Procedure x Set Size	116234	23247	5	3.58	<0.01
Group x Procedure x Set Size	140317	14032	10	2.16	<0.05
Residual	714549	6496	110(25)		
Response	34378	6876	5	2.10	NS
Group x Response x Set Size	22132	2213	10	0.68	NS
Residual	376910	3277	115(20)		
Procedure x Response x Set Size	10790	2158	5	0.91	NS
Group x Procedure x Set Size	16961	1696	10	0.72	NS
Residual	236180	2362	100(35)		
Grand Total	41780928		617		

Appendix 2.13

(continued)

(b) Percentage of trials removed for reanalysis shown above

GROUP	PROCEDURE FIXED	PROCEDURE VARIED
Retarded Adults	33.31%	31.69%
Nonretarded Children	11.75%	19.67%
Nonretarded Adults	4.93%	7.29%

Appendix 2.14

Experiment 2: Group x Procedure x Response x Set Size

analysis of variance of errors made

Source	SS	MS	df	F	p
Group	0.5542	0.2771	2	0.56	NS
Residual	13.2875	0.4921	27		
Procedure	1.4083	1.4083	1	4.57	<0.05
Group x Procedure	0.0292	0.0146	2	0.05	NS
Residual	8.3125	0.3079	27		
Response	4.4083	4.4083	1	15.69	<0.01
Group x Response	1.7542	0.8771	2	3.12	NS
Residual	7.5875	0.2810	27		
Set Size	3.1417	1.0472	3	3.39	<0.05
Group x Set Size	1.5458	0.2576	6	0.83	NS
Residual	25.0625	0.3094	81		
Procedure x Response	0.2083	0.2083	1	0.75	NS
Group x Procedure x Response	0.0292	0.0146	2	0.05	NS
Residual	7.5125	0.2782	27		
Procedure x Set Size	2.8417	0.9472	3	3.66	<0.05
Group x Procedure x Set Size	4.4708	0.7451	6	2.88	<0.05
Residual	20.9375	0.2585	81		
Response x Set Size	3.1083	1.0361	3	3.59	<0.05
Group x Response x Set Size	0.7792	0.1299	6	0.45	NS
Residual	23.3625	0.2884	81		
Procedure x Response x Set Size	0.7417	0.2472	3	1.24	NS
Group x Procedure x Response x Set Size	2.3708	0.3951	6	1.98	NS
Residual	16.1375	0.1992	81		
Grand Total	149.5914		479		

Appendix 2.15

Experiment 2: Group x Procedure x Response x Set Size

analysis of variance in error mean RT (msecs)

Source	SS	MS	df	F	p
Group	9767034	4883517	2	9.59	<0.01
Residual	13744525	509056	27		
Procedure	2374031	2374031	1	25.16	<0.01
Group x Procedure	179396	89698	2	0.95	NS
Residual	2547781	94362	27		
Response	889155	889155	1	45.57	<0.01
Group x Response	193794	96897	2	4.97	<0.05
Residual	526796	19511	27		
Set Size	3066324	1022108	3	59.96	<0.01
Group x Set Size	213911	35652	6	2.09	NS*
Residual	1380821	17047	81		
Procedure x Response	10093	10093	1	0.33	NS
Group x Procedure x Response	51510	25755	2	0.85	NS
Residual	816034	30223	27		
Procedure x Set Size	173194	57731	3	6.59	<0.01
Group x Procedure x Set Size	105538	17590	6	2.01	NS*
Residual	709920	8764	81		
Response x Set Size	71554	23851	3	3.60	<0.05
Group x Response x Set Size	32866	5478	6	0.83	NS
Residual	537052	6630	81		
Procedure x Response x Set Size	50443	16814	3	2.15	NS**
Group x Procedure x Response x Set Size	147311	24552	6	3.14	<0.01
Residual	634444	7833	81		
Grand Total	38223472		479		

* Critical F = 2.21
** Critical F = 2.72

Appendix 2.16

Experiment 2: Procedure x Response x Set Size analysis of variance in correct mean RT (msecs) for Retarded group, with test for linear trend in set size factor

Source	SS	MS	df	F	p
Subjects	6904508	767168	9		
Procedure	1175632	1175632	1	12.68	<0.01
Residual	834672	92741	9		
Response	816674	816674	1	25.11	<0.01
Residual	292673	32519	9		
Set Size	1704383	568128	3	18.86	<0.01
Linear	1662302	1662302	1	55.19	<0.01
Deviations	42081	21041	2	0.70	NS
Residual	813304	30122	27		
Procedure x Response	10907	10907	1	0.16	NS
Residual	635177	70575	9		
Procedure x Set Size	168775	56258	3	4.74	<0.01
Deviations x Linear	165456	165456	1	13.93	<0.01
Deviations	3319	1659	2	0.14	NS
Residual	320735	11879	27		
Response x Set Size	47381	15794	3	1.54	NS
Deviations x Linear	25595	25595	1	2.49	NS
Deviations	21786	10893	2	1.06	NS
Residual	277815	10289	27		
Procedure x Response x Set Size	169785	56595	3	3.65	<0.05
Deviations x Deviations x Linear	166840	166840	1	10.76	<0.01
Deviations	2945	1473	2	0.10	NS
Residual	418512	15500	27		
Grand Total	14590926		159		

Appendix 2.17

Experiment 2: Procedure x Response x Set Size analysis of variance in correct mean RT (msecs) for nonretarded children group, with test for linear trend in Set Size factor

Source	SS	MS	df	F	p
Subjects	4838505	537612	9		
Procedure	1081094	1081094	1	8.03	<0.05
Residual	1211899	134655	9		
Response	139712	139712	1	6.49	<0.05
Residual	193688	21521	9		
Set Size	1099225	366408	3	22.11	<0.01
Linear	1053861	1053861	1	63.59	<0.01
Deviations	45363	22682	2	1.37	NS
Residual	447477	16573	27		
Procedure x Response	46854	46854	1	2.99	NS
Residual	141141	15682	9		
Procedure x Set Size	79052	26351	3	2.22	NS
Deviations x Linear	31375	31375	1	2.64	NS
Deviations	47677	23838	2	2.01	NS
Residual	321074	11892	27		
Response x Set Size	38161	12720	3	1.70	NS
Deviations x Linear	32131	32131	1	4.29	<0.05
Deviations	6030	3015	2	0.40	NS
Residual	202453	7498	27		
Procedure x Response x Set Size	17448	5816	3	0.86	NS
Deviations x Deviations x Linear	60	60	1	0.01	NS
Deviations	17388	8694	2	1.28	
Residual	183104	6782	27		
Grand Total	10040887		159		

