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REHEARSAL AND RECALL IN SHORT-TERM MEMORY

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CHAPTER I

The Field of Short-Term Memory

Nearly two decades ago, one review of immediate memory research considered that through the studies "runs only the common feature that they apply to immediate recalls of series presented but once". (McGeoch & Irion, 1952). While this statement is far from adequate to describe the field of short-term memory today, it is so only because the intervening years have sired numerous disparate styles of experimentation which, despite their differences, demand inclusion under the rubric of the short-term retention of information. Many of the developments in the last decade bear witness to the ingenuity of researchers in devising new techniques for research rather than demonstrating any fundamental lack of unity in the area. This is perhaps suggested by a recent review devoted entirely to the techniques in the study of short-term memory (Broadbent, 1965). However, it is important to bear in mind that the history of research in this area is not one of a unified field from its inception and this fact has contributed in a very real way both to the popularity of short-term memory research in the last decade and to the proliferation of its research techniques.

Short-term memory has a long history in the form of research on the immediate memory span, and can claim - along with Ebbinghaus (1885) - one of the earliest experiments on the higher mental processes (Jacobs, 1887). While the first observations made were of great interest - namely the number of items which a subject could repeat back after one presentation appeared to be correlated with intelligence and the size of the set from which the items were drawn - this style of work did not provide the stimulus for the recent developments in the area. In retrospect, it is not easy to decide why immediate memory remained so under-researched for so long. However, it is possible that researchers felt that the outcome of such studies was too predictable to merit any great attention. Thus, if the presented material was within the subject's memory span, then it was guaranteed of perfect recall, and, therefore, uninteresting. Alternatively, if the material exceeded the subject's memory span, it would require multiple trials to be learned and was, therefore, a subject for learning experiments.

However, whatever the reason, the history of short-term memory can be seen as beginning quite recently at the time of the classic papers of Brown (1958) and that of Peterson & Peterson (1959). Possibly, a Zeitgeist interpretation could be made for the developments which followed the publication of these two papers and probably neither work alone could have stimulated so much research as has been conducted since. Nevertheless, there are a number of reasons why it is convenient to consider these two studies as historical determinants. Judging by the relative frequency of reference to these two papers in the literature, it would seem that the main stimulus for research was provided by the Peterson & Peterson paper which demonstrated extremely rapid forgetting of material well within the memory span. Brown produced similar results, but these received less emphasis because the main throw of his research was towards the theoretical issue of the causes of forgetting. Although the theoretical implications of both papers were considerable, it was probably this demonstration of substantial effects over very short time intervals which encouraged researchers to turn to this field. Among the reasons for doing so must be considered that of economy. There was little point in studying long-term retention over hours or days or even weeks when a similar amount of data could be generated in minutes. Besides this, forgetting over such short time intervals suggested that traditional learning experiments had ignored an important stage of the learning process and, in this respect, the studies made the important contribution of bridging the gap between the memory span and long-term memory (Hall, 1966).

The demonstration that rapid forgetting can take place in immediate memory studies was not an entirely new one, however (see Pillsbury & Sylvester, 1940), so that a number of additional considerations are necessary in placing the impetus for short-term memory research at this time. Perhaps the most important development in the post-war years in the general area of human skilled performance was that provided by communication theory (e.g. Wiener, 1948; Shannon & Weaver, 1949; Hicks, 1952). It was apparent that if man was viewed as an information processing device then the psychologist and the communication engineer were studying similar problems. Unfortunately, some of the promise of communication theory, in being able to measure in a precise quantitative way the information transmitted by a given message, was not achieved in short-term memory in so far as the information content of a message did not appear to be the limiting factor in memory performance (Miller, 1956a). Nevertheless, as a conceptual tool communication theory offered much to short-term memory. This is apparent in the language used by Brown (1958) to interpret his results. His formulation of the cause of forgetting in immediate memory as a decline in the signal-to-noise ratio of the memory trace was a clear theoretical advance on earlier notions of decay (e.g. Jenkins & Dallenbach, 1924). Indeed, until Brown adopted this theoretical position, there had been virtually no support for the decay theory of forgetting since the attack by McGeoch (1932). The dominant tradition was one of interference theory which insisted that time itself was unimportant for forgetting; it was rather the events which occur in time that determine whether information can be retrieved at a later date.

Support for this newly stated decay theory came from one other notable product of the cybernetic movement of the 1950's: Broadbent's book on perception and communication (Broadbent, 1958). This work was important for a variety of reasons. Broadbent's model of auditory attention and perception distinguished between two kinds of short-term memory, one of which was very close to the perceptual system and very transitory - of the order of a second or so. The more permanent short-term store received somewhat less attention and the relationship between this and long-term memory was not defined. However, the main interest in the apparent discovery of a sensory store was that it emphasised the problem of separating perceptual phenomena from those of memory and encouraged research to turn to situations under which the latter may be dominant. A similar but independent demonstration of how memory factors confound the study of perception was made in the area of visual perception by Sperling and others (Sperling, 1960; Averbach & Sperling, 1961; Klemmer, 1961). These developments can be seen as widening the scope of short-term retention studies to include those areas which would have traditionally been described as the domain of perception. The work of Broadbent was also important in another way. It had an overall orientation to applied psychology, despite the introductory apology that "the closer we come to the problems of everyday life the harder it is to stay with them". Broadbent, 1958, p.8.) Quite apart from the interesting theoretical issues raised by short-term memory research, the need for greater understanding of immediate memory was increasing with the increasing need for elaborate identification codes in society in the form of telephone numbers, insurance card details, etc. The largest proportion of errors in the use of these codes will occur because of failings in immediate memory to cope with copying, whether it be from telephone directory to telephone dial or from inventory to inventory. Concern with the practical applications of short-term memory is demonstrated in such studies as those by Conrad & Hille (1958), Karlin (1958), Poulton (1958) and Sinks (1959).

This review of some of the more important developments taking place in short-term memory around the time of the classic papers of Brown (1958) and Peterson & Peterson (1959) serves a double function. First of all, it illustrates that there was a substantial amount of diverse research underway at the time and, secondly, it illustrates that there were a number of good reasons at the behavioural level for distinguishing between memory at different time intervals.

Traditionally, Brown (1958) and Peterson & Peterson (1959) are credited with providing the results which stimulated a distinction being made between short- and long-term memory (e.g. Hall, 1966). However, in a sense, this distinction had always been made in that immediate memory span studies were typically reviewed separately from those on learning or long-term memory (e.g. McGeoch, 1942; Woodworth, 1938). Additionally, the basis for a distinction had long been made by such researchers as Pavlov (1928) and Hull (1943) in their use of the concept of stimulus trace. Perhaps the most sophisticated early recommendation for a short-term memory/long-term memory distinction was made by Hebb (1949), who based his argument for a mechanism to carry memory until a permanent structural change could take place on a substantial body of anatomical and physiological evidence that such a mechanism was possible. The 1950's saw the accumulation of numerous studies on the selectivity of amnesia (reviewed by Glickman, 1961) and - in particular - the case history reported by Penfield & Milner (1958) of a patient with amnesia, but unimpaired immediate memory. However, although these amnesia studies were an additional consideration for the development of a generally accepted distinction between short- and long-term memory only after the 1950's, the main reason is still probably to be found in the two papers of Brown (1958) and Peterson & Peterson (1959). The distinction which these two papers recommended was based on the relative lability of information remembered over short time intervals rather than the limited performance which earlier immediate-memory span work had noted. However, additionally, Peterson & Peterson insisted that "the course of short-term verbal retention is seen to be related to the learning process" and they conceptualised their results as a "trial of learning". Ironically, it was probably this emphasis on the similarity between short-term memory and long-term memory (i.e. short-term memory is what happens in long-term memory studies after a short time interval) which finally forced the debate on whether there was more than one kind of memory.

Viewed in retrospect, it is somewhat surprising that the research on short-term memory should not have led sooner to anything more than a distinction between short- and long-term memory. It seems apparent now that from the research of the period 1958-1961 three different kinds of memory might have been distinguished - namely sensory memory, short-term memory and long-term memory. However, such a distinction, while mentioned by Wooldridge (1963) and implied by Broadbent (1958) and Sperling (1960, 1963), did not clearly emerge until 1967 (Neisser, 1967). In view of the taxonomic elegance of this tripartite distinction, the following discussion of the main trends in the last decade will adopt this approach.

Sensory Memory It is interesting that some of the most seminal work on sensory memory should have arisen from a study of that age old "constant" of psychology, the span of apprehension. This concept bears more than a passing affinity to that of the span of immediate memory and there is, no doubt, some frequent confusion between the two. The span of apprehension refers to the number of objects which can be identified at a single glance (traditionally a tachistoscope would be used for the presentation of the material). Immediate memory refers to the number of items which subjects can repeat back without error and typically involves the sequential presentation of material. Thus, the former claims to examine perception alone and typically found a limit of 4-5 items (e.g. Cattell, 1885; Erdmann & Dodge, 1898). Although Sperling (1960) was not the first to suggest that the visual sensation in such studies may outlast the stimulus (e.g. Woodworth, 1938), he was the first to present empirical evidence of this. The experimental method was quite simply to present 12 letters or digits in three rows of 4 items, for a duration of 50 milliseconds. Immediately after the stimulus presentation, a tone was sounded to denote recall of just one of these rows. Subjects correctly reported 76% of the items requested so that at the time of the recall request subjects must have had available at least 76% of 12 letters. However, when the tone for the cue for partial recall was delayed for only one second, performance dropped to 36% which at 4.3 items was within the range normally expected in such studies. The conclusion to be drawn from this experiment was that a visual memory existed for visually presented material lasting less than one second and that the limited span of apprehension typically reported was due more to the subject's limited processing capacities than to what he could see. The essential finding of Sperling was replicated, using various procedures (Averbach & Corriell, 1961; Estes, 1965; Estes & Taylor, 1966; Mackworth, 1962c, 1963; Mewhort, Merikle & Bryden, 1969; Sperling, 1963). This research produced a number of interesting theoretical issues such as whether the sensory memory could be "erased" experimentally (Mayzner et al., 1964; Eriksen & Stetty, 1964) and whether two stimuli rapidly following one another could become superimposed on each other (Eriksen & Collins, 1964) and revived discussion of earlier relevant work on "metacontrast" (Alpern, 1952, 1953).

Particularly important for short-term memory was the re-evaluation which this work recommended of the study by Lawrence & Laberge (1956). Lawrence & Laberge presented two cards tachistoscopically for 0.1 seconds. The material was such that, in all, 6 dimensions were to be reported. If subjects were given prior instructions to concentrate on one of the dimensions, errors were made on the others. However, if the recall order of dimensions was specified after presentation, exactly the same results were obtained: last recalled dimensions were the worst recalled. On the basis of this data, the authors suggested that recall order could explain the loss of information better than selective attention. The results of Sperling (1960), however, implied that order of verbal coding of material retained in sensory memory might be an important influence in an experiment such as was performed by Lawrence & Laberge. A series of experiments by Haber (Harris & Haber, 1963; Haber 1964a, 1964b, 1966) supported this view in showing that improved performance arising from "set" to concentrate on certain dimensions is achieved by the encoding of these dimensions first. It may be noted in passing (and this point will be returned to) that the verbal coding of material from sensory memory is assumed to allow entry of the material into short-term memory (see Sperling, 1960, 1963).

The seminal work on auditory sensory memory bears some striking resemblance to that on vision reported above. Thus, Broadbent (1958) adopted one design anticipating Sperling (1960) in an attempt to tease out the manner in which auditory information is retained. The method was to present two different messages simultaneously, one to each ear. Each message had its own call sign and subjects were instructed to report as much as they could remember from the indicated ear. By using recall cues before and after presentation of the material, Broadbent was able to show that the messages were retained intact for a short period in much the same way that the later studies of visual sensory memory were to suggest. This particular experiment was somewhat complicated by different effects at early stages of practice, but a wide variety of experiments have suggested that the results pointing to an auditory sensory memory are essentially replicable. Three such studies are of particular interest in pointing to the relationship between sensory memory and short-term memory. Treisman (1964a,b,c) extended some of the earlier work on "shadowing" (Cherry, 1953). The task was one of selective listening whereby one continuous message was presented to one ear (the shadowed channel) and a supposedly different message presented to the other ear (the rejected channel). The rejected channel was introduced to the subjects as distraction to be ignored and was faded in gradually after the shadowing task had begun. In successive trials, the time lag between the two identical messages was reduced from 6 seconds to zero. At some stage subjects realised that the two messages were the same but this occurred at different temporal separations depending on whether the shadowed message was ahead of the rejected message or vice versa. When the rejected message was ahead, the time lag was as small as 1.4 seconds, but, when the shadowed message was ahead of the rejected message, subjects identified the two as the same at an average time lag of 4.5 seconds. As Treisman argued, these differences would seem to reflect two different memories. Memory for the rejected channel can be seen as an unattended sensory memory lasting just over one second. Memory for the shadowed channel can be viewed as a consequence of attention and reflecting processed material held in short-term memory.

Although there would seem compelling evidence for the existence of both an auditory and a visual sensory memory, and also grounds for believing the principles of storage to be the same in each (Sampson & Spong, 1961 a, b; Sampson, 1964), it is clear that the situations under which these memories will demonstrate themselves demand sophisticated techniques. This being the case, it is not surprising that they remain comparatively neglected phenomena.

This is especially true of auditory sensory memory, where little attempt would seem to have been made to map the likely parameters affecting its duration and nature. It is clear that the problems facing research in this area are those of separating both perceptual and short-term memory factors from those of sensory memory.

Short-term memory Although some definite time limits have been placed on sensory memory, the duration of short-term memory remains indeterminate, partly for the very good reason that it can be sustained by rehearsal. (Broadbent, 1958; Brown, 1958; Conrad, 1967; Glanzer & Clark, 1963, 1964; Sperling, 1960, 1963, 1967). This point is important in considering the time limit placed by Treisman (1964 a, b, c) on short-term memory in continuous performance. In part too, this fact has led to the existence of short-term memory as a portmanteau word so that some discussion should be made of the concept before any implied definition is given by review of the research in the area.

Although Neisser (1967) adopted the distinction between visual and auditory sensory memory, short-term memory and long-term memory (labelled by Neisser iconic and echoic, active verbal memory and long-term memory respectively), his work cannot be guaranteed to dispel confusion surrounding short-term memory. Thus, Broadbent is cited as "the best-known duplexity theorist", whereas it is felt that Broadbent was the earliest triplicity theorist.

The reason for making this novel claim requires some discussion. Broadbent's (1958) model of memory and attention has, as Neisser suggests, received considerable publicity and, for this reason, a full description will not be given here. In bare-bones outline, Broadbent postulated a store for pre-perceptual information, the "S system", to which material could be returned after perception by the "P system". This "S" store was distinguished from long-term memory (Broadbent, 1958, p.239). To view this model as a simple duplex model is to ignore the behavioural distinction which Broadbent makes between processed and unprocessed information, within the "S" system. Indeed, Broadbent (1958, p. 226-227) states "the identity of the S system in the two cases, before and after passage through the P system, is perhaps open to doubt; it may be that the store which lies before the P system is not the same as that which lies after it". However, even if processed and unprocessed information were located in the same store, this does not pre-empt a useful distinction at the behavioural level. The work of Treisman (1964) which has been discussed earlier, strongly supports this point. In any case, since the overwhelming majority of work on short-term memory is behavioural, it would seem a peculiar instance of reductionism to seek support for the behavioural evidence by reference to the stores involved, or to physiological work, as numerous authors have done (e.g. Brown, 1964; Welford, 1967).

This discussion raises one other point, which should not pass unmentioned while the confusion surrounding the concept of "short-term memory" is being discussed. Waugh & Norman (1965), in an influential paper, drew a distinction between short-term memory and long-term memory, but rephrased these concepts as primary memory (PM) and secondary memory (SM) respectively. Their ostensible reason for so doing was to follow the distinction made by James (1890) between events which have not left consciousness and are in the psychological present (i.e. PM) and events which are in the psychological past (SM). As Neisser (1967, p.200) has lamented, Waugh & Norman's use of "primary memory" to apply to short-term memory has pre-empted its use in the way which James probably intended it to be used to apply to auditory sensory memory or the "echo box" for recent auditory stimuli. However, while making no small contribution to the clarification of theory and the obfuscation of concepts, Waugh & Norman additionally present an interesting misinterpretation of Broadbent (1958). Having defined primary memory as being memory for material rehearsed in short-term memory, Waugh & Norman (1965, p.93) continue, "Our PM is similar to Broadbent's 1958 P system". This quotation captures the spirit of Broadbent (1958), as described above, but ignores the medium. Broadbent (1958), as has been pointed out, saw the storage of post-perceptual information within the S system. The "P" system is a perceptual processing system and Broadbent only once offers any statement which could be misinterpreted as implying that the P system could operate as a memory system (Broadbent, 1958, p.224) and this is when he emphasises the difficulty of drawing a distinction between perception and memory, (as all the work on sensory memory, discussed earlier, implies).

This discussion hints at some of the confusion surrounding the concept of short-term memory and perhaps recommends that definition of the term is best avoided. Little attempt has been made in the literature to define short-term memory and, indeed, researchers in the field show a marked reluctance to offer any definition, which might prove limiting. This is, perhaps, most apparent from the answers given at a conference attended by Feigenbaum, who asked for some explanation of the concepts which had been used in discussion. A number of authors in the field suggested that short-term memory applied to the retention of material over seconds or minutes, but little advance was offered on this. Indeed, one conference member, (Broadbent), neatly avoided answering the question by drawing an analogy between defining short-term memory and the problem of saying when an aircraft had taken off - for some period of time it would be difficult to say precisely whether the aircraft was still on the ground or in the air. (see Kimble, 1967).

Despite the real problem which exists in defining short-term memory, some of the major findings made in this field suggest that something more than a definition by an approximate time limit might be presented. Typically, it would seem to apply to the retention, over no more than a few minutes, and usually over a matter of seconds, of material which is relatively easily disrupted and which relies on its retention by rehearsal of that material. Further, the amount of material which can be so retained is limited to around seven items. This does not necessarily exclude all work falling outside this definition, since each piece of research must be assessed on its individual merits, but it allows the inclusion of most of the work at the behavioural level recommending a distinction between short-term and long-term memory.

Perhaps the most striking feature of short-term memory is that it is maintained by rehearsal so that, even when material is presented visually, the information which is stored appears to be in some kind of auditory form. There is a massive amount of data to support this view. The most notable work comes from observations of the kinds of errors made in short-term memory for visually presented material. Conrad (1959) and Sperling (1960) were among the earliest writers to note that errors in immediate recall were acoustically similar to the presented material. However, Conrad (1964), building on the success of an earlier paper (Conrad, 1962) demonstrated this fairly conclusively by showing that a high correlation existed between errors for letters heard in a background of noise and errors in an immediate memory task for letters presented visually. These results were replicated by Wickelgren (1965a).

The importance of this work lay, in part, in the fact that it suggested that similarity between presented items might be an important variable in short-term memory, whereas some earlier writers (e.g. Broadbent, 1963) had suggested that short-term memory differed from long-term memory in this respect. The work noting the acoustic similarity of errors in short-term memory to the presented stimuli suggested that earlier studies were investigating the wrong dimension of similarity to demonstrate any effects (Murdock, 1967a). This point was proved by the study of Conrad & Hull (1964) who showed short-term memory performance to decline when acoustically similar material was used. Numerous studies have produced essentially similar results with varying methodologies (e.g. Baddeley, 1966a, b; Baddeley, 1968; Conrad, 1963; Conrad, Baddeley & Hull, 1966; Conrad, Freeman & Hull, 1965; Dale, 1964). Such work as this recommended a distinction between long-term and short-term memory, since the former would not appear to be influenced in any detrimental way by the acoustic similarity of the material to be learned (Baddeley, 1966 a,b; Baddeley & Dale, 1966).

A number of writers have questioned what these studies actually show. Wickelgren, for instance, has suggested that the acoustic confusion effect in short-term memory may be predicted from the linguistic structure of the different letters of the alphabet (Wickelgren, 1965b, 1966a,b, 1969). The concept of linguistic structure need not be detailed here but the analysis used by Wickelgren is at the micro level of phonemic distinctive features and he relates his work to the sophisticated analysis of perceptual confusions made by Miller & Nicely (1955) and the distinctive feature analysis of Halle (1964). Hintzman (1965,1967,1968), Levy & Murdock (1968), Murray (1965) have adopted a more critical stance towards the acoustic confusion effect in arguing that this is based on articulatory confusions made by subjects. There is, however, some question as to whether the assumptions that this view makes are, in fact, valid ones (Wickelgren, 1969) and there is no reason to assume that short-term memory might rely on one system exclusively.

Although the work of such people as Wickelgren and Hintzman raises a number of interesting empirical questions, this level of debate is trivial in comparison to the finding that material in short-term memory is in some kind of auditory form. Part of the importance of this work has already been discussed and thus requires no additional modification in the light of the above criticisms. Additionally, work on the acoustic confusion effects in short-term memory suggests strongly that a rehearsal mechanism is used to maintain material and the question of whether this relies on articulatory or acoustic features of the material would seem of minor import.

Perhaps the first question to be asked therefore concerning short-term memory is why subjects should appear to remember information in this acoustic fashion. This question is intrinsically interesting, but it is an especially important one since it would appear to relate to other phenomena of short-term memory. There are, furthermore,a number of levels at which this question may be answered and these both extend and stimulate debate.

First of all, short-term memory has been often demonstrated as appearing to represent the storage of relatively unstable information. If recall is delayed by an interpolated task before recall, performance suffers a severe decrement (Brown, 1958; Peterson & Peterson, 1959; Murdock, 1961). This observation may be interpreted in a number of ways, but it is doubtful whether any interpretation could ignore the disruption in rehearsal which an interpolated task necessitates (e.g. Peterson, 1966, p. 91). Thus, rehearsal may be seen as a method of preventing the loss of unstable information.

This point leads to two further questions - why is short-term memory material unstable, and why should rehearsal be suitable for handling unstable information?

The instability of short-term memory would seem best interpreted in a functionalist way by reference to the usefulness of "buffer stores". Feigenbaum (1967) has stated that no modern computer is built without a small amount of buffer storage (although this argument is reducible to a semantic debate). However, the reason for this widespread 'buffer' provision is that it is uneconomical to have central processes delayed by a slow or irregular input. This view gives some meaning to both short-term memory and to the sensory memory discussed earlier in this chapter, and is a view supported theoretically by Bower (1967). It is worth noting that such a buffer store has a limited capacity but may operate as readily on an event-dependent as a time-dependent basis. In other words, material could be lost from such a buffer store because later items entering it knocked out earlier ones, or items could be allowed to spontaneously decay after a fixed time.

Turning to the mechanism which sustains information, verbal rehearsal would seem an efficient method for this since language skill is so well developed in normal humans. Thus, the rates at which verbal rehearsal can take place are very rapid - possibly as high as 100-150 msec. per item (Landauer, 1962; Pierce & Karlin, 1957). The efficiency with which verbal rehearsal can take place is attested by the fact that it may be exceedingly difficult to prevent its taking place. Thus, Groningen (1966) reported that approximately 50% of subjects claimed to have rehearsed material for later recall during an interpolated task of counting backwards by threes (after Peterson & Peterson, 1959). If subjects persevere in rehearsing material even when the experimental conditions operate against their doing so, then it might be expected that material which subjects think they may be required to recall would have different effects from material which subjects feel they can ignore as has been shown to be the case (e.g. Brown, 1954; Selzer & Wickelgren, 1963).

The relationship between rehearsal and the buffer-store concept of limited short-term memory is one which need not necessarily have many implications for the nature of forgetting. Earlier, the phrase "mechanism which sustains information" was used and, although this implies that material will be forgotten if not rehearsed, this need not imply that memory is prone to decay rather than disruption. The concept of rehearsal is very much associated with early decay theorists who saw the function of rehearsal as serving to revive fading memory traces (Broadbent, 1957, 1958; Brown, 1958). However, an interference theory viewpoint which postulates that material is disrupted by other events occupying the same mechanisms might just as readily require a rehearsal mechanism to prevent interfering material from entering the memory mechanisms. Such a view would emphasise the attentional aspects of verbal performance (cf. Broadbent, 1958). Unfortunately, the subject of rehearsal has been largely ignored by interference theory (Mehanic, 1964; Murray, 1966a) and so little discussion is possible at this theoretical level.

In any case, the decay-versus-interference debate has lost much of its impetus since the demonstrations cited earlier (e.g. Baddeley, 1966a,b) that interference due to the nature of the material used does occur in short-term memory in a similar manner to that shown in long-term memory. Although apparent demonstrations of forgetting in short-term memory due to decay (Broadbent, 1958; Brown, 1958) provided some of the basis for early distinctions between short- and long-term memory, Melton's (1963) attack of this view and the later work on the nature of interference in short-term memory have left the present position somewhat in favour of interference but with just as much evidence for a distinction between at least two kinds of memory as the earlier decay theorists felt they had available. Thus, the work cited earlier, on the similarity of material in the memory task, shows that it is associated with poorer memory performance, as is the case with research in long-term memory (Postman, 1961). However, the similarity between materials required to produce this effect has different dimensions in short-term memory (where it is basically acoustic similarity which is important) from those in long-term memory, where semantic similarity is more important.

Unfortunately, the issue of decay-versus-interference is complicated by the difficulty of operationalising an adequate test to discriminate between the two processes, so that, while some effects of interference due to similarity between materials may be demonstrated in short-term memory, it is not clear by how much an interpolated task before recall interferes with what is remembered, rather than prevents rehearsal, thus allowing decay to take place. Further, as Brown (1958) has pointed out, the fact that subjects may recall words from an interpolated task rather than the memory list does not necessarily imply interference between the two sets of material - failure to discriminate between the "interfering" task and the original list may be a consequence of forgetting rather than its cause.

For these various reasons, an attempt to distinguish at a general level between the relative importance of decay and interference is probably not a particularly useful one to make. This is perhaps especially so in view of the number of additional parameters which are important in short-term memory. Thus, the decrement in recall produced by an interpolated task has been well documented, but it may be considerable, even when the task is simply one of saying "O" before recalling a string of presented digits (Conrad, 1958, 1960; Dallett, 1964). However, this is only true when the to-be-remembered sequence approximates to the length of the immediate memory span: the disrupting effect of such a single item before recall is negligible when a string of 4 digits is being remembered, but becomes appreciable when the sequence is as long as 6 or 8 items (Mortenson & Loess, 1964). There would seem no reason to suppose that the disruption caused by a large amount of interpolated activity on sub-span material necessarily involves the same processes as the disruption of at-span material by a small amount of interpolated activity.

An additional complication in such short-term memory research is that the disrupting effects of an interpolated task before recall may be reduced by leaving a blank interval of a few seconds before the interpolated task is presented. However, the results of such work are far from clear cut. Brown (1958) appears to have been the first to demonstrate an improvement in recall by delaying the onset of an interpolated task. A delay of nearly 5 seconds produced an improvement of approximately 43% over the no-delay condition. This was interpreted in terms of subjects using the rehearsal opportunity to translate the nonsense syllables used into meaningful words rather than demonstrating any increased strength in the memory trace. Somewhat similar results were obtained by Peterson & Peterson (1959) but only when subjects were required to rehearse aloud during the unfilled delay before the interpolated task. This finding is somewhat puzzling since, despite Peterson & Peterson's suggestion that subjects who were not instructed to rehearse during the unfilled delay may not have done so, the evidence available would suggest that the mere lack of instructions would have been ineffective. Thus, accounts of how subjects learn material (Bugelski, 1962; Clark, Lansford & Dallenbach, 1960; Groninger, 1966) indicate that it may be very difficult to prevent subjects from rehearsing. Hellyer (1962) found that vocalising to repeated presentations of trigrams led to a smaller decrement due to an interpolated task than the control condition of no repeated presentations, while Sanders (1961) found that silent rehearsal led to the material being less disrupted by an interpolated task. However, additionally, Sanders reports that vocal recall acted as a decrement (such vocal recall might be thought comparable to the vocal rehearsal of Hellyer). The contradictions between these studies are evident, but research in the general area of rehearsal and repetition effects is even more inconclusive, showing almost as many experiments demonstrating beneficial effects as decremental ones. Studies showing improved memory performance with repetition or rehearsal include Hebb (1961) and Melton (1963); experiments contradicting these include Dalrymple-Alford (1967); Heron (1962) and Woodhead (1966a), while a number of studies have shown interaction effects with other variables (McReynolds & Acker, 1959; Mackworth, 1965; Mayzner & Schoenberg, 1967; Postman & Adams, 1958; Tulving, 1966). To be sure, different methodologies have been used but, to date, there has been little attempt to reconcile these different findings, although it is apparent that such work is central to the very concept of short-term memory.

The contribution of Brown (1958) and Peterson & Peterson (1959) to short-term memory can be seen in the orientation of so much work in this field to the decay-versus-interference debate. Studies of the effects of presentation rate on memory performance are one further instance of this. As with most "technique areas" designed to investigate the problem, the results are inconclusive in terms of the debate and not entirely consistent from the standpoint of a performance criterion alone.

A minority of studies have reported results which were taken as consistent with the decay theory of short-term memory in that they reported superior recall for fast rates of presentation (e.g. Conrad, 1957, 1958; Conrad & Hill, 1958; Fraser, 1958; Posner, 1964). However, the majority of studies have reported superior performance with slower rates of presentation (e.g. Bergstrom, 1907; Guthrie, 1933; Mackworth, 1962c; Mayzner & Schoenberg, 1965; McReynolds & Acker, 1959; Pollack, 1953; Pollack, Johnson & Knaff, 1959). Naturally, methodological differences exist between these various studies and some attempt has been made recently at mapping the likely parameters associated with differences in performance with different presentation rates. Thus, Mackworth (1964,1965) has shown that fast rates of presentation may lead to superior performance with auditory presentation, especially when the material is recorded in a rhythmic manner. These studies are especially interesting in that they may imply that fast presentation rates are beneficial only when the material is presented in an easily rehearsable form.In any case, it should be clear that presentation rate is confounded with rehearsal opportunity in all the above studies so that some conception as to the nature and function of rehearsal would seem necessary to interpret work on presentation rate.

It would be possible to fill out many more pages with "laundry lists" of controversial/inconsistent findings in the field of short-term memory. However, this would serve little purpose beyond emphasising that it is possible to relate many of these areas back to the concept of the most striking characteristics of short-term memory and in doing so stress how little is really known.

Further, it is not the purpose of this present chapter to attempt to integrate confusing and apparently contradictory findings in the field of short-term memory. For one thing, the sheer quantity of research in this field precludes any meaningful attempt to cover the many different areas in which research has been pursued but, additionally, this introductory chapter must not be anticipatory of the research yet to be reported or of the developments which took place during the time span of this research.

For these reasons, some brief general points will now be made.

Short-term memory has been described as being characterised by the retention of unstable material in some kind of acoustic form. This definition excludes a number of interesting and possibly relevant studies on the short-term retention of non-verbal material (e.g. Gilson & Baddeley, 1969; Posner, 1967) but, provisionally at least, it seems wiser to focus attention on those studies involving verbal material where some of the clearest evidence for a distinction between short- and long-term memory has emerged. Also, it may be noted parenthetically that not all studies claiming to tap short-term memory have demonstrated the presence of an acoustic confusion effect (e.g. Adams, Thorsheim & McIntyre, 1969) or the absence of any effects of semantic similarity (e.g. Dale & Gregory, 1966), but such studies are exceptional.

As was suggested earlier in this chapter, short-term memory is a field which has generated a wide variety of methodologies. This fact presents considerable problems for the interpretation of discrepant empirical findings. Further research is needed in many areas, but research which promised to integrate apparently discrepant studies would seem the ideal. The most promising area in which this might be achieved would seem to be that of rehearsal since this is so central to the concept of short-term memory. The research to be reported in the following chapters attempts to address some of the more important implications of this notion.

Summary

The present chapter attempted to explain the rapid growth of short-term memory as a research area. Consideration was given to some of the more important developments which have taken place both within and outside the field and which may have provided the main stimuli for its development. Some of the more important research areas within the field were noted and it was suggested that the acoustic nature of short-term memory provided a means of distinguishing short-term memory from long-term memory and a possible research area for integrating work in this field.

CHAPTER II

Response preference in short-term memory

One of the main points to emerge from Chapter I was that, although a visual memory may manifest itself under certain circumstances, material retained in this way is rapidly translated into some kind of auditory message which is then sustained by rehearsal. Thus, one of the characteristics of short-term memory is that, even when material is presented visually, it should be retained and forgotten according to the acoustic rather than the visual properties of that material.

The most definitive single study in this field is that by Conrad (1964) who established beyond doubt that in an immediate memory task for letters of the alphabet, even when the material is presented visually, recall errors occur which are similar in nature to errors of auditory perception arising from listening to the same stimuli partially masked by noise. To demonstrate this, Conrad needed to build up two confusion matrices for letters of the alphabet. The first matrix for memory errors showed the frequency with which letters of the alphabet were confused with each other at recall. The second for listening errors showed the frequency with which letters of the alphabet were confused with each other in perception. The overall correlation between these two matrices was significant beyond the $p<.0001$ level. There are a number of points in this design which require discussion.

First of all, the memory error matrix was far less easy to construct than the listening error matrix. This is because all response sequences had to be rejected which did not contain only one error. Thus, since most of the data generated in the memory task would need to be ignored, Conrad restricted the memory error matrix to just 10 letters of the alphabet. Material for the memory task then consisted of 6 items drawn from these 10 letters and these were presented sequentially to subjects by means of a film projector at a rate of 80 per minute. At the end of each sequence, the projector was stopped to allow written recall. The final memory error matrix was of the form 10 x 10 items.

The listening error matrix, on the other hand, is an excellent one for all the letters of the alphabet (i.e. of the form 26 x 26 items) and is built up from 1440 presentations of each letter. The difference between the size of the original listening error matrix and that derived from it, for purposes of comparison with the memory error matrix, should not have introduced any undue error (Clarke, 1956). However, it would be risky to draw the conclusion that a full memory matrix for all letters of the alphabet would bear as much similarity to the full listening error matrix as the two smaller matrices do to each other. This is especially so since the 10 items in the memory error matrix contain relatively more acoustically similar items than does the full alphabet. (The memory error matrix, in fact, contained two sets of letters, BCPTV and FMNSX, which are of high acoustic similarity within each group, but of low similarity between each group). Further, although Conrad made some effort to safeguard against errors of perception in the memory task, ideal viewing conditions cannot prevent lapses of attention on the part of subjects and are no guarantee against errors of perception. While this note of caution does not detract from the very great contribution of Conrad to short-term memory, these are considerations to be borne in mind by those many who will, undoubtedly, use Conrad's listening error matrix as a predictor of input-output discrepancy in short-term retention.

Although it is not clear in which, or how many, ways memory errors might be expected to differ from listening errors, there should - nonetheless - be some differences, since man is something more than a noisy communication channel. Such idiosyncrasies as response preferences (e.g. Skinner, 1942) might be supposed to intervene to reduce the match between a memory error matrix and that derived from listening errors. The field of response preferences has been well described (e.g. Tune, 1964, who listed over a hundred references to this phenomenon) but the striking accounts of human bias are sometimes forgotten. Thus, Bakan (1960) noted that 80% of his subjects called "heads" at the first toss of a coin. However, it is possible that the vagaries of the human operator might be equally well demonstrated in his performance on a listening task as in memory. Examination of the full listening error matrix suggested that there ware certain irregularities in the listening confusions made. Thus, there are a number of listening errors in the matrix, which are not intuitively obvious as listening errors. For example, the stimulus letter "V" presented partially masked by noise produces the response "U" twice as often as any other response, whereas it would be expected that the most frequent confusion would be an acoustically similar letter like T or B. Similarly, R is given as a response to Y more than twice as often as I. There are a number of such irregularities and the existence of these recommended that the listening error matrix should be examined in more detail.

A. The listening error matrix

The full listening error matrix of Conrad (1964) is presented in Appendix A. As stated earlier, certain irregularities exist in this which are not fully compatible with the view that the listening errors reflect the most likely acoustic confusions. There are a number of listening errors not intuitively obvious as acoustic confusions, but additionally some letters are given as responses far more often than others and further, the probability with which response R_a will be given to the stimulus S_b does not appear to be a good determinant of the probability with which response R_b will be given to the stimulus S_a. The existence of such irregularities in a memory matrix would probably have attracted little attention, but their appearance in a listening error matrix is more disturbing. These "discrepancies" carry the implication that memory described by acoustic confusability alone might be too good to be true. In view of the earlier discussion of response preferences, the relationship between this and the irregularities in the listening error matrix seemed an obvious line to follow. In particular, the question of whether response preferences are associated with the intelligibility of the letters seemed an interesting one, since Conrad (1964) would presumably argue that the higher the response frequency of a given letter, then the less acoustically distinct is that letter from others in the alphabet. This follows from the assumption that letters difficult to detect in noise will be recognised as difficult and assumed to be present whenever noise is heard. Thus, high response frequency would be associated with low intelligibility. However, an alternative hypothesis is tenable and this states that response preference exists independently of the acoustic properties of the letter. Items so favoured with response preference will be given more often as responses (although presumably only to acoustically similar items) and will show a higher detection rate when heard in noise. To examine the relationship between response preference and intelligibility the following study was conducted:-

(1) The correlation between listening intelligibility and response preference.

The intelligibility of letters had to be estimated from Conrad's listening error matrix. It was calculated by subtracting the sum of the total number of incorrect responses (i.e. listening errors) from the total number of times that the letter was presented (i.e. 1440). This is only an estimate since we have no way of knowing whether subjects completely failed to respond differentially to certain letters. However, there would seem no reason for expecting complete failure to respond to have occurred more frequently for some letters than others and, in any case, it is doubtful whether these would have occurred very often in Conrad's task. Response preferences were estimated by summing the rows of incorrect responses (i.e. the listening errors) for each letter. This gave a measure of incorrect response frequency for each letter, henceforth described as response preference.

The relationship between these two measures was investigated by computing the Spearman rank correlation coefficient on the data. Details of the ranks of letters by response preference and by intelligibility are presented in Table I, on the next page. The correlation between response preference and intelligibility yielded a value of $r_s = -.03$ ($t = .5$, $df = 24$ NS). Thus, it might be concluded that there is no relationship between response preference for letters of the alphabet and the intelligibility of those letters heard in noise. However, visual inspection of the listening error matrix indicated that there might be opposing trends for acoustically similar letters and letters which are acoustically distinct. Two further analyses were conducted on the data for the most acoustically similar letters of the alphabet (PEVTBDGC) and for those most acoustically distinct (AHIJKOQRUWYZ).

TABLE I.

Rank Order	INTELLIGIBILITY Letters Ranked	Frequency Correct	RESPONSE PREFERENCE Letters Ranked	Frequency Incorrect
1	W	1093	P	2109
2	U	1032	E	1830
3	R	991	N	1601
4	Y	909	A	1509
5	I	832	T	1427
6	A	725	U	1389
7	H	707	S	1304
8	L	683	B	1208
9	X	641	M	950
10	S	638	O	883
11	O	636	F	864
12	N	628	D	800
13	Z	623	Q	798
14	Q	507	V	797
15	P	490	X	711
16	M	463	R	652
17	J	458	L	626
18	F	450	I	523
19	E	400	H	381
20	K	398	Y	356
21	V	348	Z	348
22	T	331	J	331
23	B	271	G	326
24	D	138	K	308
25	G	81	W	301
26	C	42	C	280

Estimated from Conrad (1964)

(2)

TABLE II(a) Correlation between intelligibility and response preference for acoustically similar letters.

Rank order :	1	2	3	4	5	6	7	8
Intelligibility :	P	E	V	T	B	D	G	C
Response Frequency :	P	E	T	B	D	V	G	C

This correlation yielded $r_s = .8572$ and this value is significant at the P<.02 level (two-tailed test).

TABLE II(b) Correlation between intelligibility and response preference for acoustically distinct letters.

Rank order :	1	2	3	4	5	6	7	8	9	10	11	12
Intelligibility :	W	U	R	Y	I	A	H	O	Z	Q	J	K
Response Preference	A	U	O	Q	R	I	H	Y	Z	J	K	W

This correlation yielded a value of $r_s = .2958$ and this value occurs by chance with P>.10 on a two-tailed test.

Clearly a relationship does exist between response preference and intelligibility but this is not a general one applying to all letters. Furthermore it does not seem to be a rule which is destroyed by a few exceptions (e.g. the only maverick is W occurring 1st in intelligibility but 25th in the response preference rank). This relationship exists mainly with acoustically similar items and this may be a simple one of increased but selective guessing producing a greater number of correct detections. (The ratio of correct to incorrect responses for this group is fairly stable around 1: 4.5 with V being the only obvious exception with a ratio of 1: 2.3 - that is a comparatively high intelligibility and a low response preference).

It would seem that although response preference for letters overall does not influence their detectability when heard in noise, some acoustically similar items may be relatively better detected than others because of response preference. However, whatever the effects of response preference, it is clear that such a phenomenon exists in the responses of subjects to letters heard in noise (see Table I). It is, therefore, of interest to know how reliable response preferences are across different kinds of task. An attempt was made to examine this by correlating the response preference shown in Conrad's listening task with that contained in the data of Underwood & Schultz (1960) on associative responses.

(3) Correlation between response preference in associative responses and that in the listening error matrix.

It should be noted that although the data from Underwood & Schultz is based on associative responses given to letters of the alphabet as stimuli, summing of the frequencies with which each letter appears as a response, yields the response preference for each individual letter of the alphabet.

No implication is made that the listening error matrix may contain associative responses to the stimuli. The independence of response preference on the source of its elicitation has been attested in the listening error matrix and is a subject for further empirical investigation here.

The rank orders of the response preferences derived from Underwood & Schultz (1960) and Conrad (1964) are presented in Table III :

TABLE III

Rank order of Letters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Response Pref'ce																										
(1) Conrad	P	E	N	A	T	U	S	B	M	O	F	D	Q	V	X	R	L	I	G	H	Y	Z	J	C	K	W
(2) Underwood & Schultz	O	A	T	I	E	U	M	R	N	S	P	D	L	B	Y	V	X	C	(K	Z)	F	H	W	Q	G	J

(K & Z) represent tied ranks

This data yielded $r_s = .674$ ($t = 4.9$, $df = 24$ $p < .0005$)

This finding is most interesting in suggesting that very similar response preferences exist in two very different situations. It would seem likely that response preference may be related to the relative frequencies with which letters appear in the English language. This hypothesis was tested by correlating the response preference in Conrad's listening error matrix with the frequency of appearance of letters in the written English language given by Underwood & Schultz (1960) in their "U" count.

(4) The correlation between the "U"count and the listening error matrix response preference.

The rank orders of letters in Underwood & Schultz's "U" count and the response preference for letters in Conrad's listening error matrix are given in Table IV (next page). The correlation between these two sets of data was .47 ($t = 1.84$, $df = 24$, $p < .05$). This finding would seem to indicate that the response preferences demonstrated by subjects' responses in listening to letters presented partially masked by noise are due to the relative frequency of appearance of letters in the English language.

Since it was suspected that the correlation would be even higher than .47, an additional comparison was made between the two sets of data of Underwood & Schultz - i.e. the "U" count and the associative response frequency response preferences. viz.:

(5) Correlation between the "U"count and associative response frequency response preferences.

The two sets of data are presented in Table V (next page).

TABLE IV

Rank order of letters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Response preference	P	E	N	A	T	U	S	B	M	O	F	D	Q	V	X	R	L	I	Q	H	Y	Z	J	C	K	W
"U" count	E	T	A	O	I	N	S	R	H	L	D	U	C	M	F	G	W	Y	P	B	V	K	X	J	Z	Q

$r_s = .47$ ($t = 1.84$, df 24, $\rho < .05$)

TABLE V

Rank order of letters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Assoc. Resp. Frequency	O	A	T	I	E	U	M	R	N	S	P	D	L	B	Y	V	X	C	K	Z	F	H	W	Q	G	J
"U" count	E	T	A	O	I	N	S	R	H	L	D	U	C	M	F	G	W	Y	P	B	V	K	X	J	Z	Q

$r_s = .773$ ($t = 49$, $df = 24$ $\rho < .001$)

Thus, the response preferences apparent in the associative response data of Underwood & Schultz would seem to be very strongly associated with the relative frequency of appearance of letters in the English language. The relatively higher correlation between these two measures than between listening response preferences and the "U" count would further suggest that although the cause of response preferences in the two tasks may be the same, response preference is not the sole determinant of response frequency in a listening task.

Having demonstrated the importance of the frequency of appearance of letters in the English language for the responses that subjects make to letters as stimuli, it seemed worthwhile to examine whether the frequency of appearance of letters in English might not be related to the intelligibility of letters heard in noise.

(6) <u>Correlation between the "U" count and listening intelligibility</u>.

The two sets of data are presented in Table VI, below, for comparison:-

TABLE VI

Rank order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
"U" count	E	T	A	O	I	N	S	R	H	L	D	U	C	M	F	G	W	Y	P	B	V	K	X	J	Z	Q
Listening intelligibility	W	U	R	Y	I	A	H	L	X	S	O	N	Z	Q	P	M	J	F	E	K	V	T	B	D	G	C

The rank orders of the two sets of letters correlate $r_s = .123$ ($t = .5$, df 24 NS.) Thus, it must be concluded that there is no reliable association between the frequency of appearance of letters in English and the intelligibility of letters heard in noise.

Conclusions to the listening error matrix studies

This section enquired into the possible existence of response preferences in Conrad's listening error matrix and the possible relationship between response preference and the intelligibility of letters heard in noise. The logical extension of Conrad's argument on acoustic confusions (i.e. that response preference would arise for the least intelligible letters) was not supported. Response preference in the listening task appeared to be independent of the acoustic properties of letters and apparently reflects the frequency of appearance of letters in the English language. Furthermore, while response preference is not associated with the intelligibility of all letters, it may increase the correct detection rate of letters heard in noise for those letters for which a number of acoustically similar alternatives exist. The intelligibility of letters in a listening task would also seem to be independent of the frequency of appearance of letters in English.

One additional finding was that the response preferences exhibited by subjects in the listening task are very similar to those exhibited by subjects in an associative response task. This suggests that response preference may be stable over different situations.

In order to extend these findings, it was thought worthwhile to draw up a visual confusion matrix and examine whether similar relationships might exist for seeing errors as were demonstrated for listening errors.

B. The visual error matrix

The value of a visual error matrix is threefold. (1) At present there exists no visual error matrix although Tinker (1928) has provided a few "most probable shape confusions". (2) It was intended to use the visual presentation of letters in a series of short-term-memory experiments and such a matrix would be useful in the classification of errors. (3) It would provide a useful comparison with Conrad's listening error matrix with respect to intelligibility and response preference. Furthermore, it would give some indication of whether some stimulus letters were associated with a higher level of omissions than others (it was assumed there were no differences between letters when calculating intelligibility from Conrad's listening error matrix in the earlier section of this chapter).

Twenty six slides were prepared by photographing each letter of the alphabet printed black on a white background, so that when the negative slide was projected in a darkened room the only illumination on the screen was provided by the letter itself. (This would yield differences in the field illuminated depending on the complexity of the letter, thus, it was hoped, possibly exaggerating the differences between the discriminability of different letters.)

The apparatus used was a Zeiss projector which was fitted with a solenoid to operate automatically a variable shutter. This allowed one letter to be exposed every 10 seconds, and as the slide change was automatic, E could devote his attention to the scoring of responses.

A pilot study indicated that the optimum exposure system for this experiment was a 200 m.s. flash at reduced intensity (by variable voltage regulator "Variac"). At approximately 100 volts through a

240 volt bulb the correct detection rate was 40%. This level seemed desirable in order to yield a large number of errors for the matrix and yet be well above the chance level (1:26).

Further, the data indicated that the number of omissions was very low and that omissions did not occur for some letters more than for others. Thus, only 15 omissions were made during the experiment and no letter was omitted more than once. This finding suggests that the calculation of intelligibilityffrom the listening error matrix was not likely to have been invalidated by high differential omissions to certain letters. Thirty subjects participated in this experiment, each being presented with 2 full sequences of the alphabet. The first sequence was randomized before the experiment and the order of letters noted. The second sequence was randomized during the experiment and the order of letters noted after the experiment. Ten practice slides of single digits were presented to subjects at gradually decreasing intensities until that required by the experiment was reached. Subjects were requested to recall aloud each letter of the experimental trials and a written record was made of these by E. Repetition of a subject's ambiguous response was requested by "Sorry?" and if this still held the possibility of a listening error by E, then the response was scored as being an ambiguous one. Omissions were scored as omissions.

The data resulting from this study was sufficient to allow examination of any response preferences existing and, since the error rate was only 60%, a ranking of the letters according to intelligibility. However, the individual cell entries for errors was too low to allow any discussion of the nature of the confusions. The problem of constructing an error matrix lies in the amount of data needed and it was clear that if a satisfactory matrix was to be arrived at, then group testing of subjects was necessary. This, in turn, would necessitate written recall and therefore an illuminated room for viewing so that new slides would need to have been prepared of black letters on white ground. This would have been carried out had the intended series of short-term-memory experiments (using letters of the alphabet and visual presentation) been continued.

However, the data generated in this small scalę study is adequate for the present purposes. A number of correlations were computed, using the rank orders of intelligibility and response preferences derived from the visual confusion matrix study.

(7) The correlation between intelligibility and response preference in visual perception.

The data is presented in Table VII (next page).

The discrepancy between the present results and those obtained from the analysis of the listening error matrix may, in part, be explained by the different error rate of the tasks. Conrad's listening task gave an error rate of 40% whereas the visual perception task gave an error rate of 60%. Higher error rates may allow response preference to manifest itself as a factor in intelligibility. The process envisaged is one which could arise if the overall error rate were such that the most intelligible items were perceived accurately on a majority of trials while a large number of other items were so rarely perceived that their probability of detection depended to a large extent on the guessing rate for those items. This hypothesis is testable by

TABLE VII

Rank order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Intelligibility	V	N	O	I	(L	U)	H	J	(P	T)	Y	A	Q	E	G	D	(F	S)	(X	M)	(W	K	C)	R	B	Z
Response preference	O	I	U	T	S	P	V	L	(J	N)	Q	R	W	Z	B	C	F	D	A	M	K	H	E	X	Y	G

(LU), (PT)....(JN) represent tied ranks.

These ranks yielded r_s, corrected for tied ranks, = .43

This value is significant at the 5% level ($t = 1.71$, $df = 24$, $p<.05$)

This result is at variance with that obtained in the listening error matrix analysis where the correlation between response preference and intelligibility was -.03.

examining the correlation between intelligibility and response preference for the most intelligible letters and for the least intelligible letters separately. For this purpose, the rank of letters by intelligibility was dichotomized. For the most intelligible letters the correlation between response preference and intelligibility was .41 whereas for the least intelligible items the correlation was -.31.

Thus, the tendency is in the reverse direction to that expected. Again, this breakdown by intelligibility goes against the similar breakdown by intelligibility for the listening error matrix where it was found that the intelligibility of acoustically similar letters alone was associated with response preference. The data from the visual error matrix can be seen as demonstrating a "U" shaped distribution between intelligibility and response preference where response preference for items in the middle range of intelligibility is less than that for those above and below average intelligibility.

In view of this finding, it would seem unlikely that the response preference in the visual error matrix would be similar to that found in the listening error matrix. This is examined below.

(8) The correlation between response preference in the listening error matrix and that in the visual error matrix.

The two ranks of letters are presented in Table VIII on the next page.

The correlation between the two ranks yielded $r_s = .22$ (NS). Thus, despite the finding that the response preference in the listening error matrix was very similar to that found in the associative responses to letters by Underwood & Schultz (1960), no similarity exists in the present data drawn from the visual confusion matrix. In view of this, it would seem unlikely that the same correlation would be found between response preference in the visual error matrix and the "U" count (Underwood & Schultz, 1960) as was demonstrated between response preferences in the listening error matrix and the "U" count. This is examined in section (9).

TABLE VIII

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Rank order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Response preference:																										
(a) visual error matrix	O	I	U	T	S	P	V	L	(J	N)	Q	R	W	Z	B	L	F	D	A	M	K	H	E	X	Y	G
(b) listening error matrix	P	E	N	A	T	U	S	B	M	O	F	D	Q	V	X	R	L	I	G	H	Y	Z	J	C	K	W

(J N) represent tied ranks.

(9) <u>The correlation between the "U" count and response preference in the visual confusion matrix.</u>

The ranks are shown in Table IX , below.

TABLE IX.

Rank order	Response preference in the visual error matrix	"U" count
1	O	E
2	I	T
3	U	A
4	T	O
5	S	I
6	P	N
7	V	S
8	L	R
9	(J	H
10	N)	L
11	Q	D
12	R	U
13	W	C
14	Z	M
15	B	F
16	C	G
17	F	W
18	D	Y
19	A	P
20	M	B
21	K	V
22	H	K
23	E	X
24	X	J
25	Y	Z
26	G	Q

(J N) represents tied ranks

The correlation between the two ranks was insignificant at .224. Thus, as expected, the response preference arising in the visual confusion matrix was not related to the frequency of appearance of letters in the English language and in this additional respect differed from the response preference in the listening error matrix. In view of the discrepancies between the present results and those in the earlier section on the listening error matrix, it seemed worthwhile to examine Tinker's (1928) data on visual confusions. The reason for so doing lay more in determining whether response preference was different across visual perception tasks rather than in investigating whether the rank orders of intelligibility of letters was similar in the two studies. This is because the present interest is in memory and the listening error matrix but, further, Tinker reviews a number of other studies on the intelligibility of letters and notes very wide discrepancies in the results. Correlations between the studies cited were never negative,but were at times as low as zero. Additionally, Tinker's data is derived from a study involving the presentation of digits and various other characters so that subjects were not responding to a set of letters alone. For these reasons, the following analyses will be reported briefly.

(10) Miscellaneous correlations.

Since, for reasons of brevity, the ranks of letters by intelligibility and response preference are not shown below, the reader is referred to the earlier correlational data and to appendix B, which contains the data from Tinker (1928).

Perhaps the first question to ask is whether the work of Tinker (1928) demonstrates the same response preference as shown in the visual error matrix. The correlation between the two sets of data was not significant at .128, thus indicating that there was no relationship between the two sets of data. Further, the correlation between the response preference in the listening error matrix and Tinker's data was similarly non-significant at .222. Neither Tinker's data nor the visual confusion matrix showed a response preference in any way reminiscent of the frequency with which letters appeared in the English language (.26 and .224 respectively). Turning to the intelligibility of letters, the correlations between the listening error matrix data, the visual error matrix and Tinker's data were all insignificant. Thus, the intelligibility of letters in Tinker's data correlated -.104 with the intelligibility of letters in the visual error matrix and .260 with Conrad's listening error matrix while the correlation between the visual error matrix and the listening error matrix was similarly low at .21.

Conclusions to the visual error matrix studies

It was hoped that the visual error matrix studies would extend the findings of the earlier section on the listening error matrix in showing that response preference was a stable phenomenon existing across very different situations. The data suggested that this is not the case and that response preference may not be stable across similar situations (i.e. visual perception). However, since Tinker's data was based on only 5 subjects, it may be that individual differences obscure any stability which may ordinarily exist across studies of visual perception. The implications of the results so far must be strictly interpreted in terms of their bearing on memory phenomenon so that, to complete the analysis of data, the analysis will return to the relationship between the memory error matrix and the listening error matrix (Conrad, 1964).

C. The memory error matrix

Although response preference may not be the stable phenomenon that the section on the listening error matrix suggested, the existence of a response preference in the listening error matrix raises a number of interesting questions concerning the correlation between the memory error matrix and the listening error matrix. The correlation between these two matrices has been attested (Conrad, 1964). However, in view of the fact that intelligibility of letters may be associated with response preference (see earlier sections on the listening error matrix and the visual error matrix), it would seem important to examine the memory error matrix in more detail.

The model of memory implied by Conrad (1964) is one which views forgetting as a function of the acoustic confusability of letters. Response preference has been demonstrated as a possibly complicating factor. It is the purpose of this section to examine the relevance of response preference to forgetting in short-term memory. The first prediction of Conrad (1964) to be tested is that the acoustic confusability of letters will determine their forgetting in memory. There should exist a high correlation between the intelligibility of letters heard in noise and memory for letters such that the most intelligible letters are the best remembered.

(11) <u>The correlation between intelligibility in listening and "intelligibility" in memory</u>.

To derive a measure of the most memorable letters from the memory error matrix of Conrad (1964) it was necessary to sum the total number of errors under each letter. This gave the total number of substitutions for each presented letter and thus should approximate to the frequency with which the letters were forgotten. This procedure is similar to that adopted for calculating the intelligibility of letters from Conrad's listening error matrix. Again, the assumption is made in this estimation that the number of omissions was similar for all letters. However, the visual error matrix study had suggested that the number of omissions was likely to be low and similar for all letters. Henceforth, this estimation of the total number of errors is described in the inverse order as one of "intelligibility" of letters in memory.

The two sets of relevant data are presented for comparison in Table X (next page).

TABLE X

Rank order of intelligibility	1	2	3	4	5	6	7	8	9	10
(a) in listening	X	T	C	F	N	P	B	M	S	V
(b) in memory	X	S	N	P	M	F	V	T	B	C

The correlation between these two ranks is insignificant at $r_s = -.08$. Thus, despite Conrad's demonstration that errors in short-term memory are similar to those obtained in a listening task, the intelligibility of letters in a listening task would not seem to be associated with the probability of a letter's retention in memory. It should be noted that the calculation of intelligibility in the listening task for these letters used in the memory task is derived from the full listening error matrix and not from the listening error sub-matrix. The reason for this should be apparent in that the sub-matrix, being derived from the full matrix, does not record incorrect letter responses outside those ten used in the memory task and so cannot yield a reliable estimate of intelligibility. In any case, the correlation between intelligibility on the listening error sub-matrix and intelligibility in the memory error matrix is even further removed from the expected than is the correct estimate given above. The ranked data using the incorrect measure of listening intelligibility from the listening error sub-matrix correlated r_s $-.68$ ($t = 2.6$, df 8, $p < .05$) with the rank of letters by intelligibility in memory.