Appendix 2.18

Experiment 2: Procedure x Response x Set Size analysis of variance in correct mean RT (msecs) for nonretarded adults group, with test for linear trend in Set Size factor

Source	SS	MS	df	F	p
Subjects	2001519	222391	9		
Procedure	296701	296701	1	5.33	<0.05
Residual	501210	55690	9		
Response	126562	126562	1	28.17	<0.05
Residual	40435	4493	9		
Set Size	476627	158876	3	35.73	<0.01
Linear	450490	450490	1	101.33	<0.01
Deviations	26136	13068	2	2.94	NS
Residual	120042	4446	27		
Procedure x Response	3842	3842	1	0.87	NS
Residual	39716	4413	9		
Procedure x Set Size	30906	10302	3	4.08	<0.05
Deviations x Linear	25	25	1	0.01	NS
Deviations	30881	15440	2	6.12	<0.01
Residual	68110	2523	27		
Response x Set Size	18878	6293	3	2.99	<0.05
Deviations x Linear	6927	6927	1	3.29	NS
Deviations	11952	5976	2	2.84	NS
Residual	56784	2103	27		
Procedure x Response x Set Size	10521	3507	3	2.88	NS
Deviations x Deviations x Linear	1711	1711	1	1.41	NS
Deviations	8810	4405	2	3.62	<0.05
Residual	32829	1216	27		
Grand Total	3824677		159		

Appendix 2.19

Experiment 2: Test of linear trend in Set Size factor for each group's separate 'yes' and 'no' correct mean RT: MR = retarded adults; CA = nonretarded adults; MA = nonretarded children

(i) MR - Fixed Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	2911056	323451	9		
Set Size	964393	321464	3	10.93	<0.01
Linear	945312	945312	1	32.13	<0.01
Deviations	19080	9540	2	0.32	NS
Residual	794273	29418	27		
Grand Total	4669721		39		

(ii) MR - Fixed Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	1160009	128890	9		
Set Size	538961	179654	3	19.37	<0.01
Linear	523878	523878	1	56.49	<0.01
Deviations	15083	7541	2	0.81	NS
Residual	250409	9274	27		
Grand Total	1949379		39		

(iii) MA - Fixed Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	484470	53830	9		
Set Size	322237	107412	3	15.41	<0.01
Linear	266377	266377	1	38.22	<0.01
Deviations	55860	27930	2	4.01	<0.05
Residual	188191	6970	27		
Grand Total	994898		39		

Appendix 2.19

(continued)

(iv) MA - Fixed Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	655462	72829	9		
Set Size	499545	166515	3	14.99	<0.01
Linear	472781	472781	1	42.57	<0.01
Deviations	26764	13382	2	1.20	NS
Residual	299891	11107	27		
Grand Total	1454897		39		

(v) CA - Fixed Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	424194	47133	9		
Set Size	84614	28205	3	12.30	<0.01
Linear	76050	76050	1	33.17	<0.01
Deviations	8564	4282	2	1.87	NS
Residual	61901	2293	27		
Grand Total	570709		39		

(vi) CA - Fixed Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	492949	54772	9		
Set Size	221704	73901	3	24.76	<0.01
Linear	160291	160291	1	53.71	<0.01
Deviations	61413	30706	2	10.29	
Residual	80575	2984	27		
Grand Total	795228		39		

Appendix 2.19

(continued)

(vii) MR - Varied Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	2132547	236950	9		
Set Size	46430	15477	3	0.99	NS
Linear	24664	24664	1	1.58	NS
Deviations	21766	10883	2	0.70	NS
Residual	421159	15598	27		
Grand Total	2600136		39		

(viii) MR - Varied Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	2463416	273713	9		
Set Size	540541	180180	3	13.45	<0.01
Linear	526338	526338	1	38.99	<0.01
Deviations	14203	7101	2	0.53	NS
Residual	364524	13501	27		
Grand Total	3368480		39		

(ix) MA - Varied Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	3321538	369060	9		
Set Size	109943	36648	3	2.58	NS
Linear	109699	109699	1	7.73	<0.01
Deviations	244	122	2	0.01	NS
Residual	382944	14183	27		
Grand Total	3814425		39		

Appendix 2.19

(continued)

(x) MA - Varied Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	1923764	213752	9		
Set Size	302161	100720	3	9.61	<0.01
Linear	268571	268571	1	25.62	<0.01
Deviations	33590	16795	2	1.60	NS
Residual	283082	10485	27		
Grand Total	2509007		39		

(xi) CA - Varied Procedure, 'No' Response

Source	SS	MS	df	F	p
Subjects	1086594	120733	9		
Set Size	103170	34390	3	10.88	<0.01
Linear	97461	97461	1	30.84	<0.01
Deviations	5709	2855	2	0.90	NS
Residual	85339	3161	27		
Grand Total	1275103		39		

(xii) CA - Varied Procedure, 'Yes' Response

Source	SS	MS	df	F	p
Subjects	579145	64349	9		
Set Size	127442	42481	3	22.96	<0.01
Linear	125350	125350	1	67.76	<0.01
Deviations	2092	1046	2	0.57	NS
Residual	49950	1850	27		
Grand Total	756537		39		

Appendix 2.20

Experiment 2: Group x Procedure x Response analysis of variance in slopes for control groups

Source	SS	MS	df	F	p
Group	12676	12676	1	3.48	NS
Residual	65562	3642	18		
Response	6864	6864	1	5.47	<0.05
Group x Response	918	918	1	0.73	NS
Residual	22602	1256	18		
Procedure	3367	3367	1	1.80	NS
Group x Procedure	2989	2989	1	1.60	NS
Residual	33737	1874	18		
Response x Procedure	104	104	1	0.10	NS
Group x Response x Procedure	242	242	1	0.24	NS
Residual	18314	1017	18		
Grand Total	167372		79		

Appendix 2.21

Experiment 2: Group x Procedure x Response analysis of variance in intercepts for control groups

Source	SS	MS	df	F	p
Group	904613	904613	1	12.69	<0.01
Residual	1282943	71275	18		
Response	216632	216632	1	15.29	<0.01
Group x Response	6827	6827	1	0.48	NS
Residual	255027	14168	18		
Procedure	495968	495968	1	11.89	<0.01
Group x Procedure	96536	96536	1	2.32	NS
Residual	750728	41707	18		
Response x Procedure	5168	5168	1	0.42	NS
Group x Response x Procedure	8799	8799	1	0.71	NS
Residual	222086	12338	18		
Grand Total	4245323		79		

Appendix 2.22

Experiment 2: Group x Response analysis of variance of all three groups' slopes in Fixed Set Procedure

Source	SS	MS	df	F	p
Group	51866	25933	2	4.78	<0.05
Residual	146375	5421	27		
Response	66	66	1	0.03	NS
Group x Response	10600	5300	2	2.74	NS
Residual	52166	1932	27		
Grand Total	261073		59		

Appendix 2.23

Experiment 2: Group x Response analysis of all three groups' intercepts in Fixed Set procedure

Source	SS	MS	df	F	p
Group	218000	109000	2	2.64	NS
Residual	1116485	41351	27	7.78	
Response	109568	109568	1	20.60	<0.01
Group x Response	255	128	2	0.02	NS
Residual	143598	5318	27		
Grand Total	1587905		59		

Appendix 2.24

Experiment 2: Analysis of serial position effects in each group -

MR = retarded adults; MA = nonretarded children; CA = nonretarded adults;

Ser = Serial Position of Probed Item

(i) MR - Fixed Procedure

Source	SS	MS	df	F	p
Subjects	2406821	267425	9		
Ser	311619	103873	3	3.79	<0.05
Residual	740863	27439	27		
Grand Total	3459303		39		

(ii) MA - Fixed Procedure

Source	SS	MS	df	F	p
Subjects	1811699	201300	9		
Ser	285070	95203	3	7.98	<0.01
Residual	321617	11912	27		
Grand Total	2418386		39		

(iii) CA - Fixed Procedure

Source	SS	MS	df	F	p
Subjects	587810	65312	9		
Ser	190044	63348	3	8.47	<0.01
Residual	202032	7483	27		
Grand Total	979886		39		

Appendix 2.24

(continued)

(iv) MR - Varied Procedure

Source	SS	MS	df(MV)	F	p
Subjects	4015085	501886	8(1)		
Ser	1262062	420687	3	6.94	<0.01
Residual	1454468	60603	24(3)		
Grand Total	6731615		35		

(v) MA - Varied Procedure

Source	SS	MS	df	F	p
Subjects	3076277	341809	9		
Ser	284453	94818	3	2.50	NS*
Residual	1025458	37980	27		
Grand Total	4386188		39		

(vi) CA - Varied Procedure

Source	SS	MS	df	F	p
Subjects	839312	93257	9		
Ser	41356	13785	3	3.20	<0.05
Residual	116283	4307	27		
Grand Total	996952		39		

* Critical F = 2.96

Appendix 2.25

Experiment 2: Analysis of standard deviations in

Group x Procedure x Response x Set Size

analysis of variance

Source	SS	MS	df	F	p
Group	2386815	1193408	2	10.34	<0.01
Residual	3116919	115441	27		
Procedure	732344	732344	1	27.14	<0.01
Group x Procedure	187136	93568	2	3.47	<0.05
Residual	728573	26984	27		
Response	129331	129331	1	19.07	<0.01
Group x Response	135790	67895	2	10.01	<0.01
Residual	183151	6783	27		
Set Size	311435	103812	3	7.99	<0.01
Group x Set Size	139237	23206	6	1.79	NS
Residual	1052177	12990	81		
Procedure x Response	8679	8679	1	0.69	NS
Group x Procedure x Response	53484	26742	2	2.13	NS
Residual	338331	12531	27		
Procedure x Set Size	185635	61878	3	5.06	<0.01
Group x Procedure x Set Size	201943	33657	6	2.75	<0.05
Residual	990811	12232	81		
Response x Set Size	125258	41753	3	4.99	<0.01
Group x Response x Set Size	51205	8534	6	1.02	NS
Residual			81		
Procedure x Response x Set Size	66489	22163	3	2.08	NS
Residual	926674	10651	87		
Grand Total	12729042		479		

Appendix 2.26

(a) Experiment 2: Analysis of reduced data: RT > 1500 msecs and ± 1.96 standard deviations from lowered mean excluded from Group x Procedure x Response x Set Size analysis of variance

Source	SS	MS	df	F	p
Group	5228725	2614363	2	9.46	<0.01
Residual	7458620	276245	27		
Procedure	1221482	1221482	1	26.95	<0.01
Group x Procedure	33878	16939	2	0.37	NS
Residual	1223864	45328	27		
Response	420194	420194	1	53.96	<0.01
Group x Response	69445	34722	2	4.46	<0.05
Residual	210252	7787	27		
Set Size	1390397	463466	3	105.82	<0.01
Group x Set Size	38562	6427	6	1.47	NS
Residual	354759	4380	81		
Procedure x Response	429	429	1	0.08	NS
Group x Procedure x Response	1099	549	2	0.10	NS
Residual	135863	5255	26(1)		
Procedure x Set Size	53180	17727	3	5.49	<0.01
Group x Procedure x Set Size	10109	1685	6	0.52	NS
Residual	261667	3230	81		
Response x Set Size	20814	6938	3	3.09	<0.05
Group x Response x Set Size	4287	714	6	0.32	NS
Residual	181628	2242	81		
Procedure x Response x Set Size	2401	800	3	0.43	NS
Residual	155350	1849	84(3)		
Grand Total	18477005		475		

Appendix 2.26

(continued)

(b) Percentage of trials removed for reanalysis shown above

	PROCEDURE	
GROUP	FIXED	VARIED
Retarded Adults	12.10%	17.40%
Nonretarded Children	7.83%	14.83%
Nonretarded Adults	4.82%	4.86%

APPENDIX 3

Appendix 3.1

Experiment 3: Group x Procedure x Response x Set Size x Practice analysis of variance of errors

Source	SS	MS	df	F	p
Group	44.3521	22.1761	2	7.86	<0.01
Residual	59.2663	2.8222	21		
Procedure	42.5838	42.5838	1	37.23	<0.01
Group x Procedure	18.8819	9.4410	2	8.25	<0.01
Residual	24.0223	1.1439	21		
Response	8.5124	8.5124	1	9.63	<0.01
Group x Response	1.9772	0.9886	2	1.12	NS
Residual	18.5699	0.8843	21		
Set Size	52.2449	26.1225	2	44.08	<0.01
Group x Set Size	10.2698	2.5675	4	4.33	<0.01
Residual	24.8898	0.5926	42		
Practice	5.9722	0.9954	6	1.89	NS
Group x Practice	6.9325	0.5777	12	1.10	NS
Residual	66.2856	0.5261	126		
Procedure x Response	0.3100	0.3100	1	0.75	NS
Group x Procedure x Response	0.1498	0.0749	2	0.18	NS
Residual	8.6473	0.4118	21		
Procedure x Set Size	5.7569	2.8785	2	5.21	<0.01
Group x Procedure x Set Size	13.5674	3.3919	4	6.13	<0.01
Residual	23.2231	0.5529	42		
Response x Set Size	2.7212	1.3606	2	4.17	<0.05
Group x Response x Set Size	2.8293	0.7073	4	2.17	NS
Residual	13.7113	0.3265	42		
Procedure x Practice	3.7640	0.6243	6	1.24	NS
Group x Procedure x Practice	8.0694	0.6725	12	1.34	NS
Residual	63.2795	0.5022	126		
Response x Practice	2.1786	0.3631	6	0.72	NS
Group x Response x Practice	6.1547	0.5129	12	1.01	NS
Residual	63.8569	0.5068	126		