To return to the lack of any correlation between intelligibility in memory and in listening reported earlier and to re-phrase the paradox: it would seem that forgetting is not determined by acoustic confusability but that partial forgetting is (in that acoustic confusability can explain the kinds of errors made).

This finding would seem somewhat puzzling. If acoustic confusability does not determine the distinctiveness of letters in memory, then what does? Response preference seemed a likely candidate for this position and this question is examined below.

(12) The correlation between "intelligibility" and response preference in memory.

Response preference was calculated in exactly the same way as was done for response preference in the listening error matrix - that is, by summing the rows of responses to obtain the total frequency with which the letters of the memory matrix were given as responses. The rank order of response preference for letters was then correlated with the rank order of "intelligibility" of letters in memory as shown in Table XI, below:

TABLE XI

Rank order in memory	1	2	3	4	5	6	7	8	9	10
(a) for intelligibility	X	T	C	F	N	P	B	M	S	V
(b) for response preference	N	T	F	M	P	V	B	C	X	S

The correlation between the two ranks yielded $r_s = .15$ which does not approach statistical significance. Thus, it is concluded that the "intelligibility" of letters in memory is not associated with response preference for letters in memory. An additional correlation was, therefore, computed to determine whether memory intelligibility might be more strongly associated with the listening error matrix response preference. This response preference was correlated with the frequency of appearance of letters in the English language and it was suspected that the intelligibility of letters in memory might be associated with their frequency of appearance in English.

(13) <u>The correlation between "intelligibility" in memory and listening error matrix response preference.</u>

The two ranks of letters are given in Table XII, below:

TABLE XII

Rank order	1	2	3	4	5	6	7	8	9	10
(a) memory "intelligibility"	X	T	C	F	N	P	B	M	S	V
(b) listening response preference	P	N	T	S	B	M	F	V	X	C

The correlation between the two ranks was insignificant at $r_s = -.17$. Thus, it may be concluded that the intelligibility of letters in memory is not associated with response preference for letters in a listening task. An additional correlation, to check directly on the possibility that the "intelligibility" of letters in memory might be associated with their frequency of appearance in English, was computed against the "U" count (Underwood & Schultz, 1960). The correlation between memory intelligibility and the "U" count was, as expected, insignificant at $r_s = .13$.

<u>Conclusion to the memory error matrix studies</u>

While it was not possible to relate the intelligibility of letters in memory to response preference or to the frequency of appearance of letters in the English language, one important result did emerge from the present section. This was that there is no correlation between the intelligibility of letters in memory and the intelligibility of letters in a listening task.

<u>Discussion</u>

The importance of Conrad's (1964) paper lies in its apparent demonstration that auditory recoding takes place of letters presented visually. It carries the strong implication that material is retained in short-term memory by rehearsal and that this rehearsal is an auditory process. Thus, memory is for what is rehearsed rather than that which is actually presented.

The findings of the present chapter are relevant to the model proposed by Conrad to explain auditory short-term memory. Briefly, this model views forgetting as a fall in the signal-to-noise ratio of material in memory. As the ever-present neural noise (Hebb, 1961) increases relative to the signal strength of the remembered message, the signal becomes increasingly blurred, such that the task of recall becomes comparable to that of detecting a signal in a noisy communication channel. This chapter questions how far the acoustic properties of letters sounds determine their "detection rate" or recall probability in memory. The main findings relevant to Conrad's model are :-

(1) Letters of the alphabet are not equiprobable. There exists a pronounced response preference for certain letters of the alphabet. Although this response preference is not stable across different studies, that manifested in the listening error matrix reported by Conrad is very similar to that obtained in the associative responses to letters of the alphabet reported by Underwood & Schultz (1960) and both of these are correlated with the frequency of appearance of letters in the English language.

(2) Acoustic confusions and response preference. While response preference does not greatly affect the apparent intelligibility of letters in a listening task, it may be important in determining the apparent intelligibility of letters of high acoustic similarity.

(3) Memory and the signal-to-noise ratio. The logical extension of Conrad's (1964) model is to predict that letters readily detected in a noisy communication channel (i.e. those most intelligible when presented partially masked by noise) will be associated with high recall in memory. The analysis reported in this chapter suggested that this was not the case and that the correlation between the intelligibility of letters in listening and those in memory was virtually zero (-.08).

Before considering the general implications of these findings, a few points surrounding these results may require further elucidation. First of all, although there exists a considerable body of research on the relationship between response preference, item frequency and item intelligibility, this was not alluded to in the discussion of the relationship between these made earlier. The main reason for ignoring such work at the time is that the bulk of such work has been oriented to word frequency and tachistoscopic recognition and has produced somewhat different results from those obtained here. Numerous studies have demonstrated that words which occur most often in ordinary use have lower thresholds for recognition than words of low frequency of use in English (e.g. Howes & Solomon, 1951; Solomon & Howes, 1951). The hypothesis that the ease of recognition of common words is due to the fact that common words occur more often as guesses than rare words was soon rejected (Solomon & Postman, 1952). In place of this simple model of the word frequency effect numerous alternative models have appeared (Broadbent, 1967; Morton, 1968; Savin, 1963). Of these, perhaps that based on signal detection theory, viewing the ease of recognition of high frequency words as being due to subjects requiring less stimulus evidence than for low frequency words, provides the best fit to the available data (Morton, 1968).

There are a number of discrepancies between the findings of research on word frequency and the findings of the present chapter on letter frequency. Of these, the main one is that neither the intelligibility of letters in the listening error matrix nor the intelligibility of letters in the visual error matrix was associated with the frequency of appearance of letters in English as measured by the "U" count (Underwood & Schultz, 1960).

Although this data clearly indicates that the variables governing the intelligibility of letters are different from those associated with the ease of recognition of words, and so research on the latter cannot aid much the discussion of the present results, interpretation of present work is further complicated by the difference between the response preferences shown in the listening error matrix and those shown in the visual error matrix. However, it would seem very likely that the acoustic properties of letters in the listening error matrix and the visual properties of letters in the visual error matrix are the main determinants of the intelligibility of letters in the two situations which generated these matrices.

The complicating factor is that response preference in the listening error matrix did not correlate with that in the visual error matrix. The former response preference appeared to be largely independent of the intelligibility of letters and associated with the frequency of appearance of letters in the English language, whereas the visual error matrix response preference was apparently only associated with the intelligibility of letters in the viewing situation. There would seem a basic contradiction between these two sets of results. One hypothesis which might have reconciled the conflicting results has already been examined and rejected. This stated that letters in the visual task may have been of broadly two kinds - either intelligible enough to be correctly detected on most trials or so difficult to see that their correct detection depended entirely on the guessing rate (i.e. response preference).

There are, however, two further considerations, each of which offers some partial explanation of the discrepancy between the two error matrices but which are difficult to reconcile with each other.

The first consideration is that the listening error matrix and the visual error matrix involved the presentation of letters in different modalities. This is important for the processes involved in the detection of the letters since in each case the stimulus was of poor quality and not readily intelligible. Because of this characteristic of the stimulus, the decision as to which letter was presented on each trial would not be made with certainty and it would follow from this that subjects would examine the evidence for their decision until the time of responding. Since sensory memory (see Chapter I) would not be involved for more than one second, in both the listening error matrix and the visual error matrix, uncertain responses would have arisen from examination of processed information in short-term memory rather than from examination of the actual stimulus trace. The importance of the difference between the auditory and the visual modality is apparent in that short-term memory for auditorally presented material will be much closer to the stimulus than will short-term memory for visually presented material. Thus, Broadbent's (1958) model of AUDITORY memory and attention sees the raw stimulus retained in storage until perception and then recirculated to the same store and maintained there by rehearsal. The raw stimulus in visual memory is not so recirculated but translated into an auditory message which is then retained by rehearsal in short-term memory (Sperling, 1963). For this reason, the subject's task of detecting the stimulus becomes more difficult after a slight delay when material is presented visually. This has certain implications for the response preference in the two tasks. With the listening task, the articulatory response is much closer to the stimulus and it is much more likely, therefore, that an articulatory response preference would manifest itself. (There is good reason for viewing the listening error matrix response preference as an articulatory response preference since it correlated with the response preference of an associative response task). With the visual task, on the other hand, any articulatory response preference must be matched against the blurred presented shape of the stimulus letter (as far as the subject can remember this) and it would seem less likely that the same articulatory response preference would dominate in the responses. This would explain the lack of correlation between the response preference of the two tasks.

In the visual error matrix, it would seem feasible that if letter frequency response preference did not dominate, responses would tend to be determined by the most intelligible letters. Faced with the problem of matching a blurred shape to a letter of the alphabet, subjects would select as the match those letters which had appeared most clearly in the past. Such an argument could claim support from studies demonstrating rigidity in problem solving where subjects tend to follow successful responses rather than change to any method which involves testing new hypotheses. (Bruner, Goodnow & Austin, 1956; Wason, 1960).

The second consideration which, taken alone, goes some way towards reconciling the conflicting results of the listening error matrix and the visual error matrix studies, involves a redefinition of response preference.

Response preference, as defined in the present chapter, refers to the frequency of use of incorrect responses. However, for the subject, an awareness of any response preferences will be based on the total number of responses both correct and incorrect. There is some justification for defining response preference in this way since it is perhaps naive to assume that correct and incorrect responses would be viewed independently by subjects; indeed, it would seem likely that subjects might avoid a correct response in a random sequence if they had already responded a number of times with that item. To view response preference in this way is to open a wide debate on memory factors involved in response preference (e.g. Baddeley, 1962), subjects' concepts of randomness (Chapanis, 1953) and so on, However, these broader implications are perhaps best avoided in the present context. Suffice it to say that when the total frequency of responses in the visual error matrix is compared with the total frequency of responses in the listening error matrix, the correlation becomes significant at $r_s = .34$ ($t = 2.3$, $df = 24$ $p < .05$).

Although this finding and the above argument do constitute a consideration in the interpretation of the present work on response preference, it has certain limitations in its application. Perhaps, most importantly, it ignores the insight which a breakdown by intelligibility and response preference provides, particularly with reference to the differences in the modality of presentation of material. However, additionally, viewing response preference in terms of correct and incorrect responses leads to an empirical impasse in that none of the correlations completed, using this measure, yielded any significant coefficient. For example, the total visual response frequency did not correlate with the frequency of appearance of letters in English ($r_s = .21$) and neither did the total listening response frequency ($r_s = .23$).

For these reasons, it seemed preferable to attempt to interpret the discrepancies between the visual error matrix and the listening error matrix in terms of the different modalities used for the presentation of the letters.

While the main points to emerge from the present chapter are no embarrassment for the decay theory of short-term memory, they do constitute a criticism of the model developed by Conrad (1964). From his results Conrad argues failings in Brown's informational decay model. It will be remembered that Brown (1958,1959) describes forgetting as a fall in the signal-to-noise ratio, the effect of which on the memory trace is similar to that of smudging a chalked letter on a blackboard. Some smudging will leave the letter still legible as it has "internal redundancy", but further smudging makes reading difficult. This analogy vividly describes a visual equivalent to Conrad's acoustic forgetting.

Conrad's criticism is that information theory would argue that when a letter is no longer legible due to excessive "smudging", then "all the letters in the stimulus set are equally likely to be reported" (Conrad, 1964, p. 79). It may be suggested that because Conrad rejects information theory, he considers acoustically similar items to be equi-probable. However, the existence of a response preference correlated with letter frequency, as demonstrated in this chapter, would seem to demand some notion of probability and differential information value of letters of the alphabet.

A secondary issue concerning Conrad's criticism of information theory is that acoustic confusability is unlikely to replace such useful concepts as "order information" and the related question of transitional probabilities between items (Crossman, 1961; Warrington, Kinsbourne & James, 1966).

A major problem exists for Conrad's model when he offers the notion of acoustic confusability to replace that of redundancy. The similarity of the concepts in one sense is easy to see and if redundancy could be equated simply with the acoustic properties of letters, then the more specific term must be favoured. However, Brown (1959) lists a number of factors influencing the effect of decay of the memory trace: (1) amount of initial redundancy of the trace, (2) the coding of the information in the trace, (3) the information available from other traces. The notion of redundancy here is more general than acoustic properties of letters and could explain why no correlation exists between listening intelligibility and memory intelligibility whereas Conrad's concept cannot do this. In Brown's terms it could be that letters of the alphabet are coded with different degrees of redundancy so that at time "t" some letters have the residual information still protected by redundancy so that, even though a fall in the signal-to-noise ratio has taken place, this is still compatible with correct recall. However, other letters will have deteriorated to a level not compatible with correct recall and only when this stage of decay has been reached are acoustic confusions likely. Conrad's model can be seen, therefore, as handling the problem of what is recalled when X% of information has been lost from the memory trace for a given letter.

While Brown's model has emerged unscathed so far, it has done so partly due to the generality of its concepts. It does not offer any prediction as to which letters will be more resistant to forgetting, and so the main problem of this chapter remains. Brown's (1959) trace system redundancy (which is concerned with item probability) could handle response preference but the solution is perhaps contained in the coding processes about which, unfortunately, Brown says very little.

One further apparent contribution in specificity by Conrad is that the change in the signal-to-noise ratio is due to an increase in neural noise. This argument is developed to explain the "tip-of-the-tongue" phenomenon. This is seen as being due to random fluctuations in neural noise. However, Conrad (1964, p. 82) concludes "In this paper, decay refers to a changed pattern of neural activity in a physical sense" (sic) and Conrad suggests that this is a more specific suggestion than Brown's, which allows decay to be represented by a change in the signal-to-noise ratio either as a result of increased noise or of decreased signal strength. The bewildering implication is that the memory trace is to be seen as stable and forgetting due to an increase in noise, but that forgetting is due to decay so that the increased neural noise does not represent interference from other material in memory. It is difficult to conceive of such a system which could handle rapid and yet time/event dependent forgetting in immediate memory, whereas a model allowing a decrease in the signal-to-noise ratio as a result of interference from other remembered material or as a consequence of a decaying signal would face relatively few problems.

One additional point is that while the "tip-of-the-tongue" phenomenon would seem to be associated with well learned material (i.e. long-term memory), Conrad does not imply this. It would seem, therefore, that the "tip-of-the-tongue" phenomenon is to be interpreted as reflecting a uni-dimensional search through memory among acoustically similar items for the target word. Such a view would run counter to what is known of the phenomenon in that it would rather seem to represent a multi-dimensional search among words of similar length, meaning and sound (Brown & McNeil, 1966).

The stimulus for this chapter lay in visual inspection of the listening error matrix which revealed certain apparently inexplicable irregularities in the "acoustic confusions" made to stimulus letters. Although response preference was demonstrated to exist as a variable confounding that of acoustic confusability, it is apparent that response preference does not begin to explain individual peculiarities in the listening error matrix. A full explanation would seem to require a somewhat detailed taxonomy including letter frequencies, language habits, response preferences, acoustic confusability and memory, each further subdivided into as many categories as wit allows. It is, thus, necessary to leave this chapter very much as it was begun, with the observation that there are irregularities in the errors made in a listening task. The existence of these suggests that the acoustic properties of letters may be the dominant variable in listening errors, but that they do not provide the only dimension relevant to the responses made. Such an observation suggests that the amount of variance in short-term memory, explained by acoustic confusability, may be much less than is commonly supposed.

<u>Summary</u>

The present chapter examined one possible source of error in Conrad's (1964) demonstration that memory errors are similar in nature to listening errors. Response preference was not found to be associated with the intelligibility of letters heard in noise, but response preference in this listening task was found to be reliably associated with the frequency of appearance of letters in the English language. A small visual error matrix was constructed to allow comparison of the intelligibility of letters and response preference for letters with Conrad's (1964) data. It was found that in this visual error matrix, response preference was associated with the intelligibility of letters, but that neither intelligibility nor response preference was associated with the frequency of appearance of letters in English. This discrepancy between the two error matrices was interpreted in terms of the different modalities of presentation used.

Conrad's (1964) memory error matrix was examined in the light of this work on response preference. The most important finding to emerge was that, while the errors made in memory are similar to the errors made in a listening task, the intelligibility of letters in that task did not correlate with the intelligibility of letters in memory. This finding contradicts one of the main implications of Conrad's (1964) work. The relevance of this finding was discussed for Conrad's model of short-term memory. It was concluded that the concept of acoustic confusability in short-term memory is most useful in predicting the errors made after some forgetting has taken place rather than in predicting which items will be forgotten.

CHAPTER III

The speculative part of science: some notes towards a general theory of short-term memory.

This chapter represents a precocious attempt to formulate a general theory of short-term memory following the research of Chapter II. The principal aim was essentially quite modest: an attempt to integrate what is a somewhat fragmented field with a view to uncovering an approach which could utilise published results. It was hoped additionally that, in attempting this task, it might be possible to describe, as in the fable, the "elephant" of short-term memory by reading accounts of its various "limbs" touched by the blind. In order to determine what common ground there might exist between experiments of differing theoretical orientations, discussion covers more accurately those variables in short-term memory which are given the status of major determinants of performance rather than any theoretical models arising from their manipulation.

One such variable which is given the status of a "major determinant" by its exponent is "acoustic confusability". This notion has already been examined in Chapter II and some predictions arising from its use as a limited model have been tested.

The present interest in acoustic confusability stems from Conrad's suggestion (Conrad, 1964) that it may well be the acoustic similarity between the items of a set which limits short-term memory performance and not the size of the set from which items are drawn. Perhaps an historical note may be made here:

(1) The first part of Conrad's statement stems logically from his finding that short-term memory is apparently acoustic in nature. This does not in itself indicate that acoustic similarity between items of a set limits short-term memory performance.

(2) The second part referring to size of set must be viewed in its historical context. The formal structure offered by information theory developed by communication engineers (perhaps "communication theory" may be more appropriate in denoting its origin - Cherry, 1957) appears very relevant to the study of memory. "Information" may be defined as a measure of the amount of uncertainty removed by the receipt of a message (Shannon & Weaver, 1949) and is directly related to the 'vocabulary' size (or size of the set) from which the message is drawn. If man is viewed as an information processor then he should have an upper limit ("channel capacity") beyond which errors occur. The limit of short-term memory may be then described in terms of the information content of the message. Given the definition of information above, information can be measured in "bits" as being $\log_2 N$ where N is the "ensemble" or vocabulary size from which the message is drawn. Although it is customary to use logarithms to the base 2, the theory does not necessarily demand this (Summerfield & Legge, 1960). Since Miller's (1956a) attack on this approach, however, it seems no longer quite as respectable to view the limits on short-term memory as being due to the amount of information it can handle. ("The information concept ran into one serious problem in the study of memory: it didn't work." - Norman, 1969a. "I do not believe, however, that this approach was, or is, a fruitful one" - Neisser, 1967). There are fewer today, therefore, who would argue that short-term memory is limited by the size of the set from which items are drawn. Thus, for many, Conrad's prediction that acoustic confusability will be a more important variable in determining performance than vocabulary size may be seen as a somewhat weak test of acoustic confusability.

Nevertheless, the test (carried out by Conrad & Hull, 1964) did demonstrate the superiority of acoustic confusability over vocabulary size as a predictor of short-term memory performance. It is worth mentioning that acoustic confusability can be quantified as readily as "information" : Conrad & Hull, in drawing sequences for the test material, used letters of the alphabet and so, by referring to the listening error matrix (Conrad, 1964, and discussed in Chapter II here), were able to calculate the probability with which each item of a sequence confused with the others. However, the present interest is not so much in the support for acoustic confusability that this experiment offers but in its evidence against the operation of vocabulary size as a variable : it was "irrelevant" to performance (Conrad & Hull, 1964) in that memory was only related to the acoustic confusability of the sets used and not to the size of the sets.

The important implication of this experiment is that acoustic confusability may have been confounded in studies of vocabulary size, and the acoustic confusability of sequences may have been inadvertently increased as "information" was increased. Conrad (1964) cites one case in which vocabulary size may have been confounded by acoustic confusability : The study of Conrad & Hille (1957) found..... " the larger the vocabulary the better the span.... it is notable that the 2-digit set used the digits 2 and 3, the 4-digit set, 2,3,4,5, and the 8-digit set, 2, 3, 4, 5, 6, 7, 8, 9. Moser & Fotheringham (1960) have shown that the two digits most likely to confuse acoustically are in fact 2 and 3. Additional digits are likely to make the set in entirety less acoustically confusing..." (Conrad, 1964).

(2) contd......

The suggestion is an important one and worth examining in some detail:-

(i) At least one study using the digits 2 and 3 as a high acoustically confusable set and 2 and 4 as a low acoustically confusable set found no difference in short-term memory performance (Woodhead, 1969). (Moser & Fotheringham report 2 and 4 as rarely confusing with each other).

(ii) One puzzling aspect of Conrad & Hille's paper is that two sets of results are reported with opposing trends. The first set mentioned by Conrad (1964) is for auditory presentation. The results for the different vocabulary sizes are:

8-digit vocabulary size: 32% correct
2-digit vocabulary size: 14% correct

The second set with visual presentation, (presumably simultaneous presentation of the material: "the numbers were read rather than heard") and unmentioned by Conrad (1964), produced the following results:-

8-digit vocabulary size: 40% correct
4-digit vocabulary size: 50% correct
2-digit vocabulary size: 70% correct

These results are most interesting and Conrad & Hille suggest the result may be due to the increased time available under visual presentation leading to grouping. Unfortunately, the paper suffers from its clientele (P. O. Telecommunications Journal) and little further detail is given.

Acoustic confusability would have some difficulty in handling both sets of results.

(3) The third point concerns the real vocabulary size. Fitts & Switzer (1962) used sub-sets of items in an examination of cognitive aspects of information processing. The task consisted in simply repeating back items. With "familiar" sub-sets (e.g. ABC) response time was fast, but "unfamiliar" sub-sets

(3) contd......

(e.g. EBP) produced response times comparable to those obtained when the whole alphabet was used. The study can be interpreted as meaning not that Hick's law has broken down (Hick, 1952) but that there is a disagreement between S and E as to the size of the set. Apparently with unfamiliar sub-sets subjects were unable to "forget" items outside the set used.

It seems possible that the vocabulary sizes used by Conrad & Hull (1964) may have been subjectively equivalent. Although subjects were provided with the vocabulary set at the top of their response sheets, this may not have reduced the information per item so much as avoided overt intrusions in recall.

(4) A further but minor point concerns the listening error matrices of Moser & Fotheringham. Their study is a complicated one and 16 stimulus items were presented ("selected variants" to normally spoken digits were included). Notably 3 was presented in three different ways: "three" ; "free" ; "tree" . This may have led to its relatively poor performance.

It is difficult to know by how much studies of vocabulary size have been confounded by the effects of acoustic confusability since details of the actual items used are not often given.

One study bearing directly on this question (Harrison, 1966) reached the conclusion that for the vocabularies used in the experiment at least "acoustic confusability and information content while confounded are exactly correlated." By this, Harrison meant that acoustic confusability appeared to increase with the size of the set. The vocabularies used were 4 (playing card suits); 8 (digits); 12 (male names). However, increasing vocabulary size will not necessarily lead to an increase in acoustic confusability and future studies should certainly attempt to separate these two factors. Clearly it would appear premature to reject information as a variable in short-term memory simply on the basis of available data from studies of acoustic confusability.

The unpopularity of an information theory view of short-term memory today (Neisser, 1967; Norman, 1969a) lies elsewhere - in the difference between different vocabulary sizes not being as great as a hypothesis of constant information would require (Miller, 1956a). This does not mean differences in performance are not in the direction expected by information theory. In fact, there is some well documented evidence to show that larger vocabulary sizes are associated with poorer short-term memory performance than smaller vocabulary sizes (notably letters being worse than digits - from Jacobs, 1887, up to Warrington, Kinsbourne & James, 1966). However, the issue is by no means clear and alternative interpretations to the "size of the set" argument are possible. Thus, Jacobs suggested greater experience of random digit sequences might be a factor along with vocabulary size and Warrington et al take transitional probabilities between items as the limiting variable. However, these factors are clearly interrelated and not exclusive to an informational viewpoint, as will be suggested later.

Perhaps at this stage the study by Cardozo & Leopold (1963) should be mentioned, as this has been cited (e.g. Welford, 1968) as demonstrating no difference in performance between digits and letters. This is true, but somewhat misleading when their procedure is examined as this involved presenting sequences of increasing lengths and plotting the information loss at each length. From their published graph, it would appear that at seven items there was virtually no loss for digits or letters. At 8 items slightly more letters than digits were forgotten while at 9 items digits were clearly superior. The explanation may be that while "span" was equivalent at 7 items 7 letters used up nearly all the available storage space but 7 digits was well within the short-term storage capacity of most subjects. Thus, by the time 9 letters were being presented the limit in storage capacity had been reached with digits (slight information loss at recall) but greatly exceeded with letters (fairly considerable information loss at recall).

A further point is that, were vocabulary size "irrelevant" (Conrad, 1964), then it would be expected that there would be as many studies demonstrating better performance with large vocabulary sizes as there are studies indicating better performance with small vocabulary sizes. However, such is not the case and it may be possible to reject those few that do on various grounds - e.g. Conrad & Hille (1957) for providing contradictory trends; Crannell & Parrish (1957) since the trend is insignificant; Woodhead (1966a) because the memory task was unusual. However, a number of criticisms apply to most studies of vocabulary size and instancing them (e.g. the use of subsets, the confounding of acoustic confusability) is hardly constructive and does not explain why the information hypothesis predicts too large a difference between vocabularies. One solution is offered by Crossman (1961) who suggests that the total information contained by a recalled sequence is not simply that given by the vocabulary size - which is simply the item information - order information is also retained. Total information is therefore expressed as $n \log N + \log n!$ where n = span (number of items recalled) and N = vocabulary size. With the addition of order information ($\log n!$) the total information retained by subjects for a variety of different vocabulary sizes was credibly close to a constant 25-35 bits.

Although Crossman's experiment avoided the problem of subsets (Fitts & Switzer, 1962) in using "exhaustive" categories - i.e. sets of naturally occurring different sizes (e.g. States of U.S.A., playing cards) a number of criticisms remain. The sets are unusual and states of the U.S.A. for example differ widely in their length and pronunciability. The most important criticism, however, is that order information is considered additional to item information. Brown (1959) is credited with drawing the important distinction between these two, but himself considered item information to contain order information. Thus, for Brown item information = $(n \log_2 N) - (\log_2 n!)$ while for Crossman item information = $n \log_2 N$. These different equations imply rather different memory storage systems.

If item information is to contain order information then only a limited number of models will be applicable. Perhaps only two types of system are possible - either an associative network so that order is necessarily coded by one item serving as the cue for the next (cf. Wickelgren, 1965); or a slot or bin system which is filled by chunks of items (cf. Miller, 1956a).

On the other hand, viewing item information and order information separately, as Crossman does, may allow a more flexible system. There can be fewer limitations because the relative independence of the two types of information is not specified (they could overlap). While it is difficult to describe such a system it may be classified as an "address" (cf. Baddeley, 1968) to locate the correct item and the correct position. If Baddeley's system corresponds to that of Crossman (it is not clear from either whether this is a valid assumption) then support is claimed for it over the associative model.

Whatever the final status of Crossman's equation, his contribution is considered important in suggesting that vocabulary size alone may be too crude a measure of the information transmitted by a message.

It is difficult to be sure what more subtle measuresof information are needed, but the "response preference" of Chapter II may be one. For the present discussion, the interest in response preference is that, under a number of conditions at least, subjects appear to treat "random" sequences as stochastic series. Although the sequences are only random in a finite sense (suitable for the experiment), subjects attempt to apply a statistical matching which is inappropriate. It may be remembered that this response preference can take such a form that it appears to result from a sound knowledge of the statistical rarity of letters of the alphabet in the English language. Thus in certain situations subjects behave as if they assume that the source of the messages they receive is geared to the frequency with which letters appear in English and respond accordingly.