(continued)

Appendix 3.1

(continued)

Source	SS	MS	df	F	p
Set Size x Practice	6.0813	0.5068	12	1.47	NS
Group x Set Size x Practice	11.0496	0.4604	24	1.33	NS
Residual	86.9640	0.3451	252		
Procedure x Response x Set Size	0.1736	0.0868	2	0.16	NS
Residual	24.3263	0.5288	46		
Procedure x Set Size x Practice	6.1111	0.5093	12	1.37	NS
Residual	102.5075	0.3714	276		
Response x Set Size x Practice	3.3690	0.2808	12	0.81	NS
Residual	95.8686	0.3474	276		
Higher order interactions not tested for	109.6662	0.3808	288		
Grand Total	1109.5540		2015		

Appendix 3.2

Experiment 3: nonparametric signal detection theory analysis of probabilities of 'hits' and 'false alarms' in fixed set and varied set procedures, for each group. d' is a measure of sensitivity and Beta is a measure of caution

		PROCEDURE			
		FIXED		VARIED	
GROUP	SESSION	d'	Beta	d'	Beta
Nonretarded adults	1	4.82	5.066	4.49	1.232
	2	4.82	5.066	4.48	2.114
	3	4.21	1.471	4.32	3.018
	4	4.32	0.846	4.92	1.289
	5	4.53	3.088	4.16	1.638
	6	4.37	1.600	4.59	2.726
	7	4.71	2.099	4.13	1.245
Nonretarded children	1	3.82	1.000	3.35	1.324
	2	4.11	1.800	3.74	2.562
	3	3.64	1.395	3.41	0.818
	4	4.16	2.915	3.06	1.289
	5	3.87	1.706	2.94	1.638
	6	4.71	2.100	3.30	2.726
	7	3.87	2.750	3.40	1.245
Retarded adults	1	4.21	1.471	3.26	1.047
	2	4.59	2.726	3.25	1.397
	3	3.99	1.386	3.12	1.040
	4	4.71	2.099	3.56	0.937
	5	4.71	6.388	3.32	0.952
	6	4.58	1.000	3.38	0.948
	7	4.81	0.409	4.04	2.063

Appendix 3.3

Experiment 3: Group x Procedure x Response x Set Size

Analysis of variance in correct mean RT for Session 1

Source	SS	MS	df	F	p
Group	21337001	10668501	2	8.64	<0.01
Residual	25941547	1235312	21		
Procedure	1719740	1719740	1	17.83	<0.01
Group x Procedure	580425	290212	2	3.01	NS
Residual	2025641	96459	21		
Response	733361	733361	1	37.67	<0.01
Group x Response	249428	124714	2	6.40	<0.01
Residual	408888	19471	21		
Set Size	921333	460667	2	18.00	<0.01
Linear	920194	920194	1	35.96	<0.01
Quadratic	1139	1139	1	0.04	NS
Group x Set Size	222516	55629	4	2.17	NS
Dev x Lin	204835	102418	2	4.00	<0.01
Dev x Quad	17680	8840	2	0.34	NS
Residual	1074681	25588	42		
Procedure x Response	99495	99495	1	4.01	NS
Group x Procedure x Response	249816	124908	2	5.04	<0.05
Residual	520698	24795	21		
Procedure x Set Size	14144	7072	2	0.63	NS
Dev x Lin	9577	9577	1	0.85	NS
Dev x Quad	4568	4568	1	0.41	NS
Group x Procedure x Set Size	10867	2717	4	0.24	NS
Dev x Dev x Lin	1972	986	2	0.09	NS
Dev x Dev x Quad	8895	4447	2	0.40	NS
Residual	472005	11238	42		
Response x Set Size	886	443	2	0.11	NS
Dev x Lin	547	547	1	0.14	NS
Dev x Quad	339	339	1	0.08	NS
Group x Response x Set Size	16874	4219	4	1.06	NS
Dev x Dev x Lin	16294	8147	2	2.05	NS
Dev x Dev x Quad	580	290	2	0.07	NS
Residual	166797	3971			
Procedure x Response x Set Size	17060	8530	2	1.08	NS
Dev x Dev x Lin	11719	11719	1	1.48	NS
Dev x Dev x Quad	5341	5341	1	0.68	NS
Residual	363108	7894	46		
Grand Total	57146313		287		

Appendix 3.4

Experiment 3: Group x Procedure x Response x Set Size

analysis of variance in correct mean RT for Session 2

Source	SS	MS	df	F	p
Group	12688220	6344110	2	8.99	<0.01
Residual	14816490	705547	21		
Procedure	12077	12077	1	0.26	NS
Group x Procedure	6773	3386	2	0.07	NS
Residual	972447	46307	21		
Response	572183	572183	1	15.36	<0.01
Group x Response	122319	61160	2	1.64	NS
Residual	782491	37261	21		
Set Size	453046	226523	2	24.37	<0.01
Linear	445927	445927	1	47.97	<0.01
Quadratic	7119	7119	1	0.77	NS
Group x Set Size	44868	11217	4	1.21	NS
Dev x Lin	31473	15736	2	1.69	NS
Dev x Quad	13395	6698	2	0.72	NS
Residual	390392	9295	42		
Procedure x Response	323	323	1	0.04	NS
Group x Procedure x Response	46670	23335	2	3.11	NS
Residual	157355	7493	21		
Procedure x Set Size	64599	32299	2	3.37	<0.05
Dev x Lin	53034	53034	1	5.53	<0.05
Dev x Quad	11565	11565	1	1.21	NS
Group x Procedure x Set Size	32167	8042	4	0.84	NS
Dev x Dev x Lin	30293	15146	2	1.58	NS
Dev x Dev x Quad	1874	937	2	0.10	NS
Residual	402901	9593	42		
Response x Set Size	6368	3184	2	0.49	NS
Dev x Lin	2127	2127	1	0.32	NS
Dev x Quad	4241	4241	1	0.65	NS
Group x Response x Set Size	76130	19032	4	2.91	<0.05
Dev x Dev x Lin	24838	12419	2	1.90	NS
Dev x Dev x Quad	51292	25646	2	3.92	<0.05
Residual	274424	6534	42		
Procedure x Response x Set Size	18326	9163	2	0.89	NS
Dev x Dev x Lin	11486	11486	1	1.12	NS
Dev x Dev x Quad	6841	6841	1	0.67	NS
Group x Procedure x Set Size	30321	15161	2	1.48	NS
Dev x Dev x Dev x Lin	30321	15161	2	1.48	NS
Assigned to Error	5102	2551	2		
Residual	452086	10275	44		
Grand Total:	32422977		287		

Appendix 3.5

Experiment 3: Group x Practice x Procedure

analysis of total mean RT for each subject

Source	SS	MS	df	F	p
Group	10806080	5403040	2	11.04	<0.01
Residual	10282162	489627	21		
Practice	1978195	329699	6	17.70	<0.01
Group x Practice	985063	82089	12	4.41	<0.01
Residual	2347724	18633	126		
Procedure	87882	87882	1	3.89	NS
Group x Procedure	20891	100445	2	0.46	NS
Residual	474112	22577	21		
Practice x Procedure	217700	36283	6	8.96	<0.01
Group x Practice x Procedure	112853	9404	12	2.32	<0.05
Residual	510480	4051	126		
Grand Total	27823141		335		

Appendix 3.6

Equations for best fitting lines of

data illustrated in Figures 3.4, 3.5 & 3.6

y = slope x + zero intercept

Figure 3.4: Chronological Age Controls, nonretarded adults

PROCEDURE

SESSION	FIXED	VARIED
1	y = 22x + 446	y = 41x + 443
2	y = 33x + 372	y = 29x + 400
3	y = 33x + 367	y = 37x + 358
4	y = 51x + 309	y = 27x + 385
5	y = 27x + 373	y = 27x + 379
6	y = 32x + 347	y = 34x + 354
7	y = 34x + 364	y = 34x + 348

Figure 3.5: Mental Age controls, nonretarded children

SESSION	FIXED	VARIED
1	y = 63x + 673	y = 68x + 795
2	y = 95x + 555	y = 29x + 751
3	y = 21x + 706	y = 27x + 732
4	y = 65x + 563	y = 33x + 673
5	y = 48x + 626	y = 26x + 687
6	y = 86x + 505	y = 28x + 724
7	y = 100x + 450	y = 26x + 697

Figure 3.6: Retarded Adults

SESSION	FIXED	VARIED
1	y = 102x + 760	y = 120x + 977
2	y = 66x + 766	y = 36x + 880
3	y = 128x + 469	y = 65x + 732
4	y = 103x + 574	y = 29x + 726
5	y = 126x + 436	y = 42x + 693
6	y = 70x + 532	y = 64x + 581
7	y = 77x + 518	y = 54x + 552

Appendix 3.7

Experiment 3: Group x Procedure x Response x Practice analysis of variance in slopes

Source	SS	MS	df	F	p
Group	225519	112760	2	4.60	<0.05
Residual	514950	24521	21		
Practice	29054	4842	6	0.81	NS
Group x Practice	103026	8586	12	1.43	NS
Residual	754542	5988	126		
Procedure	96600	96600	1	7.51	<0.05
Group x Procedure	47100	235500	2	1.83	NS
Residual	270210	12867	21		
Response	150	150	1	0.02	NS
Group x Response	1162	581	2	0.07	NS
Residual	168720	8034	21		
Practice x Procedure	51918	8653	6	1.83	NS
Group x Practice x Procedure	75934	6328	12	1.34	NS
Residual	596215	4732	126		
Practice x Response	19138	3190	6	1.67	NS
Group x Practice x Response	56424	4702	12	2.46	<0.01
Residual	240879	1912	126		
Procedure x Response	18870	18870	1	2.89	NS
Group x Procedure x Response	12334	6167	2	0.94	NS
Residual	137251	6536	21		
Practice x Procedure x Response	12950	2158	6	0.74	NS
Group x Practice x Procedure x Response	16383	1365	12	0.47	NS
Residual	367350	2915	126		
Grand Total	3816677		671		

Appendix 3.8

Experiment 3: Group x Practice x Procedure x Response analysis of variance in zero intercepts

Source	SS	MS	df	F	p
Group	11714492	5857246	2	5.59	<0.05
Residual	22010848	1048136	21		
Practice	2673418	445570	6	5.04	<0.01
Group x Practice	1685934	140494	12	1.59	NS
Residual	11135300	88375	126		
Procedure	1763435	1763435	1	9.49	<0.01
Group x Procedure	684161	342080	2	1.84	NS
Residual	3903914	185901	21		
Response	1819032	1819032	1	6.96	<0.05
Group x Response	482500	241250	2	0.92	NS
Residual	5485639	261221	21		
Practice x Procedure	18110	3018	6	0.06	NS
Group x Practice x Procedure	777746	64812	12	1.32	NS
Residual	6203925	49237	126		
Practice x Response	255871	42645	6	2.01	NS
Group x Practice x Response	567113	47259	12	2.23	<0.05
Residual	2673789	21221	126		
Procedure x Response	272479	272479	1	6.71	<0.05
Group x Procedure x Response	163003	81501	2	2.01	NS
Residual	852310	40586	21		
Practice x Procedure x Response	157548	26258	6	0.96	NS
Group x Practice x Procedure x Response	356809	29734	12	1.09	NS
Residual	3436473	27274	126		
Grand Total	79093776		671		

Appendix 3.9

Experiment 3: Group x Practice x Procedure x Response x Set Size analysis of variance in correct mean RT

Source	SS	MS	df	F	p
Group	65099168	32549584	2	10.85	<0.01
Residual	62981248	2999107	21		
Practice	11875111	1979185	6	17.80	<0.01
Group x Practice	5624724	468727	12	4.22	<0.01
Residual	14009300	111185	126		
Procedure	472360	472360	1	3.33	NS
Group x Procedure	93992	46996	2	0.33	NS
Residual	2977746	141797	21		
Response	5769326	5769326	1	26.92	<0.01
Group x Response	1066684	533342	2	2.49	NS
Residual	4501008	214334	21		
Set Size	3878359	1939179	2	70.94	<0.01
Group x Set Size	466586	116646	4	4.27	<0.01
Residual	1148162	27337	42		
Practice x Procedure	1477406	246234	6	9.57	<0.01
Group x Practice x Procedure	713979	59498	12	2.31	<0.05
Residual	3243234	25740	126		
Practice x Response	55794	9299	6	1.23	NS
Group x Practice x Response	57948	4829	12	0.64	NS
Residual	954820	7578	126		
Procedure x Response	35695	35695	1	1.21	NS
Group x Procedure x Response	39529	19765	2	0.67	NS
Residual	617751	29417	21		
Practice x Set Size	151163	12597	12	1.20	NS
Group x Practice x Set Size	307788	12824	24	1.22	NS
Residual	2639586	10475	252		
Procedure x Set Size	302249	151125	2	7.44	<0.01
Group x Procedure x Set Size	125193	31298	4	1.54	NS
Residual	852639	20301	42		
Response x Set Size	405	203	2	0.02	NS
Group x Response x Set Size	17358	4339	4	0.41	NS
Residual	446005	10619	42		