The implication of this is that subjects have their own probability distributions of possible messages and if "information" is to be measured it must be done in terms of the "surprise" value of a message to a subject. Unfortunately, while subjective probability may be assessed, it remains an inference from performance made by a human experimenter who, strictly speaking, is part of the communication system he is attempting to describe. This kind of problem is intrinsic in the application of information theory to the human operator and has long been recognised as grounds for questioning the validity of such applications (Cherry,1955). However, if this results in merely a loss of elegance for information theory, there are more immediate problems to be recognised: subjective probability may appear in a relatively "stable" form as a response preference of the type described in Chapter II. However, it may also result from a cognitive appraisal of the experiment and will consequently be a greater source of annoyance. One situation in which information may be greatly reduced is where messages or items presented are not seen as equiprobable by the subject. In a memory task involving the sequential presentation of 10 items a subject is likely to consider items from an ensemble of 2 to be equiprobable since these items are repeated throughout the sequence. The information given by the sequence may be then considered as 10 x $\log_2 N$. However, an ensemble of 26 may not involve repeated items in the sequence of 10 and so the information may be considered as $\log_2 N + \log_2 N - 1 + \log_2 N - 2......$ $\log_2 N - 9$. This leads to some slight reduction in item information. The information reduction may be substantial, however, when ensembles are used which are little larger than the presented sequence if no repeated items occur. Thus, $\log_2 N$ of a digit sequence = 4.7 bits per item if each item is equiprobable after each presented item, but this drops to an average of less than 2.2 bits per item when the ensemble is exhausted by the sequence presented. Furthermore, subjective probability is clearly very subjective ground - a variety of strategies are possible for a subject and how much information is given by an unexpectedly repeated item will be far from easy to estimate.

If measurement of the short-term memory store in terms of information becomes so difficult, what alternative methods are available? Miller (1956a) concluded in a somewhat ambiguous paper that "chunks" of information provided the solution. Although the Millerian chunk is not clearly defined beyond being an organisation or grouping of the input sequence into units, two examples are instanced of this recoding. The first refers to the increasing organisation commonly found in the acquisition of skills - in learning the morse code, a man at first hears "dit" and "dah" as a separate chunk; soon he organises the dits and dahs into letters and eventually words and phrases. Thus, the chunks in skilled performance become larger and larger. The second example is an experiment by Sidney Smith who demonstrated that his immediate memory handled a constant number of chunks by successively learning and testing himself on binary digits coded as base 2, base 4, 6, 8, or 10 arithmetic. While these examples have a face validity and the chunk appears a valuable notion, it does suffer from lack of definition. The chunk, unfortunately, is essentially a subjective organisation of a sequence although it may be experimentally manipulated with some success (Cohen, 1963). Moreover, while Miller appears to reject information: "immediate memory is limited by the number of items" (Miller, 1956a, p. 92), at times he implies that information is a relevant factor, e.g....."by (chunking) ...we manage to break (or at least stretch) this informational bottleneck". (Miller, 1956a, p. 95).

However, the main question is whether chunking precludes the operation of information or acoustic confusability as variables in short-term memory. There may be common ground between these apparently mutually exclusive explanations of short-term memory.

There are a large number of studies which suggest that the relationship between items in a sequence is an important variable in short-term memory performance. More specifically as sequences become more predictable they are better recalled. Thus, as word sequences become less random and approximate more to the structure of normal English, the number of words recalled increases (Miller & Selfridge, 1950; Marks & Jack, 1952; Deese & Kaufman, 1957.) Similarly, subjects appear to be able to make use of redundancy in letter sequences as an aid to recall (Miller, 1958; Baddeley, Conrad & Hull, 1965). While these findings are consistent with an information theory hypothesis in that the predictability of the sequences must lead to a reduction in information, the result of redundancy may also be to increase "chunking" of the sequence as items organise themselves into familiar units (Miller, 1956b). Warrington, Kinsbourne & James (1966) found memory span for letter-digit sequences to be a function of the number of letter-digit transitions. Maximal performance was obtained with only one transition where this divided the list into roughly equal parts. This would no doubt encourage chunking of the sequence into two halves. Such a view may be consistent with Broadbent & Gregory (1964) who suggest that transitional probabilities are reflected in a response set which has to be shifted when a change of class occurs. However, for Broadbent & Gregory the problem presented by class change lies in the extra time taken to switch response sets whereas for Miller the change in class results in more chunks being required (to describe each separate class) than would be the case with more homogeneous material.

It seems likely that the "chunkability" of sequences will depend to a large extent on the nature of the material and acoustically similar material for example may be unsuitable for chunking and so be associated with poorer memory. At this stage, perhaps a distinction might be made between various types of chunks. The examples of chunking offered by Miller may be best described as "recoding" where rules are used to translate a number of items into a single unit (e.g. base 2 arithmetic into base 10). A second type would involve chunking of items by some kind of verbal mediation, e.g. "associative clustering" (Bousefield, 1953; Bousefield & Cohen, 1955). A third may be seen as involving "adopted chunks" of a sequence and is demonstrated by the recall of some items in the same order as presentation when there is no necessity to do so (McNulty, 1966; Rozov, 1964; Tulving & Patkau, 1962). Lastly there is the "physical grouping" of material such as digits in a temporal or rhythmic fashion (e.g. Adams, 1915).

Although these classifications are arbitrary, it does seem that because of the nature of short-term memory experiments the last use of chunking is the most applicable. This is due to the kind of materials used, the time intervals involved and the fact that the other types of coding imply some semantic mediation which is not usually found in short-term memory (Baddeley, 1966; Baddeley & Dale, 1966). Presumably, all kinds of chunking take time to occur. Thus, Klemmer (1964) found that span for binary digits was not much improved even after practice in recoding them into octal digits when exposure time was very short. However, physical grouping may be expected to occur more rapidly than the other types of chunking since it need not involve so much analysis of items in a sequence. Thorpe & Rowland (1965) found no real differences in the size of groups adopted by subjects with 1 item/second presentation rate compared to "unlimited" time and so grouping of digit sequences must be possible at a faster rate than 1 item/second.

The effect of time in allowing grouping is considered important since it may be used to explain the lack of effect of presentation rate for acoustically similar items on short-term memory (Conrad, Baddeley & Hull, 1966). Conrad et al argued that, assuming that short-term memory is of limited capacity (Broadbent, 1958; Murdock, 1965; Posner & Rossman, 1965), then it is tempting to think that acoustically similar items are poorly remembered because they overload the system in some way. Thus, increasing presentation rate should lead to much worse performance with acoustically similar items than acoustically dissimilar ones. The reason why Conrad et al found no such effect may have been that acoustically similar items cannot benefit from chunking - they exist in a homogeneous form along the only dimension on which short-term memory chunking is likely to be made - that of rhythm. This view would hypothesise that at rates fast enough tc prevent the grouping of acoustically different material, no differences would exist between acoustically similar and acoustically different material.

This argument receives some slight support from an experiment on memory span for vowel and digit sequences. This experiment is not reported in any great detail since the aims of the study were to investigate grouping strategies by subjects. It relied heavily on introspective reports at the end of the session and, unfortunately, less than a quarter of the subjects were able to produce any information on how they handled the different sequences. The hypothesis was that digits and vowels should differ in their "groupability". Digit sequences should be readily groupable because of the familiarity which subjects have in handling random digit sequences in the form of various identification codes. However, for the lack of these reasons, vowel sequences should not be so readily groupable. If grouping takes time to operate, then the difference between the memory span for vowels and the memory span for digits should increase with time as the digits benefit from becoming grouped.

EXPERIMENT (A)

30 slides of 10 items were prepared. Set (1) consisted of 15 slides of 10 digits with each digit appearing once only. Set (2) consisted of 15 slides of 10 vowels with each vowel appearing twice. Both sets of slides were relatively unstructured in their sequences. 22 subjects were presented with one entire set under one of the following conditions: (1) $\frac{1}{2}$ second exposure time; (2) 1 second exposure time; or (3) 2 second exposure time. Subjects were instructed to await the auditory cue of the slide projector carrier moving (approximately 2 seconds after exposure) before giving verbal recall. The percentage correctly recalled (correct item in the correct position) for the

different conditions was :

Exposure Time	½ second	1 second	2 seconds
Vowels	41	45	55
Digits	46	54	70
Percentage improvement of digits over vowels	12%	20%	36%

t tests computed between the conditions all yield values $p < .01$.

The above data is uncorrected for guessing. The classical guessing correction (Guilford, 1936) assumes incorrect responses to be random. Bricker & Chapanis (1953) and the work reported in Chapter II show that this assumption is not justified, but do not aid in formulating a suitable guessing correction.

From the table a differential effect of exposure is apparent since the differences between vowels and digits widen as the exposure time is increased. This would seem to argue against an interpretation solely in terms of different reading rates for the two materials.

However, a difference in reading rate may be expected and to check on the magnitude of this, 10 subjects were asked to read through the entire set of test material. They were asked to read through the printed list silently and quickly but not to miss out any items. The overall difference in time for the two lists indicated that vowels took 13% longer than digits to read. This difference is very similar to that found at the shortest exposure of ½ a second where 12% more digits were recalled than vowels, and therefore reading rate would not seem able to account for the much greater differences at the longer exposures.

The interpretation of the increasing difference between the two materials with increasing exposure time is made in terms of grouping.

As stated earlier, subjects were not helpful in providing information about their methods of remembering the material. However, when subjects were able to volunteer introspective reports on their grouping strategies, these occurred for the most part with digits at the longest (2 seconds) exposure when grouping in 2s or 3s was noted. It seems feasible that at $\frac{1}{2}$ second exposure virtually no grouping has taken place (digits and vowels yield similar spans) but by 2 seconds subjects have been able to group the digit sequences at least far more than vowels. Possibly, grouping effects may not show much beyond 2 seconds since at this exposure subjects were returning a creditable span of 7 digits, and there may be little room for improvement beyond this.

Support for the above argument is provided by Mackworth (1963) who demonstrated similarly increasing differences with increasing exposure time between digits and letters. However, her study is somewhat difficult to interpret since "message lengths employed were those which gave optimal recall for that subject at each duration" (Mackworth, 1963, p.79.) Nevertheless it is interesting to note that Mackworth's data show an asymptote for digits at 2 seconds whereas letters were still improving with duration up to an exposure time of 6 seconds.

DISCUSSION AND SUMMARY

This chapter examined the usefulness of information theory, acoustic confusability and chunking as explanations of short-term memory performance. It was argued that chunking may occur in a number of different ways but that rhythmic grouping is its most probable manifestation in short-term memory. This type of chunking may reflect characteristics of the material such as its informational content and acoustical confusability. Thus, acoustically similar items may be difficult to group rhythmically because they are acoustically homogeneous. Similarly, it was suggested in Experiment (A) that grouping may have failed to take place with the vowel sequences because of their unfamiliarity (leading to low transitional probabilities between items and articulation difficulties).

The suggestion that grouping leads to better recall is of minor interest since it is in line with Miller's (1956a) predictions of the effects of chunking, and has been observed by previous researchers, e.g. Oberly (1928); Conrad & Hille (1957); Severin & Rigby (1963); Thorpe & Rowland (1965); Wickelgren (1964). However, since grouping appeared to demonstrate itself only after a certain time (2 seconds with the digit sequences) it would seem feasible that it arises through rehearsal, that is, the rhythmic grouping is built into the sequence as it is repeated by the subject. This view of rehearsal as representing a reorganisation of the presented material to produce an improvement in recall is perhaps in contradiction to that of Brown (1958) who stated "...the effect of (such) rehearsal may be to counteract decay of the trace rather than to strengthen it much". It should be noted, however, that Brown (1958) found a 40% improvement in recall in an immediate memory task when the onset of an interfering task before recall was delayed by an extra 4 seconds. He concluded that this effect was due "not to rehearsal as such, but to finding interpretations of the letters, in the manner spontaneously reported by some subjects (e.g. "National Debt" for ND). While it is possible that Brown's subjects did group items during the rehearsal period leading to improved recall, the conclusion that interpretations of the presented material took place is not without interest. Indeed, it would appear to be an important point if the improvement mentioned earlier were due entirely to such "efforts after meaning" (Bartlett, 1932).

Everyday experience of attempting to learn material such as unfamiliar sequences of letters or nonsense syllables, (e.g. brand names, identification codes, etc.) which are to be neglected for some time before future recall, would suggest that these "interpretations" are common. However, this kind of learning by implication must involve coding material into long-term memory. It may be, therefore, that short-term retention tasks could involve in part long-term memory. That is, some <u>items</u> may be stored in long-term memory because they have been suitably coded.

It should be added at this stage that the interpretations noted by Brown are assumed to be just as much a product of the rehearsal process as is the "grouping" noted earlier. This assumption accords so well with commonsense and introspective self-analysis confirmed by helpful acquaintances that the paucity of references to rehearsal in the literature is surprising. In a sense, it is understandable that short-term memory as a field has avoided the study of rehearsal since the avowed intent of much research has been to examine the effects of presenting rehearsal on short-term retention (e.g. Peterson & Peterson, 1959), but even so subjects may still have opportunity to indulge in this activity even if only during the presentation of the to-be-remembered material. Studies of long-term memory by contrast would seem to be basically concerned with the products of rehearsal and its neglect is, therefore, less readily dismissed. It would be tedious to enumerate the published works in which rehearsal might be considered to demand mention, but is nonetheless ignored, but two recent volumes offer good examples of the subject's neglect. Kausler (1966) edits over 500 pages of "Readings in verbal learning" without reference to rehearsal, and Adams (1967), perhaps famed for his studies of "natural language mediation" (cf. "interpretation" or "effort after meaning"), sees fit to exclude rehearsal from the index of "Human Memory".

For the moment, no precedence will be set by discussing and experimenting the characteristics of rehearsal since there are perhaps more immediate problems raised by the possible effects of rehearsal. These are that putative short-term memory tasks involve both short-term and long-term memory. The evidence for this will be considered in the following chapter.

CHAPTER IV

REHEARSAL AND RECALL

The preceding chapter terminated with the suggestion that rehearsal may not be a mere repetition to offset decay but a more dynamic process of reorganization of the presented material. While grouping effects may be the most likely manifestation of this rehearsal in short-term retention experiments, it was suggested that material may be rehearsed into long-term memory. Thus, studies purporting to examine short-term memory may, in fact, tap some material from a less labile store as well. Just how much information could be contained within long-term memory would seem to depend on the opportunity for rehearsal offered by the experimental design. In many short-term memory studies the use of immediate recall or the introduction of a filled delay after presentation would suggest that the main opportunity for rehearsal occurs during presentation itself. Thus, with the sequential presentation of material, it would be expected that early presented items would be cumulatively rehearsed more than later ones (Welch & Burnett, 1924). Thus, items having the highest probability of being rehearsed into long-term memory would be those at the beginning of the presented sequence.

There are a number of experiments which support such a prediction, but of these perhaps that of Glanzer & Cunitz (1966) is the most notable in reaching the conclusion embodied in the title of their paper, "Two Storage Mechanisms in Free Recall". Basically, the above paper involves a reinterpretation of the bow-shaped serial position curve characteristic of immediate free recall. The authors suggest that this U-shape curve in fact reflects two curves, each representing output from a separate storage mechanism. Material recalled from the beginning of the list is primarily output from long-term storage and that recalled from the end is primarily output from short-term storage.

This conclusion is based on the finding that the two ends of the serial position curve are differentially affected by the independent variables of presentation rate and delay before recall. Glanzer & Cunitz show that a slower presentation rate improves recall on items at the beginning of the presented sequence but has no effect on late ones, while delay disrupts the last few items, leaving early presented ones unimpaired. These findings, they argue, are in line with the predicted effects of presentation rate and delay on long and short-term memory.

Before considering this interpretation in detail, it should be said that the findings of Glanzer & Cunitz are considered reliable since similar effects of presentation rate were noted inter alia by Murdock (1962) and similar effects of delay by Postman & Phillips (1965). However, both experiments were interpreted in terms of proactive and retroactive inhibition. Murdock offers this as "one possible explanation" for the general shape of the serial position curve of free recall, but does so in an ad hoc manner without mentioning any others or making specific reference to the effects of presentation rate. Postman & Phillips, on the other hand, put forward a specific experimental hypothesis: "since PI (proactive inhibition) increases as a function of time, the terminal part of the list, which is subject to maximal interference from prior items, should gradually lose its advantage" (as the interval between the end of presentation and recall is lengthened).

The authors deserve credit for their attempt at very detailed interpretation of the results in terms of the effects of proactive and retroactive inhibition, but the argument at times becomes tenuous. Thus, the amount of retroactive inhibition falling on early items should increase with the length of the lists, but Postman & Phillips report less forgetting of early items with the longer lists used. In an attempt to remain loyal to their thesis, the authors declare this may have been due to "the progressive selection of items for strength." This statement can presumably mean either that ~~proactive~~ retroactive inhibition can wantonly reverse its normal effect of producing forgetting, or that in the face of heavy ~~proactive~~ retroactive inhibition, subjects perversely do well.

The main hypothesis that "proactive inhibition increases as a function of time" would seem readily testable by using either a slower presentation rate, or by increasing the length of the presented list. However, in neither case are the terminal items affected (Murdock, 1962; Postman & Phillips, 1965).

The test offered by Postman & Phillips was to introduce a delay between the end of presentation and the beginning of recall. Interestingly, this delay was filled by requiring the subjects to count backwards by threes, the task used by Peterson & Peterson (1959) "to minimize rehearsal" in their study of short-term retention. Since the effects of this delay were mainly on the terminal items in the list, this would suggest that earlier items have a stability more characteristic of long-term memory. Thus, the effects of presentation rate, list length and delay are felt to support the interpretation offered by Glanzer & Cunitz, rather than that of Postman & Phillips.

Having discussed the findings of Glanzer & Cunitz, on which is based their model of "two storage mechanisms in free recall", it is now necessary to examine the model itself. The idea that immediate free recall involves readout from two distinct stores is not unique, having been suggested apparently independently by Waugh & Norman (1965). Despite the similarities between the two models, that of Glanzer & Cunitz will be presented here since their evidence is more compelling, and the notions of Waugh & Norman (e.g. primary and secondary memory) may create confusion at this stage of the analysis.

Glanzer & Cunitz do not suggest any reason for viewing the serial position curve of free recall as they do, but state what is a proposal as their hypothesis. Their findings do not in themselves constitute an explanation of the shape of this curve although such an explanation would seem a necessary preliminary to their hypothesis. In order not to prejudice their case, the statements which would seem relevant to the question of why the serial position curve should be bow-shaped under the two store model are quoted below.

"From the initial decline in the serial position curve....it may be...asserted that the capacity of long-term storage is limited. The more items there are already in, the less likely that there will be place for a new item. By definition, the short-term storage mechanism is limited not with respect to capacity but with respect to the amount of time it can hold an item."

These statements represent the only attempt to explain the shape of the curve and may not be considered particularly enlightening. Perhaps, the main criticism is that the serial position curve has apparently determined the definitions of long and short term memory given. Thus, to state that the capacity of long-term memory is limited, and then by the following sentence imply that the limit lies in the number of items it can contain, is clearly nonsense.

What the initial decline in the serial position curve would seem to suggest is that the processing rate for long-term memory is limited. In other words, as argued at the beginning of this chapter, learning through rehearsal takes time to accomplish and, with the limited time available for this offered by the experiment, the items most likely to be learned are the early ones in the list.

Rather more problems are posed by the shape of the curve for later items which are assumed to reside in short-term memory. In a sense, the decay theory offered by Glanzer & Cunitz would fit the data if it were assumed that items inevitably decay in short-term memory with time. If this were true, then the serial position curve of short-term memory would be one of recency, that is, the later an item in the sequence, the higher its probability of recall. However, such a view would be only tenable if subjects could or did not revive items by repeating them to themselves and, in this case, "pure" delay (without the interpolated task) should rapidly reduce the "recency" effect. Glanzer & Cunitz mention in passing that after such a pure delay of thirty seconds "the serial position (showed) a clear end peak".

One possible explanation of the curve for late items could be that it reflects not one subject's recall but the composite of a number of subjects, some of whom may recall only the last item, some the last two, and so on. This would avoid the problem of explaining the inevitable decay above but, even so, it would suggest a very limited short-term memory. The possibility exists, of course, that the short-term memory involved in the recall of the terminal items in a list is somewhat different from that described by most short-term memory experiments because such studies have not recognised the possibility of a substantial proportion of items entering long-term memory.

Whatever the interpretations of the results of Glanzer & Cunitz, their findings are felt to indicate the existence of two different stores in immediate free recall. The present argument has been that the stability associated with early presented items is due to rehearsal during presentation so that the terminal items in a list are relatively unprocessed and labile. This being the case, it would seem likely that, given more time, subjects should be able to encode the last few items into long-term memory in addition to the early presented items, which are already there. Thus, while pure delay has no effect on the shape of the curve for immediate free recall (Glanzer & Cunitz, 1966) it may produce a change in the stability of the last few items.

This possibility was investigated in a relatively crude pilot study, using fifteen item sequences of common English words recorded at the 1.5 second rate. Six subjects took part in this study, each one being required to complete eight trials. These trials corresponded to the conditions of immediate free recall, or a varied pure delay (0,2,5,10,15,20,30 seconds) before a filled delay (20 seconds of counting backwards by threes). To simplify the task of E and S, the presentation was made in either an ascending or descending order of delay times. The results indicated that by 30 seconds of pure delay the terminal items had become sufficiently stable as to be virtually unaffected by the normally disrupting task of counting backwards.

The effects of the filled delay immediately after presentation were similar to thosd reported by Postman & Phillips and Glanzer & Cunitz in being almost entirely confined to terminal items. This pilot study appeared to support the idea of a pure delay after presentation, allowing the rehearsal of items from short-term into long-term memory.

For the main experiment a number of modifications were made to the design. It was decided that apart from the function of rehearsal after presentation, two other questions could be examined. The first was whether the short-term memory component in free recall could be increased by encouraging the subject to consider the last five items separately from the earlier ones. This could be achieved in auditory presentation by introducing a pause before the presentation of the last five items. In terms of subject strategy, it would be advantageous for the subject to learn the first ten during presentation but then handle the last five within short-term memory for immediate unloading. The advantages of this would be in a reduction in the effort of learning so many items, while leaving open the "easy come, easy go" short-term memory for the maximum amount of material (five items should be well within the immediate memory span - Miller, 1956).

Under these conditions it might be expected that subjects should be able to recall all of the last five with immediate free recall. Further, when a filled delay is to be interpolated, a pure delay after presentation should encourage coding of these last five items into long-term memory; earlier items can be neglected (since the filled delay does not disrupt them), but late items cannot. Therefore, the strategy of rehearsing the last five during this delay could lead to a gain of possibly five items with little danger of any loss.

The second question is one conveniently answerable by the design suggested of introducing a pause before presentation of the last five items. This question is, by how much is the serial position curve of free recall influenced by the recall order? It is known that the recall of items in short-term memory can interfere with the retention of items yet to be recalled (e.g. Brown, 1954). Therefore, the recall of terminal items first in immediate free recall might disrupt any unstable early items which might exist.

Thus, the observation that early presented items are not affected by filled delay might be a fallacious one, based on the inadequate baseline of immediate free recall which introduces a filled (by terminal items) delay before the recall of early ones. One method of testing this hypothesis is to use a partial recall procedure, so that when recall is requested, subjects are only required to recall early, or middle or late presented items. Such groups of items oan be suggested during auditory presentation by pauses between the groups.

On the basis of the effects of pure and filled delay suggested by the pilot study, it was decided to employ a three factor (2 x 2 x 3) analysis of variance design for repeated measures on the third factor. The first two factors would be presence or absence of pure delay and presence or absence of filled delay. The third factor would be the repeated measures on the three groups of five words composing the presented sequence.

The pilot study suggested that after twenty seconds of pure delay the terminal items of the presented sequence had become sufficiently stable to largely withstand the effects of twenty seconds of filled delay. For the main experiment a pure delay of twenty seconds and a filled delay of ten seconds were selected since it was felt that these time intervals would demonstrate the stabilising effects of pure delay.

EXPERIMENT I

METHOD

Materials Since Murdock (1962), Postman & Phillips (1964) and Glanzer & Cunitz (1966) all used sequences of common English words, these were the test materials selected for the main experiment. Three hundred words were taken from the AA lists in the Thorndike-Lorge word count (1944). No restrictions were imposed on their selection and so they comprised nouns, adjectives, adverbs, and verbs of varying lengths. These words were organised into twenty sequences, each of fifteen items. In this task, the words composing each sequence were not placed together randomly since any approximation to English grammatical structure (for example, adjective-noun, verb-adverb sequences) was felt undesirable and to be avoided. Further, an attempt was made to match each sequence and each group of five words within each sequence for word length. When the list was completed, two judges aided E in an examination of the list for any sequences which seemed particularly difficult or easy to remember and these were reorganised.

The decision to use sequence lengths of fifteen items stemmed partly from the arbitrary selection of such lengths in the pilot study which proved an acceptable task for subjects and yet provided sufficient errors for a well bowed serial position curve. Also, Murdock (1962) and Glanzer & Cunitz (1966) used this length of sequence, thus providing results which could be compared with those obtained in the present study.

The total list of 20 x 15 item sequences was recorded by a female colleague who read the words into a Ferrograph tape recorder to the beat of a metronome. The recording session took place in a soundproof room, so that the combination of room acoustics, quality of equipment and voice characteristics of the reader provided a tape of high quality. The metronome beat, occurring every 1.5 seconds, was the signal to read each word aloud except after the fifth and tenth words, when a pause of one metronome beat was introduced. This metronome beat was audible on the completed tape. All words were read in a monotone voice except the fifth and tenth words, which were stressed suitably to indicate the end of a group of five items. Thus, the presentation rate was one word every 1.5 seconds within each of the three groups with a three second pause between each group.

This rate of 1.5 seconds per item is not especially fast. Postman & Phillips used a 1-second rate, Murdock used both a 1- and 2-second rate per item, and Glanzer & Cunitz used 3-seconds per item as their fastest speed.

When this list of the twenty sequences had been recorded, four further lists were prepared by randomising for each list separately the order of occurrence of the sequences within the list and by re-arranging within each sequence the order of occurrence of the three groups of five words. This large amount of material was prepared to obviate the tedious and often inconvenient necessity of playing back the tape when short lists are used, in order that all experimental groups receive equal exposure to each of the sequences.

<u>Procedure</u> Subjects were thirty-six unpaid undergraduate volunteers at the University of Leicester, who were tested individually in a soundproof room. Subjects were assigned randomly to one of four experimental conditions:

- A1 B1 = twenty seconds pure delay and recall request
- A2 B1 = immediate recall request
- A1 B2 = twenty seconds pure delay followed by ten seconds of filled delay (counting backwards by threes from a given 3-digit number) followed by recall request
- A2 B2 = filled delay of ten seconds followed by recall request.

The experiment was described as a memory task, and the appropriate experimental condition explained to the subject.

Partial recall procedure The partial recall procedure is superficially a complicated one. Subjects were informed that they would receive three practice trials to facilitate understanding of the task. On each trial, they were to hear a different sequence of fifteen common English words which had been tape recorded in three groups of five.

Following the experimental condition, they would receive a request for either "first" , or "middle" or "last" which denoted recall of either the first five, the middle five or the last five items respectively. These were to be written down on the paper provided in any order that they chose. In this recall, subjects were encouraged to guess at items but informed that credit would be given only to items recalled from the correct group. In the first three practice trials they would be given an opportunity to recall each of the three groups and with this knowledge they could therefore more readily predict the group to be requested. However, the test trials were completely randomised (an improbably long randomisation was given as an example) so that guessing would be useless. Further, it was suggested that guessing of the group required was known to impair performance and, in any case, would foul the experimental results. This latter entreaty to consider all groups as equiprobable on each trial was received with much sympathy and assurance of compliance.

Following the three practice trials, subjects received the three test trials with recall being demanded on all three groups. The order of recall request for these groups over the three trials was randomised. Thus, each subject provided data on the first, middle and last five items.

While a large minority of subjects became aware at the termination of the experiment that they could have predicted for which group recall would be requested on the last trial, the instructions to desist from guessing were apparently efficacious in all but two cases. All thirty-six subjects included in the analysis failed to admit guessing when strongly invited to do so, and their honesty is attested by the scores on test trial one, (76), being similar to those on test trial three, (74), ($t = 0.51$ NS). The success of the instructions was attributed largely to the implication that subjects would receive far more trials than they did, so that subjects did not have time to suspect any pattern in the groups requested for recall.

Throughout the experiment, timing was strictly observed with the aid of a stopwatch. Subjects were allowed up to ninety seconds for recall and, between trials, were diverted by conversation for approximately two minutes.

<u>RESULTS</u> In scoring a word correct it was only considered as such if it was the same as a word in the group requested or a homonym of one or a recognisable misspelling of either. Repetition of words was not counted. The main number of words correct for each group was computed and these expressed as percentages which are described in Figure I. Figure I represents the percentage recalled for each group for the four experimental conditions.

Visual inspection of Figure I suggests that the hypothesis that pure delay would stabilise terminal items is pyrrhically supported, if at all. Clearly, any slight gain in the stability of the last group is more than offset by the decrement in performance on the earlier two groups. This is borne out by the statistical results shown in Table I.