(continued)

Appendix 3.9

(continued)

Source	SS	MS	df	F	p
Practice x Procedure x Response	99029	16505	6	2.22	<0.05
Group x Practice x Procedure x Response	334300	27858	12	3.74	<0.01
Residual	939038	7453	126		
Practice x Procedure x Set Size	231598	19300	12	2.64	<0.01
Group x Practice x Procedure x Set Size	190283	7928	24	1.09	NS
Residual	1840320	7303	252		
Practice x Response x Set Size	56248	4687	12	1.24	NS
Group x Practice x Response x Set Size	173894	7246	24	1.91	<0.05
Residual	954276	3787	252		
Procedure x Response x Set Size	42504	21252	2	1.64	NS
Group x Procedure x Response x Set Size	35977	8994	4	0.70	NS
Residual	543878	12949	42		
Practice x Procedure x Response x Set Size	79088	6591	12	1.30	NS
Group x Practice x Procedure x Response x Set Size	98163	4090	24	0.81	NS
Residual	1278795	5075	252		
Grand Total	198899584		2015		

Appendix 3.10

Experiment 3: Group x Procedure x Response x Practice

analysis of variance in standard errors of estimate

Source	SS	MS	df	F	p
Group	5767743	2883872	2	5.79	<0.01
Residual	10463376	498256	21		
Practice	716547	119425	6	10.70	<0.01
Linear	547172	547172	1	49.00	<0.01
Quad	81035	81035	1	7.26	<0.01
Deviations	88340	22085	4	1.98	NS
Group x Practice	735258	61271	12	5.49	<0.01
Dev x Lin	584403	292201	2	26.18	<0.01
Dev x Quad	89528	44764	2	4.01	<0.05
Deviations	61327	7666	8	0.69	NS
Residual	1406153	11160	126		
Response	173122	173122	1	3.69	NS
Group x Response	120272	60136	2	1.28	NS
Residual	985889	46947	21		
Procedure	109140	109140	1	14.10	<0.01
Group x Procedure	8999	4500	2	0.58	NS
Residual	162597	7743	21		
Practice x Response	17082	2847	6	1.22	NS
Linear x Deviations	5030	5030	1	2.16	NS
Quad x Deviations	17	17	1	0.01	NS
Deviations	12035	3009	4	1.29	NS
Group x Practice x Response	15757	1313	12	0.56	NS
Dev x Lin x Dev	3551	1775	2	0.76	NS
Dev x Quad x Dev	1619	809	2	0.35	NS
Deviations	10588	1323	8	0.57	NS
Residual	292869	2324	126		
Practice x Procedure	78082	13014	6	2.74	<0.05
Lin x Dev	30544	30544	1	6.44	<0.05
Quad x Dev	27402	27402	1	5.77	<0.05
Deviations	20136	5034	4	1.06	NS
Group x Practice x Procedure	24548	2046	12	0.43	NS
Dev x Lin x Dev	7275	3638	2	0.77	NS
Dev x Quad x Dev	2584	1292	2	0.27	NS
Deviations	14689	1836	8	0.39	NS
Residual	597867	4745	126		

(continued)

Appendix 3.10

(continued)

Source	SS	MS	df	F	p
Response x Procedure	4270	4270	1	0.70	NS
Group x Response x Procedure	1681	841	2	0.14	NS
Residual	127949	6093	21		
Practice x Response x Procedure	23696	3949	6	1.18	NS
Lin x Dev x Dev	4379	4379	1	1.30	NS
Quad x Dev x Dev	6120	6120	1	1.82	NS
Deviations	13197	3299	4	0.98	NS
Group x Practice x Response x Procedure	25268	12634	2	3.77	<0.05
Dev x Lin x Dev x Dev	25268	12634	2	3.77	<0.05
Assigned to Error	9386	939	10	0.28	NS
Residual	456238	3355	136		
Grand Total	22314403		671		

Appendix 3.11

Experiment 3: Group x Practice x Procedure x Response x Set Size analysis of variance of standard deviations per set size, restricted to 3-way interactions

Source	SS	MS	df	F	p
Group	13324092	6662046	2	5.66	<0.05
Residual	24727328	1177491	21		
Practice	1505944	250991	6	11.05	<0.01
Group x Practice	1394070	116172	12	5.12	<0.01
Residual	2861584	22711	126		
Procedure	344301	344301	1	18.47	<0.01
Group x Procedure	29869	14934	2	0.80	NS
Residual	391517	18644	21		
Response	442330	442330	1	4.09	NS
Group x Response	282229	141115	2	1.30	NS
Residual	2271810	108181	21		

(continued)

Appendix 3.11

(continued)

Source	SS	MS	df	F	P
Set Size	927661	463831	2	22.64	<0.01
Group x Set Size	278982	69746	4	3.40	<0.05
Residual	860464	20487	42		
Practice x Procedure	162923	27154	6	2.76	<0.05
Group x Practice x Procedure	46362	3864	12	0.39	NS
Residual	1240347	9844	126		
Practice x Response	38997	6499	6	0.91	NS
Group x Practice x Response	45327	3777	12	0.53	NS
Residual	900282	7145	126		
Procedure x Response	11211	11211	1	0.98	NS
Group x Procedure x Response	2132	1066	2	0.09	NS
Residual	239948	11426	21		
Practice x Set Size	60584	5049	12	0.47	NS
Group x Practice x Set Size	145400	6058	24	0.56	NS
Residual	2719679	10792	252		
Procedure x Set Size	203416	101708	2	5.85	<0.01
Group x Procedure x Set Size	72963	18241	4	1.05	NS
Residual	730563	17394	42		
Response x Set Size	44974	22487	2	2.86	NS
Group x Response x Set Size	9829	2457	4	0.31	NS
Residual	330377	7866	42		
Practice x Procedure x Response	36382	6064	6	0.73	NS
Residual	1151082	8341	138		
Practice x Response x Set Size	91856	7655	12	1.26	NS
Residual	1677651	6078	276		
Procedure x Response x Set Size	11415	5707	2	0.53	NS
Residual	497791	10822	46		
Higher order interactions	2225517	7727	288		
Grand Total	64751552		2015		

Appendix 3.12

Experiment 3: Percentage of trials removed when those with RT > 1500 msecs and then > $\pm$1.96 standard deviations from the mean are excluded

Chronological Age Controls: nonretarded adults

PROCEDURE:	FIXED		VARIED	
RESPONSE:	YES	NO	YES	NO
SESSION: 1	4.25	4.46	6.48	4.78
2	5.10	4.74	5.10	6.16
3	5.40	5.07	5.14	5.32
4	4.79	5.10	6.16	5.03
5	6.25	5.59	6.27	5.35
6	5.10	5.34	4.53	5.87
7	5.07	5.31	5.40	5.08

Mental Age Controls: nonretarded children

PROCEDURE:	FIXED		VARIED	
RESPONSE:	YES	NO	YES	NO
SESSION: 1	17.43	18.62	21.30	21.45
2	7.43	18.59	7.33	7.10
3	8.12	11.46	8.38	8.48
4	8.02	7.30	6.27	10.62
5	7.49	9.97	7.65	8.23
6	5.92	9.22	7.27	9.46
7	6.41	7.04	7.58	8.19

Retarded Adults

PROCEDURE:	FIXED		VARIED	
RESPONSE:	YES	NO	YES	NO
SESSION: 1	21.88	21.57	43.70	46.06
2	19.55	22.69	10.09	24.20
3	9.14	20.17	11.24	21.60
4	10.42	19.72	6.05	18.13
5	9.12	18.38	7.87	11.99
6	5.90	20.62	9.59	14.62
7	7.82	9.80	5.46	8.19

Appendix 3.13

(a) Experiment 3: Group x Practice x Procedure x Response x Set Size analysis of variance in reduced mean RT

df from missing values are shown in brackets

Source	SS	MS	df	F	p
Group	10105070.0	5052535.0	2	3.14	NS
Residual	33836416.0	1611257.9	21		
Practice	2303612.5	383935.4	6	9.00	<0.01
Group x Practice	1181861.6	98488.5	12	2.31	<0.05
Residual	5332271.0	42658.2	125(1)		
Procedure	2650700.8	2650700.8	1	6.51	<0.05
Group x Procedure	953907.3	476953.7	2	1.17	NS
Residual	8555334.0	407396.8	21		
Response	2793390.3	2793390.3	1	197.79	<0.01
Group x Response	112664.8	56332.4	2	3.99	<0.05
Residual	296580.0	14122.9	21		
Set Size	1543340.9	771670.4	2	131.96	<0.01
Group x Set Size	56295.8	14074.0	4	2.41	NS
Residual	245612.0	5847.9	42		
Practice x Procedure	277305.6	46217.6	6	1.45	NS
Group x Practice x Procedure	317041.3	26420.1	12	0.83	NS
Residual	3818716.5	31822.6	120(6)		
Practice x Response	166817.9	27863.0	6	5.03	<0.05
Group x Practice x Response	25309.7	2109.1	12	0.38	NS
Residual	690597.9	5524.8	125(1)		
Procedure x Response	18838.5	18838.5	1	2.07	NS
Group x Procedure x Response	17346.0	8673.0	2	0.95	NS
Residual	191090.5	9099.5	21		
Practice x Set Size	89418.1	7451.5	12	2.81	<0.05
Group x Practice x Set Size	140685.5	5861.9	24	2.21	<0.05
Residual	662973.0	2651.9	250(2)		

(continued)

Appendix 3.13

(continued)

Source	SS	MS	df	F	p
Procedure x Set Size	26881.2	13440.6	2	2.63	NS
Group x Procedure x Set Size	6823.5	1705.9	4	6.33	NS
Residual	214591.0	5109.3	42		
Response x Set Size	6797.4	3398.7	2	2.65	NS
Group x Response x Set Size	5771.6	1442.9	4	1.18	NS
Residual	53796.0	1280.9	42		
Practice x Procedure x Response	31446.7	5241.1	6	1.92	NS
Group x Practice x Procedure x Response	21346.0	1778.8	12	0.65	NS
Residual	303857.6	2737.5	111(15)		
Practice x Procedure x Set Size	41493.4	3457.8	12	1.40	NS
Group x Practice x Procedure x Set Size	88258.1	3677.4	24	1.49	NS
Residual	593418.4	2472.6	240(12)		
Practice x Response x Set Size	44400.1	3700.0	12	2.07	<0.05
Group x Practice x Response x Set Size	69252.7	2885.5	24	1.61	NS
Residual	448009.1	1792.0	250 (2)		
Procedure x Response x Set Size	14362.9	7181.4	2	3.59	<0.05
Group x Procedure x Response x Set Size	7526.6	1881.7	4	0.94	NS
Residual	84101.4	2002.4	42		
Practice x Procedure x Response x Set Size	19090.1	1590.8	12	1.66	NS
Group x Practice x Procedure x Response x Set Size	33838.4	1409.9	24	1.47	NS
Residual	212643.3	957.9	222(30)		
Grand Total	787109040		1946		

(continued)

Appendix 3.13

(continued)

(b) Group x Practice x Procedure analysis of total mean RT after mean RT was reduced by excluding long RTs

Source	SS	MS	df	F	p
Group	6175015	3087508	2	19.55	<0.01
Residual	3316511	157929	21		
Practice	751030	125172	6	18.47	<0.01
Group x Practice	212423	17702	12	2.61	<0.01
Residual	833587	6777	123 (3)		
Procedure	81252	81252	1	9.95	<0.01
Group x Procedure	25915	12958	2	1.59	NS
Residual	171458	8165	21		
Practice x Procedure	118293	19715	6	10.74	<0.01
Group x Practice x Procedure	41916	3493	12	1.90	<0.05
Residual	212939	1836	116 (10)		
Grand Total	11940341		322		

Appendix 3.14

Experiment 3: slopes (msecs/item: Column I) and intercepts (msecs: Column II) calculated when long RTs are excluded as described in Chapter 4 (reduced data) and when all data is included

		PROCEDURE							
		FIXED				VARIED			
		Reduced data		All data		Reduced data		All data	
SESSION/GROUP		I	II	I	II	I	II	I	II
Nonretarded adults	1	14	458	22	446	27	460	41	443
	2	27	337	33	372	23	400	29	399
	3	22	381	33	368	24	384	37	358
	4	38	335	51	309	20	391	27	385
	5	19	385	27	373	20	379	27	379
	6	26	354	32	347	25	365	34	354
	7	25	377	34	364	26	358	34	348
Nonretarded children	1	28	694	63	673	38	783	68	795
	2	46	645	95	555	37	675	29	751
	3	19	640	21	706	34	647	27	732
	4	39	587	65	563	21	651	33	673
	5	30	618	48	626	17	655	26	687
	6	56	555	86	505	25	674	28	724
	7	66	507	100	450	26	640	26	696
Retarded adults	1	57	653	102	760	51	839	120	977
	2	36	698	66	766	47	707	36	880
	3	69	539	128	469	37	674	65	728
	4	40	640	103	564	31	647	29	726
	5	64	509	126	435	34	631	42	693
	6	38	546	70	532	38	554	64	581
	7	37	573	77	518	40	534	54	552