FIGURE I
EXPERIMENT I

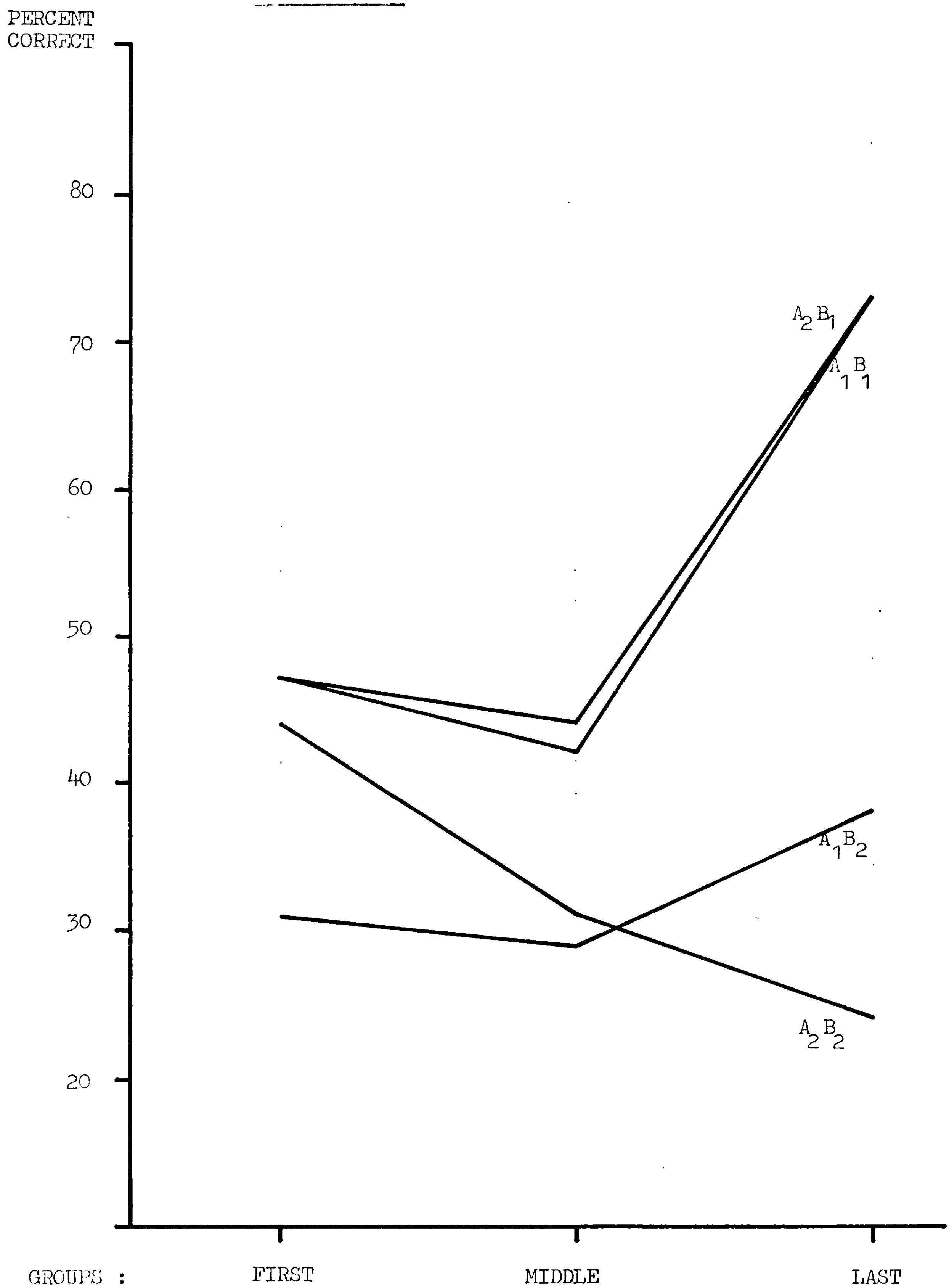


Table I

Source		df	F ratio	Significance Level
A (pure delay)		1,32	0.12	NS
B (filled delay)		1,32	13.34	.01
AB (interaction)		1,32	0	NS
C (groups)		2,64	3.17	.10
AC (interaction)		2,64	0.32	NS
BC (interaction)		2,64	5.7	.01
ABC (interaction)		2,64	0.66	NS
Difference between:				
(1) B1 - B2 under A1	See Fig. I	1,32	7.10	.01
(2) B1 - B2 under A2		1,32	6.2	.05
(3) A1 - A2 under B1		1,32	0.01	NS
(4) A1 - A2 under B2		1,32	0.01	NS
(See also Appendix D)				

The main effect of pure delay is not significant nor is the interaction of pure delay with filled delay. If anything, the opportunity to rehearse items before the filled delay is a disadvantage (the difference under A1 between B1 and B2 is slightly greater than that under A2 between B1 and B2). The main effect of filled delay is, as expected, significant in leading to poorer performance, especially in the last group (BC interaction significant). Somewhat surprisingly, the difference between the three groups approaches significance only at the 10% level.

The advantages predicted from the partial report procedure were twofold. On the one hand, improvement was expected, on the first and middle groups, particularly in immediate recall, since they would no longer be delayed by the immediate recall of the terminal items. On the other hand, the number of terminal items held in short-term memory for immediate recall was expected to increase as subjects were encouraged to handle the last five items as a separate group.

The results of the present experiment can be compared with those from the more conventional procedure of full free recall: viz.

Table II showing percentage correct

Experimenter	Presentation Rate	First 5 words	Middle 5 words	Last 5 words
Murdock*	1 second/item	47	42	77
Cumberbatch	1.5 secs/item	47	44	73
Glanzer & Cunitz*	3 secs/item	48	34	46

*derived from published graphs

The results of Postman & Phillips are not comparable, since the authors used sequence lengths of 10, 20 and 30 items.

The close similarity between the results of the present experiment and those of Murdock would seem to indicate that neither of the expected advantages of partial recall took place. The poorer performance on terminal items in the Glanzer & Cunitz study does not, of course, contradict this statement, but this difference is, nonetheless, interesting and will be discussed more fully below.

Discussion

The results of Experiment I were disappointing in the failure to confirm any of the hypotheses put forward.

The finding that pure delay did not serve to stabilise terminal items was somewhat surprising in view of the results of the pilot study. The reason for this lack of effect is far from clear, but since the partial recall procedure was the main difference between the present experiment and the pilot study, peculiarities of this procedure may provide the solution. There are, moreover, a number of possible reasons why the partial recall technique may be suspected.

Since subjects were unaware of which group they would be required to recall, they were encouraged to pay equal attention to all three groups. It seems unlikely that the demands of full free recall would be such as to lead to subjects dividing their attention equally over the presented sequence. In fact, the rationale of this experiment was in part that items are not equally rehearsed over the sequence. While this may have been a factor in the obtained results, it is unsupported by the data of immediate recall, which suggests that performance on the three groups is similar to that obtained with full free recall.

A second possibility exists that the partial recall technique demands memory for order as well as item information, and that order information, as it were, decays more rapidly with time. Thus, with increasing delay, more and more order information is lost so that subjects find it increasingly difficult to comply with the request to recall items from particular positions (first five, middle five or last five).

Unfortunately, an analysis of the number of intrusions from other groups within the sequence, given under the different conditions, would not cast any light on this as an explanation since it cannot be assumed that guessing strategies will not change over the conditions of delay. Subjects may either not record items when they are unsure of the group to which they belong or alternatively, when few items from the correct group are remembered, subjects may fill out their answer sheets with more risky guesses from the other groups. Thus, to examine this possibility at all, a separate experiment, using full recall but with a request for the recall of items in the correct groups would be necessary.

In comparing the immediate recall scores on the three groups with the results presented by Murdock and Glanzer & Cunitz, it was noted that the latter study obtained much lower recall on the last five items. It is not immediately obvious why the Glanzer & Cunitz study should differ in this respect from Experiment I, reported above, and that of Murdock. However, the latter two studies used auditory presentation while Glanzer & Cunitz used (sequential) visual presentation. It would be comparatively easier to ignore incoming stimuli with visual presentation (by relaxation of visual acuity) and rehearse instead earlier items. A proportion of subjects adopting this strategy would lead to a proportionate reduction in the end peak of the curve. At the same time, some benefit would be expected in memory for earlier items. However, all three studies show similar recall levels for the first group.

In view of the slower presentation rate used in the Glanzer & Cunitz study (3 seconds per item against 1.5 seconds (Cumberbatch) and 1 second (Murdock)), this is especially puzzling since the slower rate should have led to better performance on early items. The explanation of this would appear to be that Glanzer & Cunitz used army recruits as subjects while both of the other studies employed university students. The difference in intelligence between the two samples in conjunction with the differences in presentation modality could well account for the difference in performance.

The results of a number of studies wouldssuggest that high I Q subjects have a faster processing rate than low I Q subjects. The serial position curve of short-term memory and serial learning show better retention of early items with the more intelligent subjects (Lepley, 1934; Barnett, Ellis & Pryer, 1960; Postman & Jensen, 1963).

Thus, while a university student sample would be expected to retain more early items than an army recruit sample, if the latter are allowed to rehearse early items at the expense of later ones, then the difference in performance may no longer exist at this point. The effect on later items will be marked, however; the high I Q sample will show high recall on terminal items while the low I Q sample will show much lower retention.

If the results of Glanzer & Cunitz are considered in this way, then it would be expected that the effects of filled delay would be less disrupting than in the present study. This is because in Experiment I, subjects would have rehearsed earlier items less (due to the faster rate and auditory presentation) and handled more of the terminal items in short-term memory. The relevant data are shown in Table III

	Glanzer & Cunitz % correct, using slow visual presentation			Cumberbatch Expt. I % correct, using fast auditory presentation		
Condition	First 5	Middle 5	Last 5	First 5	Middle 5	Last 5
Immediate Recall	48	34	46	47	44	73
10 secs filled delay	50	32	39	31	29	33

These results are in line with the above prediction in showing much greater overall loss due to the effects of filled delay in Experiment I, and in particular a more marked reduction in the recall of the terminal group. However, the improvement due to slower presentation in the visual modality may be exaggerated by the use of partial recall in Experiment I, since, as argued earlier, delay may have produced forgetting of order information, thus depressing recall for item information.

Conclusion The failure to demonstrate any beneficial effects of rehearsal opportunity given before a filled delay was felt to have resulted from the partial recall procedure used in the experiment. It was suggested that partial recall demands both item information and order information and that the latter may decay more rapidly than item information, thus leading to a failure in recall of the items from the appropriate group.

By the same token, the apparent failure to demonstrate beneficial effects of partial over full free recall may have resulted from the necessity of retaining order information, thus reducing the channel capacity available for the items themselves. However, no firm conclusions can be drawn from comparisons with the results of two similar experiments, since the information reported affords comparison on only the gross details of experimental design, procedure and analysis.

In order to investigate further the problems raised by this research, a number of experiments were designed. The first of these, again to investigate the effects of pure delay on the serial position curve of free recall, is reported below.

Experiment II

The purpose of this experiment was to examine the effects of pure delay on the serial position curve by interpolating a filled delay before recall. The lack of any effect of pure delay in Experiment I may have been due to the partial recall procedure adopted. This experiment, therefore, follows the pilot study to Experiment I in demanding full free recall.

Procedure The method of Experiment I (vide) was broadly retained in using the same 2 x 2 x 3 factorial design with pure delay x filled delay x groups as the variables. The same material was used as in the earlier study, namely common English words. The experiment differed only in demanding of subjects that they should attempt to recall as many items as possible in any order from the presented sequence.

Forty-four subjects took part. As in the previous experiment, these were student volunteers who were tested individually. The experiment was described to them as a memory task and the materials used were explained. Mention was made of the recording method (i.e. that they would hear three groups of five words). The scoring method was detailed (i.e. that homonyms and misspellings would be classified as correct), since a number of subjects requested information on this point in Experiment I. The experimental condition to which subjects had been allotted was then described and any questions of procedure answered.

Subjects were to await the recall signal (O.K.) before writing down on the paper provided as many words as possible in any order. They then received two practice trials (Ss were informed they were such) followed by three test trials. As in Experiment I, the recall interval was ninety seconds and in the inter-trial interval two minutes, during which the subject was diverted by conversation.

Results Figure II represents the obtained data in graphical form, showing the percentage correct over the three groups for purposes of comparison with Figure I of the previous experiment. It is apparent from these data that the opportunity for rehearsal before a filled delay did serve an advantageous function. This is demonstrated by the statistical analysis summarised in Table IV, below:

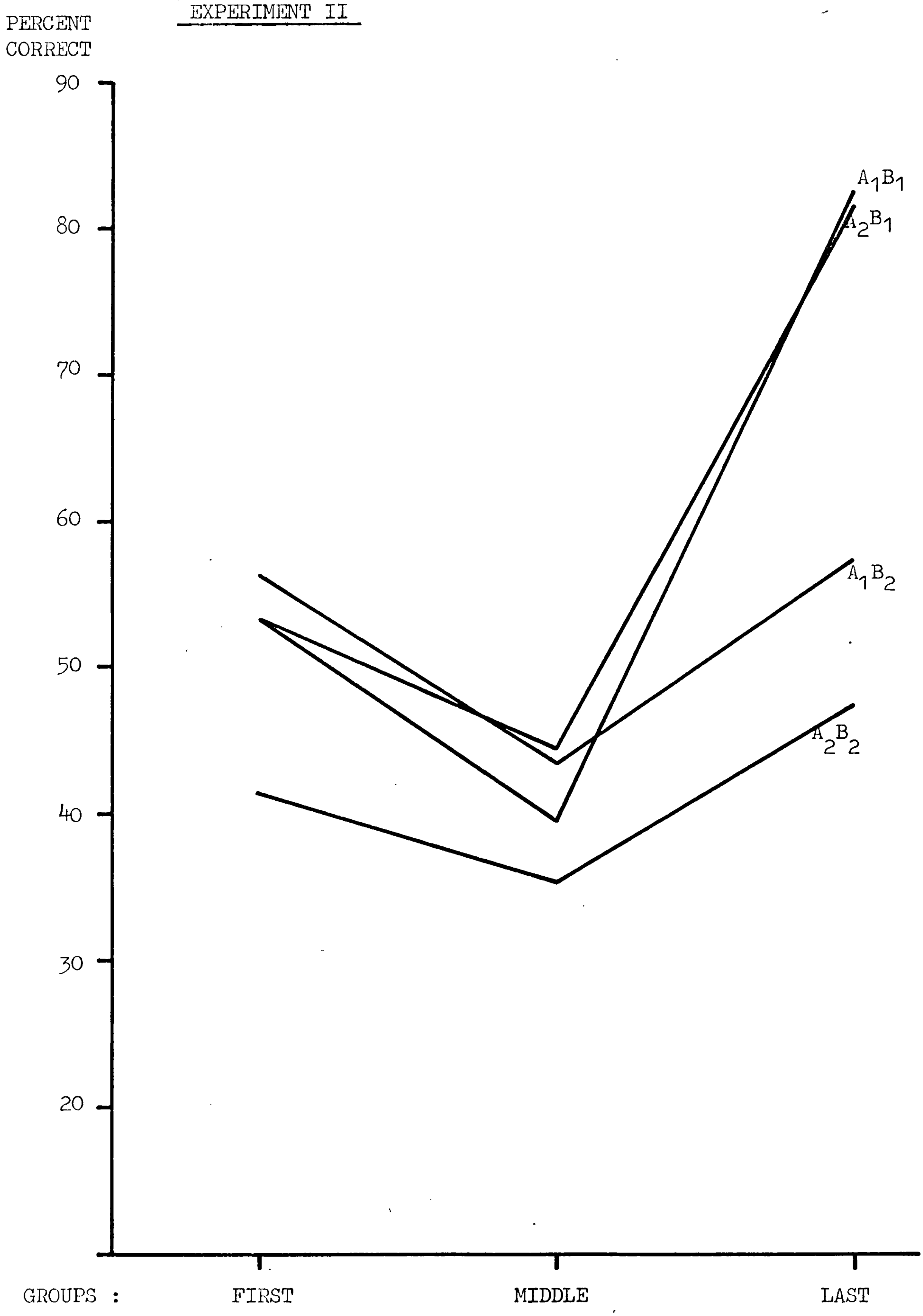
Table IV

Source of variation	d f	F ratio	Significance level
A = pure delay	1,40	3.68	.10
B = filled delay	1,40	21.72	.01
AB interaction	1,40	28.21	.01
C = groups	2,80	34	.01
AC interaction	2,80	0.41	N S
BC interaction	2,80	10.5	.01
ABC interaction	2,80	.45	N S
differences between			
B1 - B2 under A1*	1,40	2.579	N S
B1 - B2 under A2*	1,40	24.8	.01
A1 - A2 under B1	1,40	.11	N S
A1 - A2 under B2	1,40	9.278	.01

*see Figure II for legend and graphical representation see also Appendix D.

Thus, while the improvement in performance with pure delay (A) reaches significance at the 10% level, the interaction with filled delay is significant beyond the 1% level. As figure II shows, the effect of pure delay before the filled delay (condition A1 B2) is to make all three groups more resistant to the disrupting effects of filled delay. In fact, there is no significant difference between B1 and B2 under A1, and the difference between A1 - A2 at

FIGURE II
EXPERIMENT II



B2 is significant at the 1% level, although the graph does show some loss of terminal items with filled delay. There is a clear difference in performance over the three groups (C effect significant) and the filled delay disrupts items, mainly from the last group (BC interaction significant).

Discussion These results supported the predictions made following the pilot study. An opportunity to rehearse items before a filled delay very much reduces the disrupting effects that such a delay has. The discrepancy in the findings between Experiments I and II would suggest that subjects in partial recall cannot benefit from rehearsal as the subjects in full recall do. Why this should be has not been resolved but, at least, the main hypothesis of pure delay has been supported.

Inspection of the graphical representations of the results shows, however, that there is a substantial loss of terminal group items, despite the rehearsal opportunity. The difference in recall scores significant at the 1% level (see Appendix D) may suggest that the rate at which subjects can transfer material from short- to long-term memory is slower than that suggested by the pilot study. However, in view of the forgetting of initial group items with filled delay, some revision of the two-storage mechanisms model would seem in order.

The model proposed by Glanzer & Cunitz suggests that early items are contained in a stable long-term memory while terminal items are contained in a labile short-term memory store. Forgetting of early items would seem to imply either failure to retrieve from this stable storage or an unstable long-term memory store, or perhaps loss of unstable short-term memory items amongst other items contained in stable long-term memory.

In view of the characteristics normally attributed to short-term memory, the last would seem an unlikely proposition. The first would be, in the present context, an unhelpful explanation. Therefore, the results may suggest an incremental long-term memory. This was implied in the discussion of Experiment I when it was used to suggest the reason for the more stable memory for early items in the Glanzer & Cunitz study. Since the view is not an unlikely one, it was introduced without comment, although it would seem to differ from the concept of long-term memory as used by Glanzer & Cunitz.

There exist some unexpected differences between Experiments I and II, apart from the different effects of pure delay. Perhaps the most interesting of these is the overall lower recall score in Experiment I. This can be seen from the results shown in Figures I and II. The differences in per cent recalled for the immediate recall condition are presented below (Table V) for comparison:

Table V

	First	Middle	Last
Experiment I : Partial recall	47	44	73
Experiment II: Full recall	53	44	81

Data on partial recall suggest that the usual effect is one of improvement in the per cent recalled (e.g. Brown, 1954; Anderson, 1960; Sperling, 1960). It would appear that this effect is not demonstrated with free recall. The benefit of the partial recall technique for ordered recall is perhaps obvious under the present model in that the unstable terminal items are no longer obliged to wait until early items have been unloaded. Thus, with free recall, the advantage offered by partial recall is lost. Moreover, the procedure may actually produce a decrement if, as suggested, the necessity of remembering the groups takes up channel capacity which, under full recall, can be devoted to the items themselves.

The other effect which is unexpected and puzzling is the different effect of filled delay alone in the two experiments in leading to some change in the distribution of recall scores over groups. For the moment, no explanation is available and so discussion of these results must await further research.

The full free recall procedure, used in the present experiment, allowed analysis of the recall order given by subjects under the different conditions. It is assumed that with immediate recall, subjects must unload late items first if they are not to be disrupted by the filled delay provided by the recall of other items.

However, two possibilities suggest themselves for the pure delay condition. Subjects may simply repeat the last few items so that they are just as unstable at recall as they were immediately after presentation. Alternatively, subjects may rehearse the terminal items into long-term memory, (perhaps unnecessary since no filled delay is to be imposed), so that recall of the last items first is no longer a necessity for their recall. For the analysis, the presented and recalled sequences were dichotomised into early and late (this involved dropping one item in all sequences containing an odd number of words). A χ^2 test was then computed on this data and the results of this are presented in Table VI (on next page).

TABLE VI

Immediate recall			Pure delay			Pure + Filled delay			Filled delay		
Recall:	Early	Late	Recall:	Early	Late	Recall:	Early	Late	Recall:	Early	Late
EARLY PRESENTED	27	90	EARLY PRESENTED	33	79	EARLY PRESENTED	49	63	EARLY PRESENTED	43	37
LATE	109	46	LATE	94	49	LATE	62	48	LATE	42	49
$\chi = 63 > 10.38$ sig. > .001			$\chi = 37 > 10.38$ sig. > .001			$\chi = 3.5 > 2.71$ sig. > .10			$\chi = 1.43$ N S		

The table illustrates the pronounced tendency in immediate free recall for subjects to recall last items first and then go back to recall the early presented items. The tendency is only slightly diminished by pure delay, but the effect of filled delay is such as to lead to the recall order being much closer to that of the presented sequence. It seems possible that the effects on stability of pure delay in the absence of any filled delay interpolated before recall may be very slight since no marked change in recall order is apparent.

Conclusion The present experiment, using a full free recall procedure, demonstrated the beneficial effects of pure delay on items in increasing their resistance to the disrupting effects of filled delay. The advantage of pure delay - an opportunity for rehearsal - was not restricted to the terminal ("short-term memory") items, thus suggesting that the model of Glanzer & Cunitz requires some revision. Because early presented (i.e. long-term memory) items also benefited from pure delay, the two-storage mechanisms model may be retained only if the strength of material in long-term memory is considered to be incremental.

In the many questions raised by this research, the effects of partial recall is considered to be among the most important and intriguing. This is so particularly in the context of the effects of rehearsal on recall.

Experiment III

The earlier two experiments suggested that, with identical materials and presentation rates, different results on a memory task could be expected when one study used a partial recall procedure and the other full free recall. The main difference obtained was in poorer overall performance when partial recall was demanded. This finding was unexpected, especially in the immediate recall condition, where partial recall scores were not higher than those of full free recall although earlier studies (Brown, 1954; Anderson, 1960; Sperling, 1960) have found that the former procedure leads to a substantially superior performance.

Of particular interest was the differential effect of pure delay before the filled delay in the two studies. With partial recall, performance was depressed to a uniformly low level over all three groups in the sequence, whereas full free recall demonstrated an improvement over all three groups compared to the performance after filled delay alone.

To investigate the reason for these differences, the experiment III was designed. The main difference between full free recall and the partial recall condition was that subjects were required to remember the group to which items belonged. This "order" type information may have occupied channel capacity, thus depressing performance and further it may have decayed through time, thus artificially depressing the recall scores for the items themselves. To examine this, Experiment III used full free recall but requested that in recording their responses subjects should note in which group the items were presented.

Method The design was identical to that of the previous experiment II (vide), except that subjects were asked to write down their responses in three groups, corresponding to the first, middle and last five items in the presented sequence. The subjects were informed that while it was very important to record items under the correct group, they should not omit an item if they could not remember the group in which it occurred. In such cases, they should guess at the group. In writing down their responses, they were free to recall items in any order.

Forty subjects (undergraduate volunteers) were individually tested after being allocated one of the four experimental conditions as used in the previous two studies. Each subject received two practice trials, followed by two test trials, which were separated from each other by two minutes of neutral activity (conversation).

<u>Results</u> Responses were scored correct if the correct item appeared under the correct group. As earlier, homonyms and misspellings were judged as correct.

Figure III represents the percentage recalled for each condition over the three groups. It is clear that these results are somewhat different from those obtained in either of the previous experiments (see Figures I and II). However, the expected lack of effect of pure delay is obtained and shown with the complete statistical results in Table VII, below:

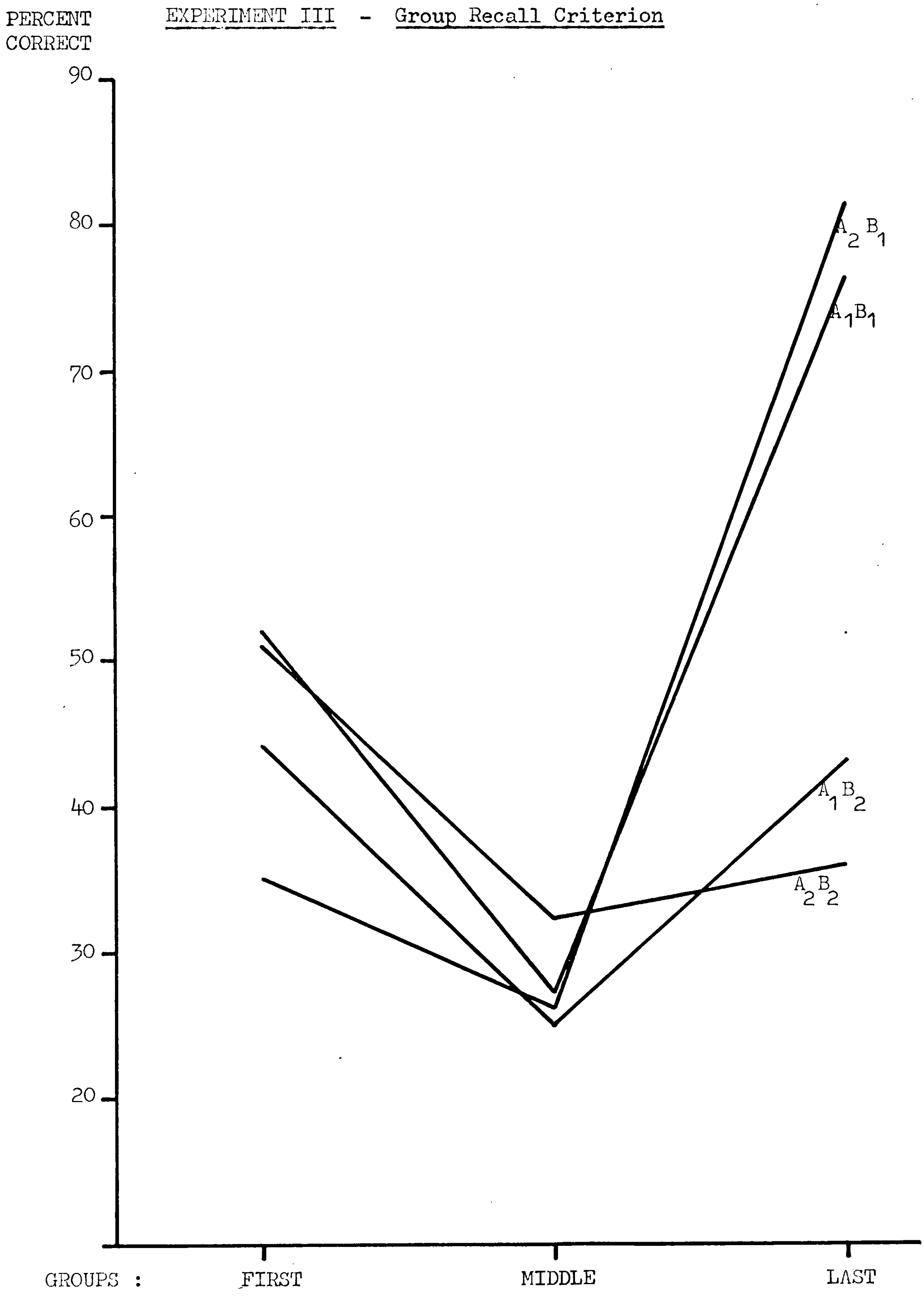
TABLE VII

Source of variation	d f	F ratio	Significance level
A = pure delay	1,36	0.3	N S
B = filled delay	1,36	6.31	.05
AB interaction	1,36	0.6	N S
C = groups	2,72	4.9	.01
AC interaction	2,72	0.8	N S
BC interaction	2,72	2.98	.10
ABC interaction	2,72	3.99	.05
Difference between:			
(1) B1-B2 under A1	1,36	5.3	.05
(2) B1-B2 under A2	1,36	1.5	.25
(3) A1-A2 under B1	1,36	0.5	N S
(4) A1-A2 under B2	1,36	0.1	N S

<u>See also Appendix D</u>

FIGURE III

EXPERIMENT III - Group Recall Criterion



It would seem, therefore, that the necessity of remembering the group in which items are presented prevents any stabilising effect of pure delay from being demonstrated. While in this respect the results are similar to Experiment I, they differ from it in suggesting that in the present experiment the effects of filled delay are less disrupting. Thus, in Experiment I, the percentage recalled in the two non-filled delay groups (i.e., immediate recall and pure delay alone) was greater than the percentage recalled in the present experiment (55% and 54% as against 47% and 52%), but in Experiment I the percentage recalled by the two filled-delay groups (i.e., filled delay alone and pure delay + filled delay) was smaller than in the present experiment (34% and 32% against 40% and 37%). To some extent the attenuation of the effects of filled delay which led to there being no significant difference between the immediate recall and filled delay conditions is accounted for by the comparative lack of primacy in the immediate recall of the word lists. Thus, for the first group of items, immediate recall is inferior to the filled delay before recall conditions (significant at the 10% level). This depression in immediate recall scores of the first group of items would seem to have contributed to the significant pure delay x filled delay x groups interaction.

Discussion While the different graphs of Experiments I, II and III lead to difficulty in the interpretation of the effects operating, some conclusions are possible. It was suggested that the necessity of remembering some order information (the group in which items were presented) under the partial recall procedure may have depressed performance in two ways. The first possible effect is that this order information takes up some of the limited channel capacity available, thus leaving less room for the storage of item information.

The second possibility is that this order information may decay rapidly with time and at a faster rate than the item information, thus preventing subjects from recalling the full item information which they have available. This second possibility can be examined by re-analysing the data of the present experiment and scoring as correct items recalled in the wrong group (i.e. intrusions). This is a meaningful method since subjects were encouraged to write down all the items that they could remember, guessing at the group when they were not sure of an item's position in the presented sequence. This scoring procedure is, therefore, one adopting a free-recall criterion.

The table below shows the improvement in recall scores resulting from including the "wrong group" items (denoted by scoring method 2), and Figure IV represents this data graphically.

TABLE VIII

	First 5	Middle 5	Last 5	Total
A1 B1 % correct by scoring method (1)	52	27	76	51.6
A1 B1 % correct by scoring method (2)	55	34	78	55.4
A2 B1 % correct by scoring method (1)	35	26	81	47.3
A2 B1 % correct by scoring method (2)	40	27	83	50
A1 B2 % correct by scoring method (1)	44	25	43	37.3
A1 B2 % correct by scoring method (2)	48	36	53	45.6
A2 B2 % correct by scoring method (1)	51	32	36	39.6
A2 B2 % correct by scoring method (2)	56	35	38	43.0

The results of scoring as correct items which were from other groups is depicted graphically in Figure IV. It can be seen that the number of items recalled correctly as items, but assigned to the wrong group, tends to increase with the length of the delay between presentation and recall. The actual number of items in the incorrect group for each recall condition is given in Table IX. (These scores represent the total given by ten subjects over the two test trials.)

FIGURE IV
EXPERIMENT III - **Free Recall Criterion**

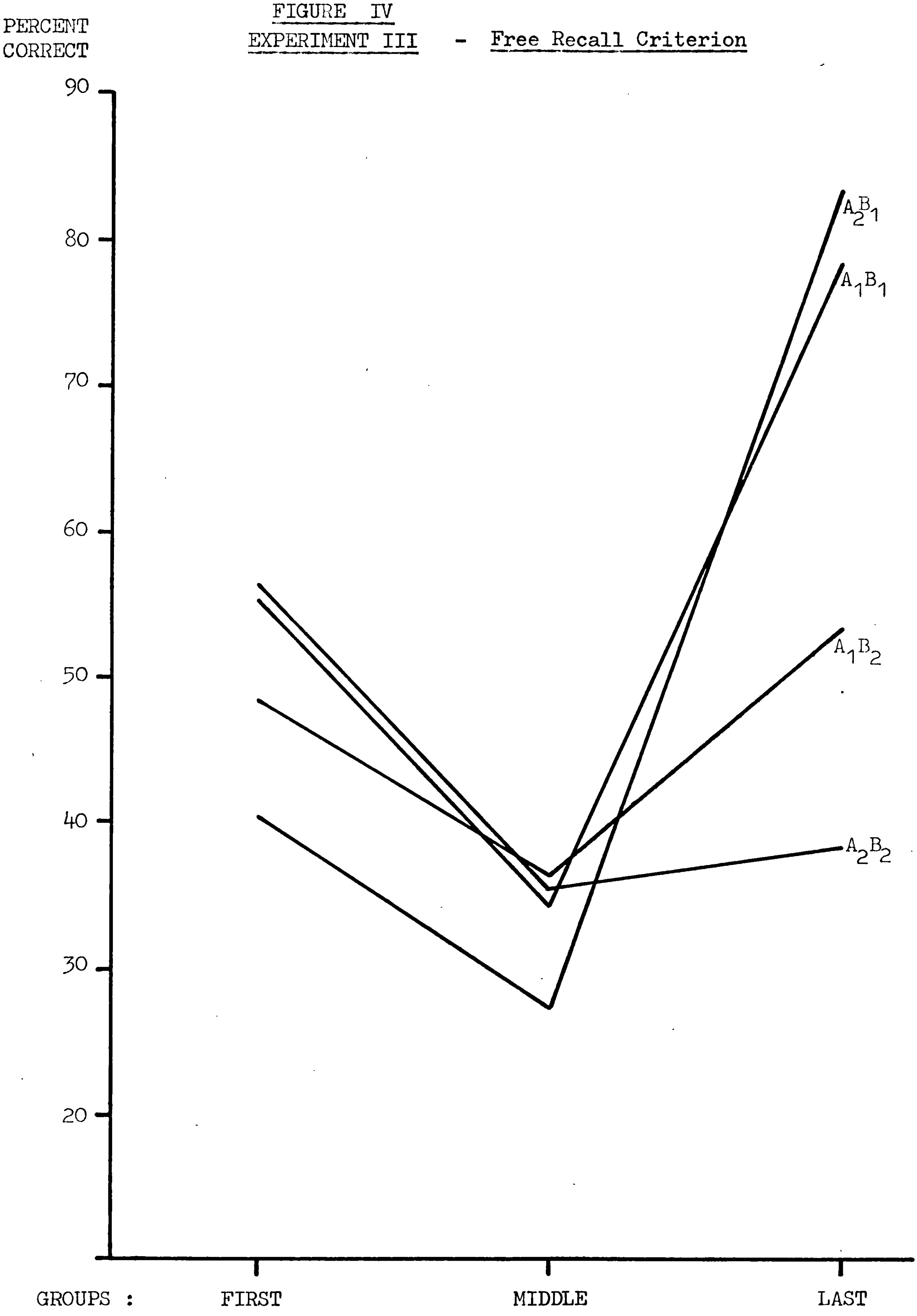


TABLE IX

A2 B1	=	immediate recall (no delay)	=	8 items
A2 B2	=	filled delay (10 seconds delay)	=	10 items
A1 B1	=	pure delay (20 seconds delay)	=	12 items
A1 B2	=	pure + filled delay (30 seconds delay)	=	25 items

Unfortunately, the number of items recalled in the wrong group is too small for any firm conclusions to be drawn. However, of interest is the fact that the condition which most benefits from the more liberal scoring criterion is that involving the longest delay. It is not clear why this condition should produce so many intrusion errors, but this finding does, at least, explain in part the differences between Experiments I and II in the effects of pure delay before a filled delay. It seems very likely that pure delay before a filled delay in Experiment I did produce a relatively depressed recall score because a certain amount of group location information was lost. However, the scoring of intrusions as correct responses in Experiment IV does not raise recall of this condition very much above that of filled delay alone, so that it would seem useful to invoke some notion of limited channel capacity for memory in which group information competes with that for the items themselves. Discussion will return to this question.

The discrepancies between Experiment I and III are far greater than would have been wished, since it was felt that the present experiment was a closely similar study. The main difference lay in the effects of filled delay being somewhat attenuated compared to the earlier experiment. However, another important difference also occurred. From the recall profiles it is apparent that in Experiment I there was less difference between recall scores over groups compared with Experiment III and this is borne out by the analysis of variance for the two sets of data. In Experiment III the main effect of groups was significant at the 5% level, whereas in Experiment I the main effect of groups was merely significant at the 10% level. In other respects the recall profiles were roughly similar with the sole exception of the immediate recall scores on the first group of items being relatively depressed in Experiment III compared to that of the other recall conditions.

Although these differences between the experiments may reflect chance factors rather than treatment effects, it seems probable that the partial recall procedure would have given rise to smaller differences between the groups than the full recall procedure since the former procedure emphasised the importance of paying equal attention to each of the three groups. This emphasis was implicit in the subjects' task since recall after each sequence was for one group only, but more than this, the recall instructions were to the effect that subjects should pay equal attention to the three groups.

It is difficult to envisage the processes which might have intervened to produce any differences between Experiment I and III in the effects of filled delay and it is tempting, therefore, to attribute these to chance variations. However, one possibility exists which is that under the filled delay condition,the partial recall technique of Experiment I may have ancouraged less guessing than did the full recall of Experiment III. A difference in guessing criterion could affect the number of items correct, assuming that there is some probability of a guess being correct. The reason why a difference might be expected between Experiment I and Experiment III is that the maximum number of words subjects were required to recall was different and, while it is assumed that the number of guesses made might be some proportion of this, there would seem no reason to expect a linear relationship to exist. Thus, following the interfering task, more guessing might be expected in response to the greater uncertainty (i.e. more guesses are needed to make a respectable score.

One way of examining the guessing criterion adopted is to look at the number of intrusions, as was done in Experiment III. This would allow some comparison between Experiment I and III, since in both of these the subjects were required to record items in the correct groups. Items allocated to the wrong group are defined as intrusions. To compare the two experiments, Experiment I was rescored to record the total number of intrusions under each condition. As with Experiment III, any word from the correct sequence, but recorded under the wrong group, was defined as an intrusion. The data for the two experiments are presented in Table X:

TABLE X - Number of intrusions in Experiments I and III

		EXPERIMENT III Data based on 10 x 2 x 15 items presented Total number of intrusions.	EXPERIMENT I Data based on 10 x 3 x 5 items presented, but x 2 for comparative purposes Total number of intrusions.
Immediate recall	A2 B1	8	28
Pure delay	A1 B1	12	42
Filled delay	A2 B2	10	56
Pure + Filled delay	A1 B2	25	60

It will be seen that when the number of intrusions from Experiment I is corrected to allow for the fact that the data collected was only half that of Experiment III, the table shows considerably more intrusions in the partial recall condition of Experiment I. However, clearly this data does not support any interpretation of the differential effects of filled delay in Experiment I and III in terms of differential guessing criterion. The proportion of guesses in the filled delay conditions of Experiment I to that in Experiment III is very similar to the proportion obtained under the absence of filled delay. Thus, the attenuated effects of filled delay in Experiment I compared to III cannot be interpreted in terms of differential guessing criterion. This difference may reflect chance factors and certainly no explanation would seem readily available.

Nevertheless, the results of the comparison are far from uninteresting. The difference in the number of intrusions in the two experiments is quite apparent. What the data would seem to suggest is that the number of guesses per trial is constant, regardless of the number of items which the recall condition specifies. In other words, Experiment I generated roughly three times as many intrusions for each block of 15 words recalled as did Experiment III. This result is somewhat surprising, since it was felt that subjects would record confident responses and then record guesses in some rough proportion to the number of certain responses given. The finding which contradicts this hypothesis would not seem explicable in terms of the demand characteristics of the two experiments. Indeed, Experiment III actively encouraged guessing whereas no instructions were offered on this in Experiment I. Thus, if anything, Experiment III would be expected to produce a more risky guessing criterion than Experiment I.

The main interest in Experiment III is that it attempted to investigate the discrepancy in results between Experiment I and II. The most important discrepancy lay in the effects of a rehearsal opportunity (pure delay) before a filled delay. Experiment III does cast some light on the problem in suggesting that the recall scores of the pure and filled delay conditions were depressed relative to the other conditions in Experiment I, because of the forgetting of group information, which is necessary for the recall of item information under the partial recall procedure. It should be stressed that the intrusions demonstrated in Experiment I are not considered relevant data to this issue since complete recall was not required. These are only suggestive of the guessing criterion adopted and not indicative of anything which might constitute an effect on the guessing criterion. Thus, with complete recall, as used in Experiment III, we can assume that subjects will have recorded all the item information which they have available, and that the allocation of correct item information to the wrong group will be a consequence of inaccurate group information. With partial recall, on the other hand, we cannot assume that the number of items recalled from the correct sequence, but in the wrong group, will reflect the total number of items of which the group information has been forgotten. This is perhaps most apparent when one considers that only five items are requested for recall. Thus, with 50% correct recall, the subject is only required to supply an extra 2.5 items per trial. There is no way of knowing how many items in excess of 2.5 were lacking group information at recall in Experiment I.

The results of Experiment III are, therefore, suggestive ones only. If "group" information is a contributory factor in the relatively depressed recall scores of the pure and filled delay condition in Experiment I, then forgetting of the group information alone would not seem sufficient to account for this. The favoured hypothesis is that retention of the group information takes up some of the limited channel capacity and this is critical in the pure and filled delay condition. Exactly how this would operate is not clear. Nor for that matter is the nature of the group information. It could be in the form of some characteristic of the stimulus such as voice quality, which is used as a "time tag", for example (Yntema & Trask, 1963). Alternatively, the identity of the group may be provided by a much more specific "order" information covering each of the serial positions. In the former case, the "tag" may not be rehearsed with the item and so may suffer loss simply as a function of time. In the latter, it may be sustained through rehearsal if the group information is provided by the ordered retention of items. For example, "associative threads" (Ebbinghaus, 1885), running through the sequence, would tend to provide the correct item in the correct position throughout rehearsal and at recall. The observation that there is a tendency for order information to be lost with time would seem to suggest that order information may not be retained with rehearsal. However, further discussion will be made of the nature and effects of order information so this matter will not be pursued at this stage.

One final point deserving mention is the superior performance on the first group of items of the pure delay condition compared with that of immediate recall. This may reflect better rehearsal of the earlier items with this condition because this condition allows rehearsal of later items after presentation. However, this result was not expected and is not consistent with the results of Experiments I and II.

Conclusion Experiment III was similar in design to the first study in this series in demanding recall of the presented sequences in three groups of five. As in the first experiment, no benefit was accrued from the opportunity to rehearse items before a filled delay. The experimental results, therefore, differed from Experiment II in this respect. This suggested that the reasons for the lack of this effect in Experiments I and III might lie in the demand for some degree of "order" information by the instructions requesting recall of items in temporal groups.

This possibility is investigated in the following experiment.

Experiment IV

The purpose of this experiment was to investigate the effect of order information on the retention of items under the various conditions of delay, as used in the earlier studies. In the three previous experiments, the differing results obtained were attributed to the "order" information demanded by the recall procedure of Experiments I and III. This recall procedure may be best described as "free recall with grouping", in that subjects were allowed recall in any order but were requested to record their responses in three groups corresponding to those in the presented sequence.

While the amount of order information required at recall is in a sense low (an item is either early, middle or late in the sequence) the actual information in bits per item given by knowing the correct group is 1.585 (i.e. $\log_2 3$). Thus, for a fifteen-item sequence, on this basis, the total amount of information carried by this group knowledge is 15 x 1.585 = 23.775 bits. This is a substantial amount of information and if it is stored separately from the item information (see Chapter III for discussion of this) then some decrement in performance may be expected. However, the order information given by remembering a full sequence of fifteen items in the correct order would be even greater at nearer forty bits.

One way of examining the load of order information on performance, therefore, would be to increase the demands of the recall task from one of correct item in the correct group to that of correct item in the correct position. Unfortunately, the task then is usually no longer one of free recall but of ordered recall.

Since the present interest is in the effect over time (with pure and filled delays) of the need to retain order information, the experiment reported below was designed to avoid ordered recall and to use free recall while increasing order information.

Method

Except for the instructions given to subjects, the design was identical to the earlier experiment in so far as it used the same recorded sequences of common English words and the same conditions of pure and filled delay before recall.

To increase the order information, while retaining the free recall instructions, response sheets were designed so that subjects could recall items in any order but place the correct item in the correct position. These response sheets consisted of blocks of cells in the form of five rows by three columns corresponding to the three groups of five items of the recorded sequence.

The forty subjects (student volunteers individually tested) used in the experiment were instructed in the use of the response sheets. They were asked not to omit any items through lack of knowledge of their positions.

In this experiment, subjects were not randomly allocated to the four conditions but were assigned to conditions depending on their performance on an immediate recall sequence. Although this is an unconventional procedure, the purpose was to reduce as far as possible any initial differences in ability between the four groups.

After the allocation sequence, subjects were informed of the full procedure details and allowed one practice trial before receiving three test trials. The administration of the trials was similar to that reported for the earlier experiments.

Results The response sheets were scored by two methods:

(1) Correct item in the correct position (= cell) i.e. ordered recall criterion.

(2) Correct item regardless of position i.e. free recall criterion.

(1) Ordered recall scoring

Figure V gives the profile summary of the percentage recalled under the four conditions for the three groups. This can be used in the interpretation of Table XI (below) which presents the statistical analysis of the results.

TABLE XI

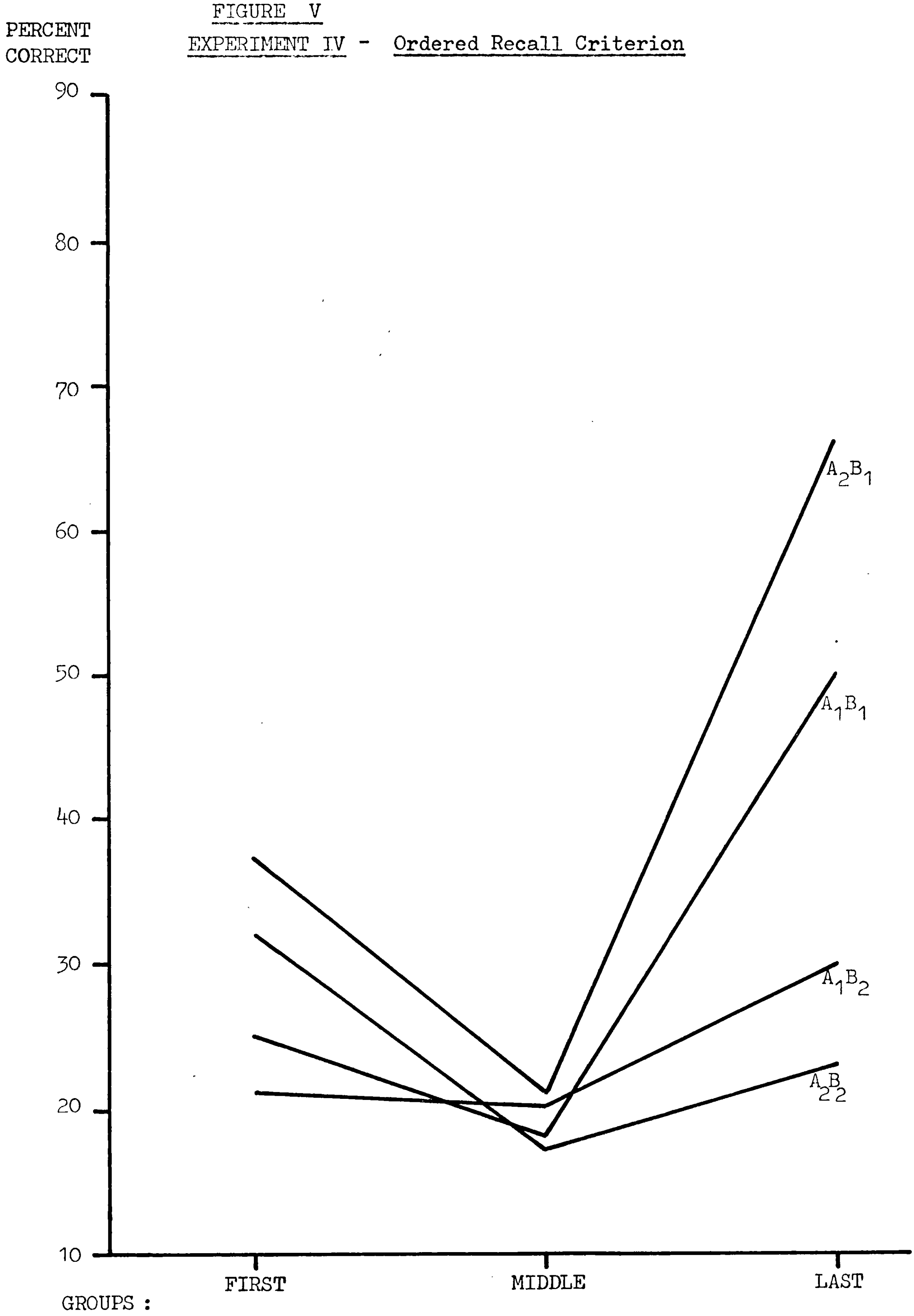
Source of Variation	d f	F ratio	Signific. Level
A = pure delay	1,36	2.73	.25
B = filled delay	1,36	14.69	.01
AB interaction	1,36	2.73	.25
C groups	2,72	40	.01
AC interaction	2,72	2.29	.25
BC interaction	2,72	20.55	.01
ABC interaction	2,72	2.29	.25
Difference between:			
(1) B1-B2 under A1*	1,36	2.38	N S
(2) B1-B2 under A2*	1,36	15	.01
(3) A1-A2 under B1	1,36	5.46	.05
(4) A1-A2 under B2	1,36	0	N S
*see Fig. V see also Appendix D			

The results resemble those of the earlier studies in demonstrating the disrupting effects of filled delay, particularly on items in the terminal group (B effect and BC interaction both highly significant). Also, as predicted, the results are in line with those of Experiment III in so far as they fail to demonstrate any beneficial effects of rehearsing the material before a filled delay.

Thus, the total amount recalled under the two filled delay conditions (i.e. filled delay with presence and absence of pure delay) is identical in both cases at 109 items or 24% of the total possible. In other respects, the results are unexpected: pure delay alone results in substantially lower recall scores than the immediate

FIGURE V

EXPERIMENT IV - Ordered Recall Criterion



recall condition. This difference is significant at the 5% level. However, interestingly, filled delay does not further depress the recall scores of the pure delay condition (B1-B2 under A1 NS).

Before attempting an interpretation of these results, the second analysis of the data will be presented, since the present interest lies more in the effects of the retention of order information on the number of items remembered and less in the number of items remembered in the correct position.

(2) Free recall scoring

This method of scoring enables analysis of the effects of the retention of order information by comparison with the earlier studies conducted. Scoring in this way should yield the total number of items which subjects had available at recall since subjects were instructed to write down all the words that they could remember even if they could not remember their position in the presented sequence.

Figure VI shows the profile summary for the percentage correct on the three groups for the four experimental conditions. A separate trend analysis computed for the free recall criterion data is summarised in Table XII, below:

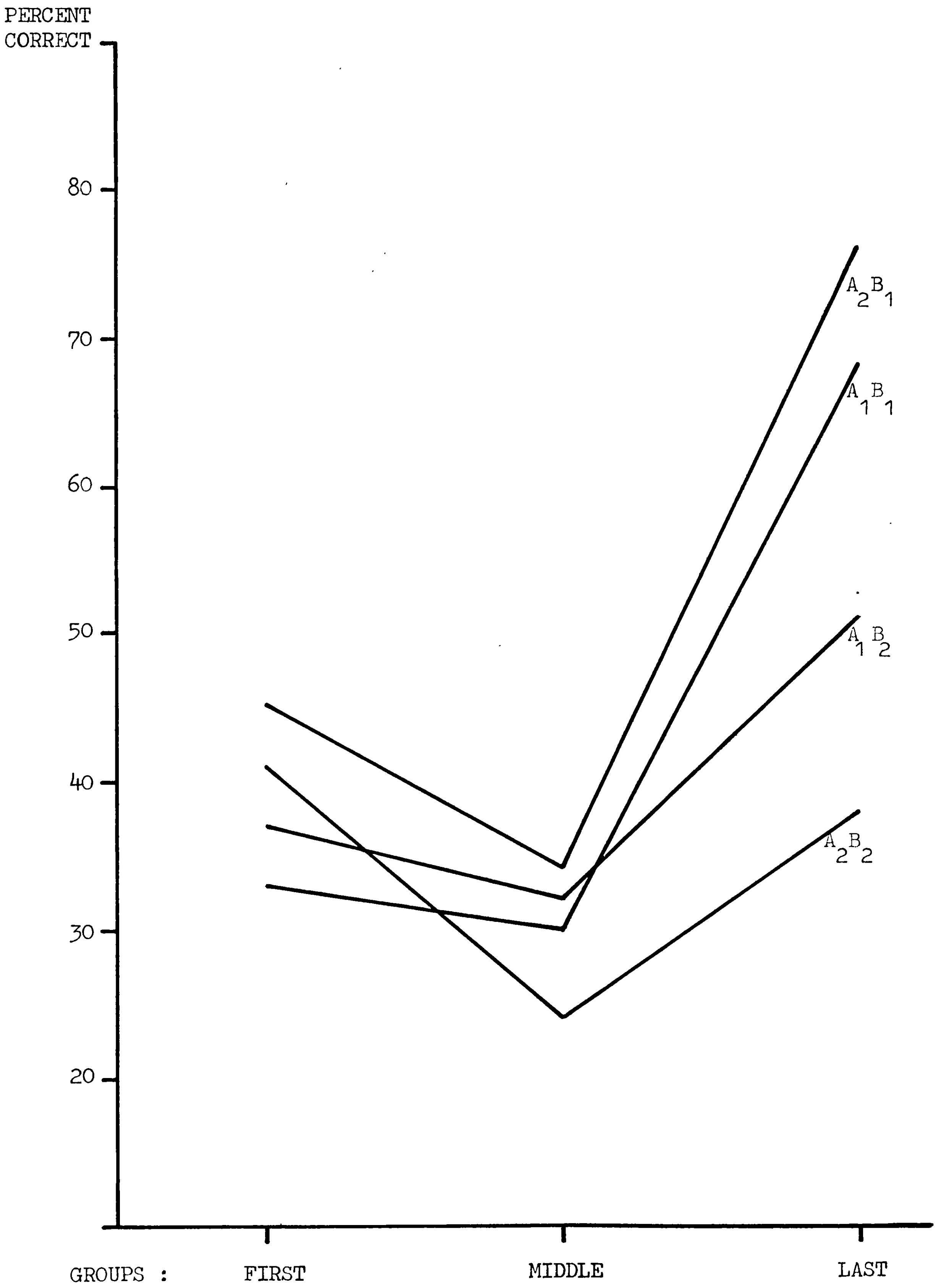
TABLE XII

Source of Variation	d f	F ratio	Significance Level
A pure delay	1,36	0.2	N S
B filled delay	1,36	16.55	.01
AB interaction	1,36	6.8	.05
C groups	2,72	36.84	.01
AC interaction	2,72	1.67	.25
BC interaction	2,72	9.45	.01
ABC interaction	2,72	.056	N S
*Difference between:			
(1) B1-B2 under A1	1,36	1.06	N S
(2) B1-B2 under A2	1,36	22.32	.01
(3) A1-A2 under B1	1,36	4.76	.05
(4) A1-A2 under B2	1,36	2.29	.10

*See Figure VI (see also Appendix D)

FIGURE VI

EXPERIMENT IV - Free Recall Criterion



While the change in analysis from an ordered recall criterion to that of free recall produced little change in the main effects or their interactions, some change in the profile of the recall scores (Figure VI) is apparent. It is clear that the largest improvement resulting from the different scoring method lies under the pure plus filled delay condition such that there is now an indication that it may be reliably superior to the filled delay alone condition. (A1 B2 > A2 B2 at the 10% level). As in the ordered recall criterion results, pure delay alone produces a decrement but the effect is less marked. These opposing trends of pure delay account for the now significant AB interaction. However, the failure of filled delay to depress performance after a pure delay is common to both sets of data (B1-B2 under A1 NS.)

Discussion The results are interesting in showing that an opportunity to rehearse material can lead to some stabilising of the items retained, but that the order of these items is likely to be forgotten. Thus, in the present experiment, there is no significant interaction of pure delay with filled delay when the recalled sequences are scored by the criterion of correct items in the correct position, but when a free recall criterion is adopted, this interaction does become significant.

In Experiment III, the "order" information locating an item in the correct group appeared to decay as a function of time regardless of the intervening activity. Somewhat similar results are apparent in the present experiment and this is clearly seen when the number of items recalled in the wrong position is expressed as a percentage of the number of items recalled in the correct position, viz.:

A2 B1 (no delay) = 24%
A2 B2 (10 seconds filled delay) = 40%
A1 B1 (20 seconds pure delay) = 42%
A1 B2 (30 seconds pure and filled delay) = 70%

These findings would suggest that order information is lost more rapidly than item information. Although it is difficult to separate these two types of information completely, a subsidiary experiment (previously unreported) suggests that when item information is lost no order information remains.

This observation was made in the present experiment by providing all subjects with the items of the last presented sequence printed on individual cards, and requesting them to place the cards in the correct order. Since the average number of items recalled in the correct position in the experiment was just less than 5 (4.5) then subjects would be expected to achieve just over 1 further correct item (1.05) on a chance basis (1 in 10) since their task would be to allocate the ten items given to the ten unknown positions remaining. In fact, the gain in number of items (placed in the correct position) was 1.25 per trial. This is not significant above the chance level (Z = 1.4 < p.20).