APPENDIX 4

Appendix 4.1

Experiment 4: Practice x Response x Set Size
analysis of variance in number of errors made

Source	SS	MS	df	F	p
Subjects	78.6866	11.2409	7		
Practice	8.4453	0.4968	17	1.25	NS
Residual	47.4227	0.3985	119		
Response	10.3134	10.3134	1	15.29	<0.01
Residual	4.7214	0.6745			
Set Size	73.1137	24.3712	3	8.71	<0.01
Residual	58.7682	2.7985	21		
Response x Set Size	13.2873	4.4291	3	15.99	<0.01
Residual	5.8168	0.2770	21		
Response x Practice	10.7648	0.6332	17	1.54	NS
Residual	48.8255	0.4103	119		
Set Size x Practice	16.0582	0.3149	51	0.88	NS
Residual	127.4349	0.3570	357		
Response x Set Size x Practice	24.8220	0.4867	51	1.30	NS
Residual	133.9488	0.3752	357		
Grand Total	662.4297		1151		

Appendix 4.2

Experiment 4: Nonparametric signal detection theory analysis of probabilities of 'hits' and 'false alarms'. d' is a measure of sensitivity and Beta is a measure of caution

SESSION	d'	Beta
1	3.37	1.000
2	3.42	1.158
3	3.99	1.158
4	3.81	1.638
5	3.89	0.938
6	3.94	2.182
7	3.99	1.158
8	3.79	1.122
9	3.76	1.777
10	4.18	3.935
11	3.87	1.459
12	3.83	2.208
13	4.17	1.439
14	3.82	1.061
15	3.93	1.833
16	4.12	2.239
17	4.22	2.208
18	3.85	2.126

Appendix 4.3

Experiment 4: Analysis of total mean RT per session of practice by analysis of variance with practice treated as repeated measures

Source	SS	MS	df	F	p
Subjects	853066	121867	7		
Practice	374831	22049	17	3.42	<0.01
Residual	760122	6442	118(1)		
Grand Total	1988018		142		

Appendix 4.4

Experiment 4: Equations for best fitting straight lines of data illustrated in Figure 4.2

Session	Equation (y = slope x + zero intercept)
1	$y = 34x + 734$
2	$y = 22x + 652$
3	$y = 42x + 569$
4	$y = 46x + 560$
5	$y = 62x + 514$
6	$y = 60x + 506$
7	$y = 76x + 472$
8	$y = 54x + 509$
9	$y = 51x + 512$
10	$y = 55x + 475$
11	$y = 40x + 512$
12	$y = 61x + 449$
13	$y = 39x + 510$
14	$y = 53x + 489$
15	$y = 65x + 466$
16	$y = 62x + 459$
17	$y = 44x + 488$
18	$y = 63x + 440$

Appendix 4.5

Experiment 4: Practice x Response

analysis of variance in slopes

Source	SS	MS	df	F	p
Subjects	207317	29617	7		
Practice	46959	2762	17	1.77	<0.05
Residual	186064	1564	119		
Response	158	158	1	0.04	NS
Residual	25642	3663	7		
Practice x Response	24261	1427	17	1.16	NS
Residual	146099	1228	119		
Grand Total	636499		287		

Appendix 4.6

Experiment 4: Practice x Response

analysis of variance in intercepts

Source	SS	MS	df	F	p
Subjects	1842420	263203	7		
Practice	1458819	85813	17	3.53	<0.01
Residual	2893594	24316	119		
Response	734471	734471	1	14.70	<0.01
Residual	349797	49971	7		
Practice x Response	277246	16309	17	1.60	NS
Residual	1210446	10172			
Grand Total	8766793		287		

Appendix 4.7

Experiment 4: Practice x Response x Set Size

Analysis of variance in mean RT per set size

Source	SS	MS	df	F	p
Subjects	6950592	992942	7		
Practice	3128789	184046	17	3.56	<0.01
Residual	6144865	51638	119		
Response	3142733	3142733	1	24.10	<0.01
Residual	912919	130417	7		
Set Size	3856570	1285523	3	21.27	<0.01
Residual	1269092	60433	21		
Response x Set Size	7594	2531	3	0.28	NS
Residual	192515	9167	21		
Response x Practice	417812	24577	17	2.01	<0.05
Residual	1453534	12215	119		
Set Size x Practice	381617	7483	51	1.46	<0.05
Residual	1835270	5141	357		
Practice x Response x Set Size	278400	5459	51	1.24	NS
Residual	1575417	4413	357		
Grand Total	31547720		1151		

Appendix 4.8

Experiment 4: Practice x Response x Set Size

analysis of variance in standard deviations

Source	SS	MS	df	F	p
Subjects	4855957	693708	7		
Practice	1951221	114778	17	2.39	<0.01
Residual	5721179	48077	119		
Response	97020	97020	1	1.00	NS
Residual	680175	97168	7		
Set Size	747390	249130	3	4.57	<0.05
Residual	1144863	54517	21		
Response x Set Size	61778	20593	3	1.60	NS
Residual	270031	12859	21		
Response x Practice	331136	19479	17	1.91	<0.05
Residual	1215589	10215	119		
Set Size x Practice	525969	10313	51	0.99	NS
Residual	3725087	10434	357		
Response x Set Size x Practice	553942	10862	51	1.02	NS
Residual	3814001	10683	357		
Grand Total	25695338		1151		

Appendix 4.9

Experiment 4: Percentage of trials removed (as described in Chapter 4) when very long RTs are excluded

SESSION	NO	YES
1	16.15	8.73
2	12.83	6.56
3	9.36	6.20
4	8.53	7.36
5	9.21	6.62
6	6.14	5.51
7	7.49	6.62
8	7.46	6.02
9	7.68	6.09
10	6.74	4.98
11	6.17	5.60
12	6.57	5.66
13	6.99	6.60
14	6.27	5.36
15	5.53	5.18
16	13.08	7.31
17	5.24	5.01
18	6.14	7.39

Appendix 4.10

Experiment 4: Analysis of total mean RT per session of practice after very long RTs have been removed (as described in Chapter 4)

Source	SS	MS	df	F	p
Subjects	426280	60897	7		
Session	124919	7348	17	3.19	<0.01
Residual	271538	2301	118(1)		
Grand Total	822737		142		

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