The present experiment was expected to demonstrate similar but greater differences between Experiments III and IV, as were shown between II and III, since more order information was demanded in IV than in III. These experiments can be summarised in terms of the mean number of items recalled per subject for each condition:

TABLE XIII

Condition	Experiment II full free recall	Experiment III full recall in groups (marked as free recall)	Experiment IV full ordered recall (marked as free recall)
A1 B1	8.7	8.3	6.6
A2 B1	9.0	7.5	7.7
A1 B2	8.0	6.8	6.0
A2 B2	6.2	6.4	5.1

While there is a tendency for the recall scores to be lower in Experiment IV than in III, thus supporting the hypothesis that an increase in order information would reduce recall scores, the pattern is not one which explains the discrepancies between Experiments II and III. The effects of retaining order information on the number of items and the stability of items is difficult to interpret in view of the varied and unexpected effects over the different conditions. Examination of the recall profiles over groups does suggest possible starting points for interpretation. For example, the improvement in recall with the interpolation of pure delay before recall in Experiment III is provided by the difference in scores between immediate recall and pure delay alone at the first group of items. With Experiment IV, on the other hand, the reversal of the effects of pure delay is again largely provided by the difference in recall scores at the first group of items. Further, Experiments III and IV have in common a trend towards immediate recall being superior to pure delay alone on the last group of items. It can be seen from the relevant graphs that the loss of order information does not change this relationship particularly, so that any explanation of these results must include this finding too. This presents no mean problem. Superficially, the trend for pure delay to produce lower recall of terminal items is the easier problem to tackle since we know from earlier data (Experiment II) that the tendency to recall late items presented late increases with the delay before recall. Thus, pure delay may tend to act as a filled delay before the recall of terminal items. Filled delay before recall lowers performance (Experiments I, II, III and IV) and therefore it is not surprising that pure delay reduces recall of terminal items over the immediate recall condition. Unfortunately, Experiment II does not display this trend when it should. Experiment I does not show any tendency for any decrement in the recall of terminal items either, but this would, of course, be predictable from the above argument, because the partial recall procedure could not allow any increased delay of terminal group items. Experiment II could be excepted as relevant data if it were assumed that the trend towards pure delay depressing terminal group items only occurred when order information was being retained. This could be the case, but the only reason for believing this possible is the noted correlation between delay and the tendency to recall items in the presented order. Of course, this speculation in terms of order information is an empirical question : the effects of recalling late items late under conditions of free recall and ordered recall could be examined. Since the best way of conducting this experiment would probably be to interpolate a filled delay before recall, then data is already available in the form of Experiments II and III or Experiments II and IV. Experiments II and III provide better data for comparison than do Experiments II and IV, since, in the former, the immediate recall scores on the terminal group of items are nearly identical (81% and 83% respectively). If the hypothesis that the retention of order information leads to lower recall on terminal items is true, then Experiment II should be significantly superior to III on the terminal group under the filled delay condition. In fact, the amount recalled in Experiment II was 48% as against 38% in Experiment III. While the trend is in the predicted direction, this difference is not significant (t value below unity). However, even if this difference were deemed sufficient to account for the lower recall of terminal items with pure delay, dissatisfaction must be expressed about the level of this explanation. In other words, it is not apparent why recall order should change with increasing delay before attempted recall, unless as a consequence of the unavailability of certain items or the increased stability of others (i.e. terminal items) which no longer need to be recalled early.

There are even greater problems in attempting to interpret the differences between Experiments III and IV in the recall scores of the first group of items under the conditions of immediate recall and pure delay. In Experiment III there is a reminiscence effect, whereas in Experiment IV pure delay produces a decrement on the first group of items. Although these differences may reflect chance variations, both of these effects are quite pronounced. (In Experiment III, A1 B1 > A2 B1 $F = 4.4$, $df = 1,36$, $p < .05$ while in Experiment IV, A2 B1 > A1 B1 $F = 3.7$ for ordered recall criterion and $F = 3.3$ for free recall criterion, $df = 1,36$ $p < .10$). The results of Experiments I and II show very similar recall scores for these two conditions so that whatever reason there is for the discrepancies between Experiments III and IV it would seem to be associated with the retention of order information and with full recall. Unfortunately, there is no apparent reason for this. Possibly, the process involved, which resulted in the different recall scores on the first group of items is that of differential rehearsal under the two conditions of immediate recall and pure delay, but there are no clues as to why differential rehearsal should have taken place or indeed whether it did.

Perhaps the main difficulty in interpreting the results of these experiments is that we have no way of knowing whether the immediate recall scores over the groups do represent what subjects have available before the various conditions of delay are imposed. Indeed, it would seem unlikely that subjects would not attempt to handle the presented information differently, depending on the task to be performed before recall is allowed. Thus, emphasis on the rehearsal of early presented items would seem a useful subject strategy when a filled delay is to be imposed before recall. While it is possible to suggest in this way useful or probable subject strategies arising in response to experimental treatments, the advantages of doing so in the present context are limited. This is because the experimental design adopted is not one which allows the effects of treatment variables on remembered items to be separated from those effects arising from a subject's anticipation of those treatment variables. This would seem an important but neglected point in memory research. In a sense, this fear of confounding of results provided the stimulus for the first main experiment of this present series in so far as the partial recall procedure attempted to investigate whether terminal items were, in fact, disrupted by a filled delay imposed before recall. However, the main throw of the present discussion is one which urges caution in the use of such language as "filled delay disrupts terminal items...." when we have only the evidence that a filled delay condition produces lower recall of terminal items than an immediate recall condition. What is needed before an adequate model of memory can be attempted is to know what information is remembered prior to the introduction of post presentation treatments.

This is by no means a simple problem, but one approach to resolving this will be discussed in the introduction to the following experiment.

Conclusion The main finding of Experiment IV was that an opportunity to rehearse items can increase their resistance to the disrupting effects of a filled delay, but that the order in which items were presented is likely to be forgotten. The effects of the experimental treatments were not entirely in line with the prediction made from the previous experiments, so that a further experiment is considered necessary for the interpretation of the results reported so far.

Experiment V

In Experiment IV it was suggested that the experimental design utilised in the present series of experiments may make certain unjustified assumptions which create problems in the interpretation of treatment effects. Thus, the effects of a filled delay before recall are deduced from the difference between the scores under the immediate recall condition and those under the filled delay condition. While this is a valid assumption, it is so on a relatively undifferentiated level. It is quite possible that the amount of material available before the filled delay, under the filled delay condition, is not the same as that available under the immediate recall condition and, mutatis mutandis, the same may be true for the pure delay condition.

There are reasons for expecting such differences since the practice trials offered subjects opportunity for a cognitive appraisal of the situation (e.g., perhaps suggesting for them that certain items or groups of items should be rehearsed more than others). Thus, the results of the experimental design, using full recall, do not differentiate between the cognitive effects on a subject of the treatments and their physical effects on the material which subjects are holding in store. The problem becomes more acute when the distribution of responses over the sequence is considered since the different conditions may encourage differential rehearsal over the sequence. Moreover, we cannot assume that any cognitive effects which arise from the anticipation of treatments in an experiment using free recall will be identical to those arising from an experiment using ordered recall.

Experiment I - using a partial recall procedure - would seem to offer one solution to the problem of cognitive effects, since it encouraged subjects to pay more equal attention to the three groups of the presented sequence. However, there is no guarantee that equal rehearsal of groups will take place and the partial recall technique has also the disadvantage that it is wasteful of data and does not lend itself readily to free recall criterion analysis. An alternative method of ensuring equal rehearsal during presentation under the different conditions is therefore preferable.

To prevent differential rehearsal under the different conditions, it would seem necessary to impose heavy demands on the subject by either preventing him from rehearsing or only allowing a fixed number of rehearsals per item. Both of these techniques would be suitable but pilot trials, using the former technique, suggested a number of disadvantages over the latter. First of all, it was an unpopular technique in that such an attention-demanding subsidiary task as digit-counting was considered irritating. The reason for this was in the sheer demand of the final task but, apparently, the "need" to rehearse items was so strong that "deprivation" must be listed among the main causes of this. This raised the second problem of the adequacy of any attempt to prevent rehearsal. Subjects indicated that a subsidiary task, no matter how demanding, would be unlikely to guarantee that no differential rehearsal of items would take place over the presented sequence. Further recall scores using this technique were very low, so that an attempt to prevent rehearsal would be comparatively wasteful of data. On all these accounts, the technique of using a fixed number of rehearsals per item appeared superior.

A variety of alternative approaches to the problem of separating the effects of experimental treatments per se from the effects of the anticipation of those treatments was considered. However, none appeared to be without obvious disadvantages. Thus, one possibility would be to present to each subject at random all of the experimental conditions so that anticipations of certain treatments would affect all conditions. Perhaps the main disadvantage of this approach is that the experiment is defined for the subject and unless the results are counter-intuitive (in terms of the expectations of the subjects) we cannot know whether the experiment has recorded anything more than the phenomenon of self-fulfilling prophecy. Of course, such research would not be without interest, but it is not the best of designs for addressing the present problem.

The only other alternative, perhaps, is to impose the experimental treatments unexpectedly on the subject. This would be most useful in that this would allow definitive statements about the effect of experimental treatments on what is being remembered. Unfortunately, this approach presents a variety of problems, the most difficult of which is that of briefing the subject sufficiently to allow him to accommodate the post-presentation condition to which he has been allocated without encouraging him to anticipate that treatment. This is more important for - and more difficult to achieve in - some conditions than others. Thus, an unexpected pure delay would be hard to introduce without interrupting the subject with filled delay (to inform him of this rehearsal opportunity before recall).

For these reasons, the technique of controlling rehearsal by allowing subjects a fixed number of rehearsals per item recommended itself for the purpose of attempting to reduce the effects of the subjects' anticipation of experimental treatments.

Method In view of the manner in which the word sequences had been recorded, i.e. 1.5 seconds per item within each group of five items, and a three-second pause between groups, a pilot study was required to suggest the optimum method of controlling rehearsal. It soon became clear that subjects could not say aloud each item within the groups more than once if they were to correctly detect the following presented item of the sequence. Therefore, subjects were asked to say each item aloud once as soon as they had heard it.

At the end of a group, in order to fill the pause recorded between groups, subjects were asked to repeat all five items in a group. The procedure appeared satisfactory, although it was found that subjects were likely to need more time between groups to verbalise the five words than the recorded sequence allowed. With some practice, it was possible for E to stop the tape recorder (using a non-locking pause button) consistently at approximately a second before the first item of the next group. Thus, as the subject spoke the last word of a group, the pause button was released to allow the first item of the next group to be presented without delay. This allowed the three-second pause between groups to be extended to something in the region of six seconds.

This procedure of allowing subjects to verbalise each item once, as presented, and then to repeat all five items of each group at the end of the presentation of each group, appeared to fill quite satisfactorily all the free time during presentation which could be used for rehearsal, and was adopted in Experiment V.

For purposes of comparison with the previous experiment, the present study was identical except that the controlled rehearsal procedure was adopted during presentation. Thus, forty subjects were tested individually. Each subject was tested on one of the four experimental conditions to which subjects were allocated after "matching" on one practice trial of immediate free recall. Recall was made by allowing subjects to write down items in any order in the correct cells of the response sheets (as used in Experiment IV). As earlier, subjects were requested to guess at the position of items in cases of doubt rather than omit the item. Each subject received two practice trials followed by three test trials.

At the termination of the experiment, subjects were invited to comment on the task and were specifically asked if they had been able to rehearse to themselves the material during presentation. None of those tested felt this was possible. The purpose of the vocalisation (to prevent differential rehearsal of items) was then explained, and all subjects agreed that it was effective, but somewhat unpleasant to perform.

Results As in the previous experiment, the data was analysed by the ordered recall criterion and then separately by the free recall criterion.

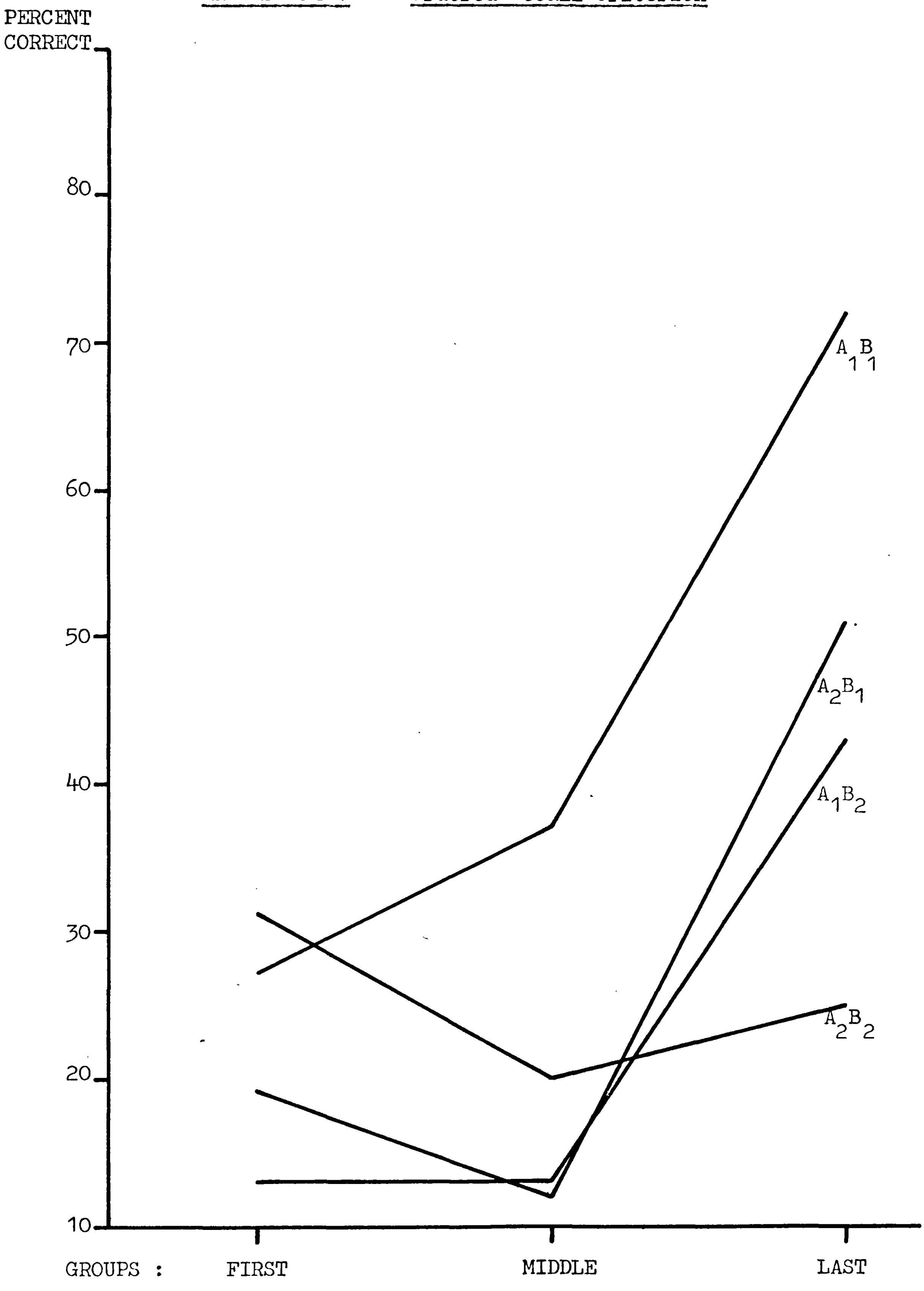
(1) Ordered recall criterion The results are summarised in Figure VII, in the form of profiles of percentage correct over groups for the different conditions. The change in the profiles compared with the earlier studies is remarkable. The trend analysis computed on the raw scores is summarised in Table XIV :

TABLE XIV

Source of Variation	d f	F ratio	Signif. level
A pure delay	1,36	3.76	.10
B filled delay	1,36	8.9	.01
AB interaction	1,36	6.52	.05
C groups	2,72	58.7	.01
AC interaction	2,72	9.31	.01
BC interaction	2,72	12	.01
ABC interaction	2,72	3.9	.05
Difference between:-			
(1) B1-B2 under A1	1,36	15.4	.01
(2) B1-B2 under A2	1,36	.1	N S
(3) A1-A2 under B1	1,36	10	.01
(4) A1-A2 under B2	1,36	0	N S
see Fig. VII see also Appendix D.			

FIGURE VII

EXPERIMENT V - Ordered Recall Criterion



The effects of filled delay (B) in leading to lower recall, particularly on the last group of items (AB interaction), are as predicted and obtained in the previous studies.

However, the present experiment differs in many other respects. Examination of Figure VII shows that there is a much clearer separation between conditions, and the profiles of the different conditions are all relatively dissimilar compared to the earlier experiments. Thus, the C effect (of groups) is highly significant and all the interactions possible with it (i.e. AC, BC, ABC) show significant trends. Of particular note, within the context of profile separations, is the advantage displayed by the pure delay alone condition over that of immediate recall. Pure delay is of no advantage when filled delay follows (23% correct against 25.5% for the filled delay alone condition) so that while the main treatment does show a significant effect, the AB interaction enables the null hypothesis of no effect of pure delay to be rejected with a higher degree of confidence.

Before discussion of these results, those arising from the second analysis of the data using the free recall criterion will be presented.

(2) <u>Free recall criterion</u> Figure VIII represents the recall scores arising from the more liberal scoring criterion. As in Experiment IV, a marked improvement is occasioned by this change of scoring method. However, unlike Experiment IV, there is no suggestion that pure delay is of any benefit before a filled delay when a free recall criterion is adopted. Thus, the significant A x B interaction arises because pure delay alone results in superior performance to the immediate recall condition.

FIGURE VIII

EXPERIMENT V - Free Recall Criterion

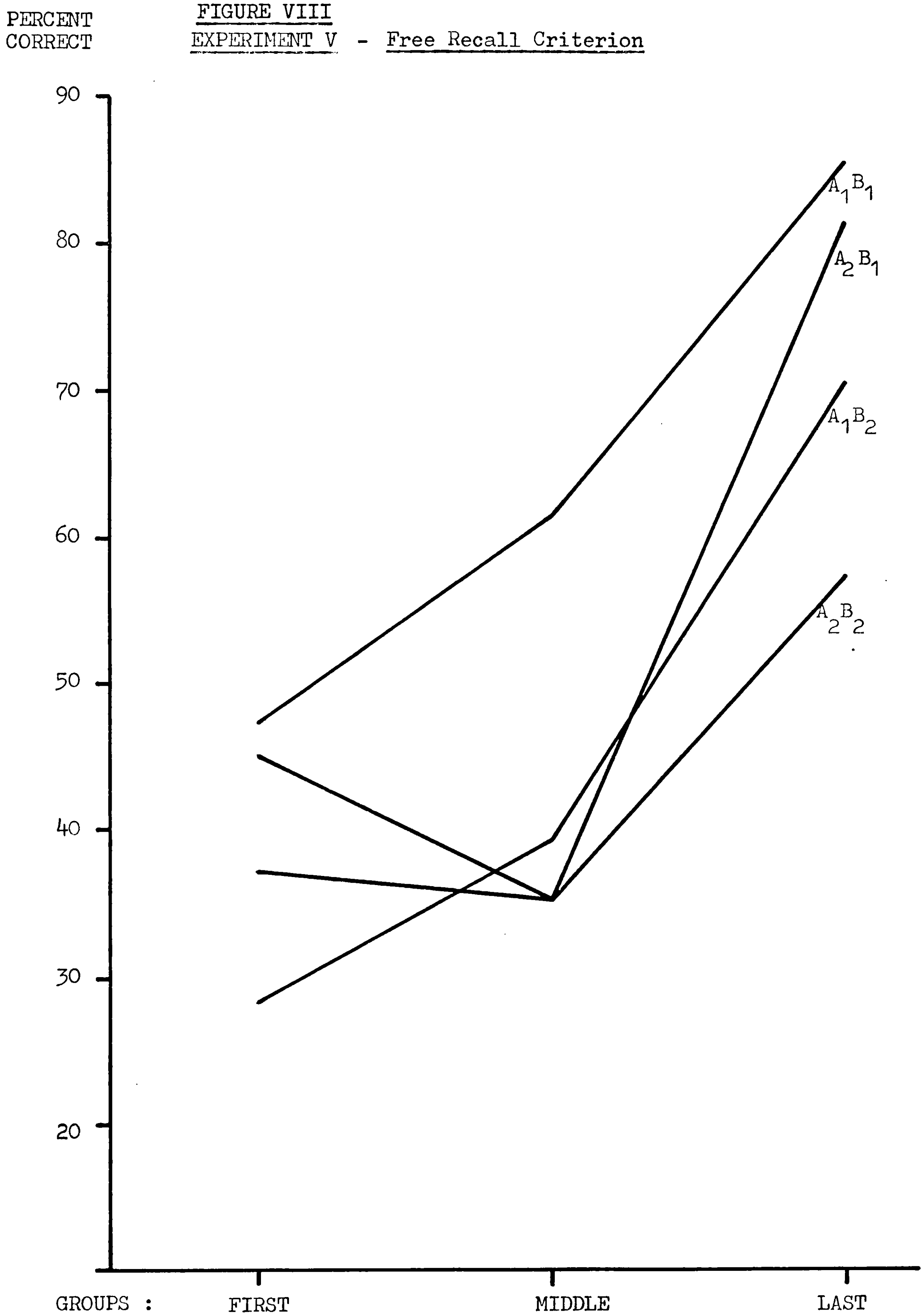


TABLE XV

Source of Variation	d f	F ratio	Significance level
A pure delay	1,36	4.7	.05
B filled delay	1,36	16.3	.01
AB interaction	1,36	5.4	.05
C groups	2,72	53.0	.01
AC interaction	2,72	3.3	.05
BC interaction	2,72	1.8	.25
ABC interaction	2,72	3.7	.05
Difference between:			
(1) B1-B2 under A1	1,36	20.0	.01
(2) B1-B2 under A2	1,36	1.4	.25
(3) A1-A2 under B1	1,36	10.0	.01
(4) A1-A2 under B2	1,36	0	N S
See Figure VIII See also Appendix D.			

Of particular interest in these results is the lack of significance of the B x C interaction. Thus, unlike all the other experiments in this series, the filled delay conditions do not lead to the largest loss of items at the terminal group. (The pronounced recency effects under all the conditions is apparent in Figure VIII). The significant A x C interaction is due to the more pronounced recency and less pronounced primacy of the two pure delay conditions. (This effect is more marked in the data from the ordered recall criterion scoring, because of the shape of the profile of the filled delay alone condition). It is the exceptionally pronounced primacy and relatively attenuated recency of the filled delay alone condition which would appear to be responsible for the significant A x B x C interaction in both this set of data and that arising from the ordered recall criterion scoring.

Discussion As with all the experiments in this series, the present study offers as many questions as it provides answers. The main purpose of Experiment V was to replicate the previous experiment, but to control the rehearsal taking place during presentation, so as to examine more precisely than hitherto the effects of the various delay treatments on what is remembered. Perhaps the starting point for discussion should be, therefore, the evidence in favour of the assumption that the controlled rehearsal was effective in distributing rehearsal equally over the three groups of items.

First of all, the subjects' reports - as described earlier - suggested that equal attention had been paid to the items during presentation. If this were the case, however, then the recall profiles resulting would be expected to be characterised by a very much diminished primacy effect, particularly under the condition of immediate recall. While the various conditions overall do differ from the results of the previous studies in this respect, the lack of any primacy effect is most pronounced in the two pure delay conditions. The main evidence against the assumption that items were equally rehearsed is provided by the immediate recall condition scored to the ordered recall criterion. (See Figure VII). Examination of the reliability of this primacy effect (as measured by the difference between the recall scores on the first group of items and the recall score on the middle group of items) indicates, however, that the effect is an insignificant one (t,df = 18 = .49 NS).

The effects of filled delay are also interesting in that if items were all equally rehearsed, then the early presented items would be expected to suffer a larger decrement, due to filled delay, than in the previous studies. Unfortunately, it is apparent that this is far from being the case when the results of immediate recall are compared with those of filled delay alone. Indeed, the recall profiles of these two conditions, particularly in Figure VII, are remarkably reminiscent of the results of Experiment III, where loss of terminal items, due to filled delay, coincides with some improvement on earlier ones, such that filled delay does not lead to any overall decrement (compared with the results of immediate recall). The two pure delay conditions, on the other hand, provide somewhat contradictory information in suggesting that with both scoring criteria the effects of filled delay are equally disruptive over the three groups. This would seem to indicate that a roughly equal number of unstable items are present under each group of items and this may be an indication that, compared with previous studies, early items are relatively less well rehearsed and late items relatively better rehearsed. These two pure delay conditions, however, present less compelling evidence than the other two conditions, since they leave open the possibility of differential rehearsal of items during the pure delay before recall and the information provided by Experiment V is most useful in suggesting what is remembered when differential rehearsal does not take place.

In view of the importance attached to the adequate control of rehearsal in this present experiment and the puzzling lack of effects of filled delay alone, a subsidiary experiment was conducted to check on the adequacy of the design in controlling rehearsal. Basically, the method was to replicate Experiment V, but to impose unexpected filled delays before recall. If Experiment V has adequately controlled rehearsal, then the effects of unexpected delay should not differ from the effects of expected delay.

Experiment VI

Method Thirty subjects were individually tested on either immediate recall or with a rehearsal opportunity before recall, in exactly the same way as in Experiment V. At the outset of the experiment, subjects were told that they had been allocated to an "easy condition", in that other subjects were required to count backwards from a given number by threes, before recall. An example was given of what was meant by this, and the subject was invited to try the condition, so that he might savour his good fortune in not being required to perform the task. The subject then performed one practice trial of the condition to which he had been allocated (i.e. either A1 B1 or A2 B1), vocalising each item as it was presented, as in Experiment V. Then followed

three test trials of that condition. Finally, on the last trial,
immediately before the expected recall, the subjects were interrupted and asked to count backwards by threes for ten seconds to fulfil the requirements of the other two conditions (i.e. A1 B2 or A2 B2). A number of subjects (five) were considered to have experienced enough difficulty with this unexpected condition as to require their being replaced by further subjects.

Results The results are presented, with those of Experiment V, for comparison. Data was scored to the ordered recall criterion and then separately to the free recall criterion. Figures in brackets indicate scores on the free recall criterion analysis.

TABLE XVI Percentage correct by ordered recall and by free recall criterion in Experiments V and VI.*

		GROUPS OF ITEMS:-			
		First	Middle	Last	Total
Expt. V.	A1 B1	27 (47)	37 (61)	72 (85)	45 (64)
Expt. VI.	A1 B1	21 (40)	35 (70)	66 (85)	40.5 (69)
Expt. V.	A1 B2	13 (28)	13 (39)	43 (70)	23 (45)
Expt. VI.	A1 B2	23 (35)	19 (45)	50 (65)	33.3 (48)
Expt. V.	A2 B1	19 (37)	12 (35)	51 (81)	27 (51)
Expt. VI.	A2 B1	15 (45)	9 (45)	60 (90)	28 (56)
Expt. V.	A2 B2	31 (45)	20 (35)	25 (57)	25 (46)
Expt. VI.	A2 B2	40 (65)	16 (40)	30 (49)	29 (51)

* Free recall criterion in brackets

Although the results overall are marginally higher in Experiment VI than in V, it will be noted that against their respective baselines, the effects of filled delay are almost identical in the two studies. It seems unlikely, therefore, that the control of rehearsal by vocalisation during presentation could allow any effects of the anticipation of treatments to intrude into the results of Experiment V. (The marginally higher results of Experiment VI could be due to the fact that this experiment was conducted during the vacation period, when students, still at the university, could possibly be more intelligent. Certainly, the relative lack of students in the coffee bars resulted in a larger proportion of subjects being obtained from the university library than in Experiment V.)

In Experiment V, the effects of filled delay alone in simply altering the distribution of correct responses over groups may, therefore, be considered a fairly reliable one. It can be seen that this result arises, in part, because after filled delay alone the items in the earlier two groups tend to be remembered in the correct order somewhat better than the corresponding items of immediate recall. Thus, the difference between immediate recall and the filled delay alone condition, when the data is scored to the ordered recall criterion, is insignificant with an F ratio of 0.1. However, in the data scored to the free recall criterion, there is a trend towards a reliable difference between these two groups ($F_{1,36} = 1.5$ $p < .25$). This tendency for filled delay alone to result in better retention of order information, comparatively speaking, than the immediate recall condition, contradicts the findings of Experiments III and IV. It will be remembered that in these two experiments order information appeared to decay with time more rapidly than item information. Turning to the other conditions for further examination of this point, it is apparent that there is no tendency for this to be true in Experiment V. In this present study, the ratio of items remembered in the wrong position to items remembered in the correct order is very similar for all the conditions, except that of pure delay alone. Expressed as a percentage the figures are : -

A1 B1	43%	A2 B1	87%
A1 B2	96%	A2 B2	80%

It will be seen that these ratios are considerably higher than those obtained in Experiment IV (where the average over the conditions was 44%.) This would suggest that the vocalisation during presentation required in Experiment V is a condition which is not conducive to the retention of order information. Thus, however order information is retained, it would not seem to depend on the repetition of items in the order in which they are presented, unless vocalisation of material disrupts the efficiency of this method. It may be wrong to look to the pure delay alone conditions as being exceptional to the other conditions, since it is apparent from the data that it is the terminal group of items which fails to benefit much from the move from ordered to free recall scoring. No doubt the very high recall of these terminal items allowed a ceiling effect to operate, whereby it was not possible to remember many items in the incorrect order, since over 70% of items were recalled in the correct order. The way in which order information is retained would seem an important issue, but since the examination of the full serial position curves could prove useful in indicating which items are best retained in the correct position and these curves are to be presented later, discussion will return to this question.

The central problem in the interpretation of Experiment V is that the results would seem internally contradictory. Thus, to begin by attempting to explain the strikingly superior performance of the pure delay alone condition over that of immediate recall, it would seem useful to invoke some concept such as "reminiscence". However, the only reason whereby some improvement might be expected is that the information retained becomes consolidated in some way. Many factors could lead to some improvement in recall with time - the forgetting of competing information, random fluctuations in the signal-to-noise ratio, the dissipation of inhibition, the transfer of material from short-term to long-term memory and so on, but these would all seem to be suggestive of increased resistance to forgetting of the to-be-remembered information. Unfortunately, the effects of filled delay following a pure delay are far more disruptive than the effects of filled delay alone, and this suggests that after pure delay there are more unstable items than immediately after presentation. The only way in which this observation could be conceived as at all possible would be if, immediately after presentation, there were a large number of items which were too unstable to suffer the interference of recall, but which were sufficiently stable to be rehearsed. Rehearsal of such items would then need to be sufficient to allow enough stability for the items to be recalled, but less than that required for such items to withstand the effects of the filled delay task. Such a phenomenon might be conceivable, were it to occur solely within the terminal group of items, but in the present experiment all groups of the presented sequence are afflicted with this unstable reminiscence effect. In other words, material held in short-term memory by virtue of being last presented could fulfil these requirements (although such an interpretation would not be without problems), but the existence of such material early in the presented sequence would seem very unlikely in view of the disrupting effect, which later presented items would have; unstable early items would be eliminated by the presentation of later material. The alternative, to view later items as creating instability in earlier ones, would not seem tenable since the kind of instability required in the above explanation is one where items are in a rapidly fading state rather than a weakened one. Indeed, the only circumstance under which this kind of instability would be expected is where last presented items are held in short-term memory. However, Experiment V did contain some unusual features in its control of rehearsal and the vocalisation of items as they were presented. It is assumed that in this experiment early items did not receive the processing from which they ordinarily benefit and this must result in some relative weakness in the strength of early items. Possibly, the vocalisation of items, coupled with the lack of opportunity for common rehearsal, led to some emphasis on the acoustic characteristics of the items such that the characteristics of short-term memory became manifested in the coding of early items in long-term memory.

However, besides being highly speculative, one observation made during Experiment V suggests that the above interpretation is not true. Experiment V was most useful in allowing acoustic confusions in recall to be classified as listening errors or memory errors. Unfortunately, although the vocalisation during presentation could generate information on this, no systematic recording was made of listening errors during vocalisation. Nevertheless, the subjective impression from being present at the vocalisations was that subjects very rarely indeed heard words incorrectly. Perhaps the most striking feature of the procedure was that subjects would imitate the intonation of the recording when vocalising each item as it was presented, but, when all five words were recalled at the end of each group, the subjects' own dialect would dominate and, in addition, acoustic confusions appear. Further, perusal of the data suggested that very few acoustic confusions were made in addition to those made in this very immediate recall. This would seem to suggest that the acoustic characteristics of the presented material are not retained as the dominant characteristics of the material for more than a few seconds.

Although there are many further points which require discussion, it would seem unlikely, in view of the difficulties encountered so far, that any attempt to pursue these could lead to fruitful discussion. On account of the present impasse it is preferable to attempt to integrate the present experiments in the light of the empirical and theoretical work of others, and since the full serial position curves have not been presented so far, to examine these for a more fine-grained analysis of the data.

Conclusion Experiment V represented a useful departure from the design of previous research in attempting to obviate the possibility of cognitive effects due to the anticipation of experimental treatments confounding with the effects of those treatments on what is remembered. The adequacy of experiment V in controlling cognitive effects was validated by a subsidiary experiment (VI). The results showed that the disappearance of the recency effect under the filled delay condition could not be accounted for by the failure of subjects to pay attention to terminal items. The results were unexpected in showing better recall after pure delay than immediate recall and yet greater attenuation of recall scores after filled delay in the pure delay condition than the immediate recall condition. Although the results were felt to be internally contradictory, a highly speculative interpretation was offered in terms of very unstable items existing throughout the sequence immediately after presentation.

Summary The stimulus for Chapter IV lay in some recent research which suggests that in immediate free recall terminal items are held in short-term memory whereas earlier items are held in long-term memory. The main evidence for this lies in the apparently disrupting effects localised on terminal items of a filled delay before recall.

Experiment I tested the hypothesis that terminal items are not unavailable after a filled delay but are simply not recalled first. A partial recall procedure was used to investigate this but the hypothesis was not supported by the data. Experiment I also investigated whether terminal items could be rehearsed into long-term memory if a pure delay was offered before filled delay. Contrary to the results of a pilot study (using full recall), no evidence was found that this was possible. Experiment II attempted to replicate the pilot study in using full free recall and, in doing so, found that a pure delay before a filled delay led to increased resistance to forgetting. However, the benefit of pure delay was not found at the terminal items alone nor did the terminal items fail to show a substantial loss due to filled delay.

A subsidiary finding of note was that Experiment II did not yield lower recall scores than the earlier experiment. It was suggested that the advantage usually reported for partial recall only arises when ordered recall is required because partial recall allows terminal (short-term memory) items to be recalled without delay. With free recall, requesting full recall is of no disadvantage since subjects can recall these last items first. Experiment III investigated the reason for this discrepancy between Experiments I and II in the effects of pure delay. It did so by replicating Experiment I in so far as subjects were required to remember in which of the three groups items were presented, but followed Experiment II in requesting full recall. As expected, the results showed no advantage of a rehearsal opportunity before a filled delay. The reason was, in part, that subjects grew increasingly inaccurate with time in their allocation of items to the correct group. It was suspected that the necessity of remembering this group information may have depressed recall, particularly under the condition of pure plus filled delay. A subsidiary finding of Experiment III was that the number of guesses subjects make per trial appeared to be constant regardless of the number of items which they were requested to recall.

Experiment IV examined more closely the effects of the need to retain information additional to item information. The procedure was to increase the demands of the task from remembering items in three groups to remembering items in the correct position. The results suggested that while pure delay may lead to some gain in the stability of items, the order in which the items were presented is likely to be forgotten. Although the results were also consistent with the hypothesis that the necessity of remembering order information tends to lead to a loss of item information, this was not more marked in the longest delay condition of pure plus filled delay. One further finding was that no memory for order information remains when item information is forgotten.

Experiment V and the subsidiary Experiment VI were designed to investigate a possible artefact in research designs. The purpose was to attempt to exclude the cognitive effects of the anticipation of experimental treatments from the effects of treatment per se. The main experiment controlled rehearsal during presentation whereas Experiment VI validated this method by presenting unexpected treatments. The results suggested that differential rehearsal of material under the filled delay condition in the earlier studies could not account for the low recall of terminal items. The results were characterised by attenuated primacy effects and therefore were consistent with the hypothesis that the primacy effect depends on cumulative rehearsal. Among the more unexpected findings was a strong reminiscence effect under pure delay alone, even though there were more unstable items under this condition than after immediate recall. The chapter concluded with the recommendation that the full serial position curves should be examined for a more fine-grained analysis. This is done in the following chapter, where an attempt is made to integrate the experiments and relate the findings to other published work.

CHAPTER V

Rehearsal and recall: further analysis and discussion

The time period embraced by the research reported in the preceding chapter saw a remarkable development in the field of short-term memory, such that the basic conceptualisation of the serial position curve of immediate free recall, as reflecting both short-term and long-term memory components, has become widely accepted. However, despite the numerous studies which have been generated in this problem area, relatively little advance has been made in areas pertinent to the outstanding problems of the earlier chapter.

Before examining in more detail and at a wider level the results of Chapter IV, it would seem worthwhile to discuss briefly some recent developments which are in line with the model adopted for the research reported earlier.

The work of Glanzer & Cunitz (1966) has contributed greatly to the recent research, which has examined free recall data for the basis of a distinction between short-term and long-term memory. However, the paper by Waugh & Norman (1965) has emerged as possibly even more influential. Viewed in retrospect, it is apparent that Waugh & Norman (1965) had developed a more sophisticated theory of short-term memory than Glanzer & Cunitz (1966) and, in addition, both anticipated and extended their findings, albeit partly, by reanalysis of previously published results. Although Waugh & Norman were unjustifiably neglected, it is clear that the cryptic presentation of material in their paper must have contributed in no small way to its neglect by other researchers. Thus, a number of the recent studies on the "two storage mechanisms" theory have only cited Glanzer & Cunitz among the relevant precursors (e.g. Baddeley, 1970; Bartz, 1969; Craig & Bartz, 1969; Ellis & Hope, 1968; Jahnke, 1968). Also, Kintsch (1970), in reviewing this model of memory, emphasises the work of Glanzer & Cunitz and only some pages later does he review the theoretical contribution of Waugh & Norman (Kintsch, 1970, pp. 154-160). Further, Norman (1969a), in reviewing the paper he co-authored with Waugh, emphasises the theoretical contribution which Waugh & Norman made, without reference to any of the empirical work, so that the reader is left with the impression that an interesting notion is being presented, rather than a tested theory.

Waugh & Norman (1965) did, however, present convincing evidence for their model. First of all, they presented the results of an experiment, varying presentation rate to show that the probability of recall of the presented item (digit sequences) was proportional to the number of items intervening between presentation and recall and "for all practical purposes was independent of the rate at which the digits were read" (Waugh & Norman, 1965, p.92). The authors assume that the instructions to subjects to concentrate only on the last presented digit were effective and the study was, therefore, only measuring "primary memory". There are reasons for disbelieving the efficacity of such instructions (see Chapter I), but since only four subjects were tested, personal relationships with the experimenters may have accounted for an unusual degree of cooperation and the authors' empirical results certainly support their assumptions. Secondly, Waugh & Norman present reanalyses of earlier studies of free recall by Deese & Kaufman (1957) and Murdock (1962) to support their theory of the independence of short-term memory of presentation rate but, in this instance, restrict their analysis to terminal items of the lists. The authors compare these reanalysed results with some published data by Waugh (1962) which also show that the recall performance on terminal items is independent of list length and of whether the items were presented in a massed fashion (repeatedly in a row) or a distributed fashion (repeated in different places in the lists).

The recent developments in short-term memory have served to underline the reliability of these findings that terminal items are not affected by the same variables which affect earlier items in a list.

The main findings to have emerged are that variables which affect long-term memory and early presented items of a sequence - such as word frequency, semantic and associative factors - do not influence terminal items of a list (Craik & Levy, 1970; Glanzer & Schwartz, 1971; Kintsch & Buschke, 1969; Raymond, 1969). Not unexpectedly, there are many more studies which make the point that the recency effect of immediate free recall represents memory for comparatively very unstable material (e.g. Bruder, 1970; Craik, 1970; Cohen, 1970; Ellis & Hope, 1968; Ellis & Anders, 1969; Glanzer, Gianutsos & Dubin, 1969; Madigan & McCabe, 1971; Tell, 1971; Thurm & Glanzer, 1971). Further, the reliability of such effects allows the interpretation of a number of earlier studies in terms of different memories being involved at different serial positions (e.g. Howe, 1965, 1967; Murdock, 1963; Posner, 1964).

Of particular interest for the present thesis are those studies which have examined repetition and rehearsal in terms of the "two storage mechanisms" model. Some discussion will be made of these before re-examining the empirical work described in the previous chapter, since this subject is central to the experiments reported earlier. Some of these studies are complicated by interaction effects or are confounded with vocalisation and these will be discussed in more detail at a later stage, since only the last two experiments reported utilised the technique of vocalisation-at-presentation. Further, these studies by no means present a tidy picture of effects and make very little attempt to reconcile their differences with previously reported research.

A certain amount of recent research presents results consistent with the "two storage mechanisms" model and the results described in the earlier chapter, in so far as they attribute the primacy effect of the serial position curve to cumulative rehearsal of material (e.g. Thurm & Glanzer, 1971; Corballis, 1969; Sampson, 1969) and such results, are quite consistent with the research reported in the earlier chapter, with the recent work cited above and with such early studies as Welch & Burnett (1924).

More interesting are those studies which deal with the "fate of primary memory items in free recall" (Craik, 1970). A number of studies have suggested that the material retained in terminal positions cannot be recalled when subjects are offered a second and unexpected opportunity to recall the presented sequence (e.g. Craik, 1970; Madigan & McCabe, 1971). These experiments are not too important for the question of whether material held in short-term memory can be rehearsed into long-term memory, since they merely show that such processing is not essential. They do not indicate whether subjects are able to process terminal items. However, such studies are interesting in that they demonstrate that the act of recalling short-term memory items does not lead to any "automatic" transfer to long-term memory.

A similar kind of experiment performed recently is one which has examined the Hebb (1961) effect in terms of the "two storage mechanisms" hypothesis. Hebb (1961), it will be remembered, demonstrated that when digit strings in an immediate memory task are repeated, some improvement in recall takes place. Subjects listened to 9 digits presented at the rate of 1 item per second. Twenty-four such trials were given and, on every third trial, the same string of 9 digits was repeated. Recall on these repeated strings improved as a function of trials whereas the new strings did not change, so that a practice effect can be ruled out. As Melton (1963) has pointed out, Hebb felt that this proved that immediate memory does not simply involve activity traces but lays down some more permanent memory trace. If immediate memory is viewed as representing both long- and short-term memory, with early presented items being retained in long-term memory, then it might be expected that learning would only take place for early items in the presented string. Such a view is supported by Bartz, 1969, and by Craig & Bartz, 1969, who showed that improvement with repetition of digit strings only takes place on early presented items. Further evidence for this comes from Schwartz & Bryden (1966) who failed to show any effect of repetition when the first two items of the repeated string were changed. Interpretation of these findings is somewhat complicated by the results of Bower & Winzenz (1969) who, in addition to essentially replicating the above studies, showed that a change in the grouping of repeated digit strings (e.g. 17-683-945-2 repeated as 176-8-394-52) can prevent learning taking place. This experiment would seem to question by how much material is recoded in memory by processing and may suggest that when material is presented in a rhythmic or grouped manner (see Chapter III), then subjects do not attempt to recode the information. Support for this view would seem to be provided by Müller & Schumann (1894) who apparently noted that subjects repeated back material in a "chunked" fashion, when nonsense syllables were presented to them in a rhythmic manner. McLean & Gregg (1967) have recently presented similar findings in showing that when random sequences of letters were presented visually in groups of 1,3,4,6 and 8 items, subjects appeared to recall the material in groups corresponding to the size of those used at presentation. Such findings would be quite consistent with those studies reporting superior recall for grouped sequences (e.g. Ryan, 1969a,b; Severin & Rigby, 1963; Thorpe & Rowland, 1965) in so far as they suggest that presenting material in a grouped fashion saves subjects having to process the information for themselves.

It is not clear from the data of Bower & Winzenz (1969) how much change in the grouping of the digit strings was necessary to prevent any beneficial effect of repetition. However, the amount of material held in long-term memory on a new trial would largely reflect the presentation rate and possibly only involved the first two items of a sequence (cf. Matthews & Hoggart, 1970).

These studies of the Hebb effect are interesting but are perhaps most relevant to the previous chapter only in supporting the "two storage mechanisms" view by demonstrating that the learning in this task takes place in a serial manner. They do not offer any data relevant to the question of whether terminal items of a presented sequence can be transferred from short-term to long-term memory, nor do they offer much theoretical advance on the conceptualisation of the preceding chapter.

Unfortunately, to date there has been no empirical evidence relevant to the question of whether subjects can transfer terminal items successfully to long-term memory if given the opportunity to do so. However, one recent theory of human memory represents an ambitious and sophisticated attempt to address the relationship between rehearsal and short-term and long-term memory.

Atkinson & Shiffrin (1968) proposed that memory consists of three major components: a sensory register, a short-term store and a long-term store. All three are similar enough to the tripartite distinction adopted earlier as not to require definition. In most verbal learning and memory tasks the sensory register will not contribute to performance because its duration is too short. However, the short-term store is particularly important in that it constitutes a "rehearsal buffer" which allows the transfer of material to the long-term store. Transfer takes place with a probability proportional to the length of residence of material in the buffer and items are disrupted from this buffer by new incoming items. It is impossible to do justice here to this model, cited above (see also Brelsford & Atkinson, 1968; Shiffrin, 1970; Shiffrin & Atkinson, 1969;) which covers over 100 pages in its fullest form. However, perhaps the most interesting feature of the model is that it places emphasis on the control processes possible in memory. Thus, there is a wide variance in the amount and form of the transferred information. When a subject rehearses material in the short-term store by simply repeating it, "the information transferred would be in a relatively weak state and easily subject to interference. On the other hand, the subject may divert his effort from rehearsal *to various coding operations which will increase the strength of the stored information." (Atkinson & Shiffrin, 1968, p. 115).

*Atkinson & Shiffrin use this concept in the sense of mere recirculation of information - i.e. repetition

This aspect of the model has two features worthy of comment. The first and most unusual is that material can be lost from long-term memory. The second is that a slow transfer of information from short- to long-term memory is possible with mere repetition but this will be much increased by a deliberate attempt to make this transfer possible. Unfortunately, for the present discussion, the empirical work in support of the model is derived from an item probe task which discourages the use of the buffer store as a means of processing information into the long-term store. The task adopted in the experiments is very close to that outlined by Yntema & Mueser (1960, 1962) and similar to that utilised by Waugh & Norman (1965). It involved the presentation of continuous sequences of trials of paired associates with random selection of stimuli for test. The subject's task was to give the most recent response paired with the test stimulus. The data arising from such experiments gives the probability of correct recall as a function of the lag between item presentation and item test. Both Waugh & Norman (1965) and Atkinson & Shiffrin (1968) present this kind of data almost as if it were the recency effect of an immediate free recall experiment. However, item probe and free recall studies would typically differ in the important respect that subjects would know when the sequence was going to end in free recall experiments. Since the rehearsal buffer is seen by Atkinson & Shiffrin as being under the control of the subject, it would seem possible that subjects could clear this buffer at some optimum point before the last few items were presented and refill this to capacity with terminal items for immediate unloading.

For the present discussion the item probe task has the disadvantage noted earlier that it does not facilitate long-term memory processing. This is a point which Atkinson & Shiffrin (1968, p.124) recognise ; "... the subject soon learns that the usual long-term storage operations, such as coding, are not particularly useful.... the subject is forced to rely heavily on his short-term store....". Of course, Atkinson & Shiffrin did not attempt to test all of the implications which their model makes, but the use of the item probe procedure results in their test of the rehearsal buffer - long-term store relationship being of only slight relevance to the research reported in the previous chapter. This experiment (Atkinson & Shiffrin, 1968, Experiment IV, p. 153 ff.) examined whether an increase in the duration of an item in the rehearsal buffer could be made possible by experimental treatment. This was tested by requiring subjects to vocalise twice each item as it was presented. This procedure led to an improvement in the recall scores over a silent study control condition. Although these results are apparently in line with the authors' expectations (a full discussion of the hypothesis is not offered) a number of problems are presented by this study.

First of all, it would seem that the occasions on which subjects do not use the rehearsal buffer are those on which subjects can remember more information by not storing a recent item in the buffer. For example, "the buffer at some particular time may consist of a combination of items especially easy to rehearse and the subject may not wish to destroy the combination" (Atkinson & Shiffrin, 1968, p. 128). Thus, forcing the subject to enter each new incoming item into the rehearsal buffer could be expected to lead to poorer performance on Atkinson & Shiffrin's model. Secondly, the improvement due to the vocalisation at presentation is almost entirely localised on the last few presented items. Performance for the two groups is identical on the last item presented, but superior for the vocalising group on the penultimate item and the two items presented before this. All earlier items show very similar recall probabilities. Although the model of Atkinson & Shiffrin allows information transferred to the long-term store to be in a weak state, the results would seem to demonstrate only that the probability of a recent item being located in the rehearsal buffer is higher when subjects are required to vocalise the presented material. As such, the results are quite consistent with other studies examining the effects of vocalisation at presentation to visually presented material to be discussed later.

At a somewhat broader level than that of empirical findings is that of quantitative limits placed on parameters by Atkinson & Shiffrin. One of the interesting aspects of their model is that it represents one of the first, and remains one of the most successful and illuminating attempts at a mathematical/computer model of human memory. Atkinson & Shiffrin attempt to describe their empirical results by curve fitting according to certain parameters. Of these, that of the capacity of the rehearsal buffer and that of the rate of information transmission from the rehearsal buffer to the long-term store are of particular interest. Unfortunately, as with nearly all of the recent mathematical/computer models (see Norman, 1970), the level of analysis of the curve fitting lags well behind that of the initial conceptualisation of the problem. This is perhaps most clearly seen in the Atkinson & Shiffrin data since their analysis covers more empirical work than most such studies. Throughout the series of experiments analysed, little attempt is made to assess the meaning of the parameter values which are thrown out. Of course, these values are largely taken in support of the initial model since they "work" in describing the data. Just one example will be given of this since it is most relevant to the work of Chapter IV.

Atkinson & Shiffrin report parameter values for the rate of information transmission from the short-term store to the long-term store of between 0.04 and 0.2 per second. Little attempt is made to explain the great variation in these information transmission rates, and it is not entirely clear what unit of measurement is used. Presumably, the values refer to the probability of recall of items per second of duration in the buffer store. However, the fact that the lowest information transmission rate (of .04 per second) was obtained from analysis of free recall experiments would suggest that there is something drastically wrong in their method of estimating parameters. The reason for asserting this is that the majority of the information transmission rates are obtained from analysis of item probe studies, which, as Atkinson & Shiffrin recognise, discourage transfer of material to long-term memory. Studies of free recall, on the contrary, typically show a very large long-term memory component and strongly suggest that the task encourages information transfer from short- to long-term memory. This aspect of free recall studies has been well emphasised in earlier discussion.

A somewhat similar criticism may be applied to attempt to estimate the size of the short-term memory store. A number of writers have offered values for this parameter and although more than one technique has been suggested for this, the arguments remain unconvincing. Broadly speaking, three methods of assessing the size of short-term memory have been recommended.

The first method, put forward by Tulving & Colotla (1970) is one which classes recalled information as being from short-term memory provided that no more than 7 words (either later stimuli or responses) have intervened between an item's presentation and its recall. This formula ignores the possibility of some terminal items being contained within long-term memory and yet recalled early. This could happen where a terminal stimulus has certain distinctive features which allow its rapid access to long-term memory (the subject's own name as an extreme example) but is nonetheless recalled at the same time as terminal items because the subject attempts to recall items in temporally equivalent groups. (cf. Tulving, 1969).

The second method, described by Baddeley, Scott, Dynan & Smith (1969), relies on the difference between the recall scores of immediate recall and recall after an interpolated task. This formula ignores the possibility of forgetting in long-term memory and the possibility of items being contained in long-term memory at terminal positions in immediate free recall.

The third method allows for the fact that the immediate recall of terminal items may tap long-term memory and applies a suitable correction for this probability (Waugh & Norman, 1965). A slight variation on the standard psychophysical guessing correction recommended by Waugh & Norman for this has recently been offered by Baddeley (1970). These 2 methods are preferable to the other two, but ignore the possibility of forgetting in long-term memory (Atkinson & Shiffrin, 1968).

These various estimates of the size of the short-term memory component in free recall are clearly open to question but, in comparison to the estimates of the transfer rate from short-term memory to long-term memory, do not yield such widely discrepant rates. The range reported for the size of the short-term memory store would seem to be from a minimum of 2.1 (Baddeley, 1970) to 3.6 items (Craik, 1970). However, this range is sufficient to urge caution in this area.

Turning to the theoretical developments in the last few years, it is sad to note that there is little in the way of guidelines for predicting the outcome of the main experimental hypothesis of the preceding chapter. The model of Atkinson & Shiffrin would seem the most relevant in that these authors imply certain outcomes consist with the hypothesis that a pure delay before a filled delay should lead to the transfer of material from the buffer store to long-term memory. Since the basics of their model have already been presented, it is unnecessary to restate the relevant arguments here. Suffice it to say that the mere recirculation of information in short-term memory should lead to some transfer to long-term memory but that if active recoding by rehearsal is attempted by subjects, then such transfer should be much more rapid and more permanent.

The experiments of Chapter IV

Since the outcome of these experiments has been adequately summarised at the termination of the preceding chapter, the reader is referred to this for introduction to the present discussion. Experiment I of the preceding chapter used a partial recall procedure to test the two hypotheses that information from terminal items was still available after a filled delay and (if not) that a pure delay before a filled delay would allow its transfer to long-term memory where it would not be disrupted by an interpolated task.

The results of this experiment taken in conjunction with those of Atkinson & Shiffrin (1968) suggest strongly that terminal items are largely unavailable after a filled delay and that other results demonstrating this (e.g. Glanzer & Cunitz, 1966; Postman & Phillips, 1965) are not interpretable in terms of subjects choosing not to recall terminal items first.

The second hypothesis that a pure (unfilled) delay of 20 seconds before a filled delay (digit subtraction task) lasting 10 seconds would allow the transfer of all the terminal items in the recency effect from short-term to long-term memory was not supported. The rehearsal opportunity offered by the pure delay did not lead to any significant improvement in recall under a filled delay alone condition. Since this result contradicted a pilot study using full recall, a series of experiments was initiated to investigate the problem. In these experiments discussion and hypothesis were generated more by the discrepancies between the experiments in the series than by the original question.

It would seem useful, therefore, to make some general statements about the experiments as a series in terms of the fate of terminal items.

As a series, the experiments of Chapter IV indicate that while some gain in the stability of terminal items is occasioned by rehearsal opportunity, the order in which these items are remembered is likely to be forgotten. Although the differences were not always significant, none of the experiments failed to show some improvement in the recall of terminal items in the pure plus filled delay condition over that of filled delay alone.

The puzzling aspect of these findings is that the number of terminal items recalled after the pure plus filled delay was never as great as that in the immediate recall condition. In other words, the expectation that subjects would be able to transfer all of the terminal items from short- to long-term memory and thus make these items resistant to the disrupting effects of the interpolated task was not confirmed. There would seem to be two possible explanations for this - either subjects were not able to transfer all the material in the last presented group to long-term memory or items were transferred, but some forgetting took place in long-term memory. There is some reason for disbelieving both of these possibilities.

Taking, first of all, the question of the ability of subjects to transfer terminal items to long-term memory, it is possible to give some estimate of the likely transfer rate and that actually achieved. If subjects for some reason found the processing of information more difficult to achieve as list lengths increased, it would be expected that the number of items recalled from the long-term memory in the terminal group would always be less than the number recalled in the middle group of the sequence. Except for experiment I, none of the other experiments in this series supports this hypothesis. For this reason, no reduction in the processing rate should be expected during the additional rehearsal opportunity offered when the sequence has been presented. Indeed, since all items in the terminal group are already in the rehearsal buffer, it should be higher. Although the experiments differ in many respects, it is possible to give a crude overall indication of the processing rates during presentation and during the rehearsal opportunity. The number of items recalled from the final group after filled delay alone suggests a long-term memory transfer rate over all the experiments was approximately 0.15 items/second. The difference between the number of items recalled after pure delay plus filled delay and that recalled after filled delay alone may allow a rough estimate of the transfer rate to long-term memory during the pure delay. Over all the experiments this transfer rate is .03 items/second. Thus, on these crude estimates, the transfer rate from short- to long-term memory would seem to be approx. 5 times higher during the presentation of items than it is during silent rehearsal following presentation.

It would seem very unlikely that terminal items are not rehearsed during this rehearsal opportunity, since in each experiment the pure delay alone condition showed little if any forgetting of terminal items compared with the immediate recall condition.

Turning to the possibility that terminal items were rehearsed into long-term memory but forgotten during the filled delay, it cannot be stated with any certainty whether this was the case. The problem of knowing whether forgetting takes place in long-term memory over short retention intervals would seem impossible to answer, since there would seem little way of distinguishing operationally between rapid forgetting in long-term memory and rapid forgetting in short-term memory. However, if the terminal items which have been transferred to long-term memory are liable to forgetting at a slower rate than items still in short-term memory, then the order of recall for the transferred items might be expected to be of some importance. In particular, since last presented items are recalled last after pure plus filled delay (see Experiment II), then requiring subjects to recall these items first should lead to some improvement. The results of experiment I using a partial recall procedure do not support this hypothesis. Thus, if forgetting takes place after terminal items have been transferred to long-term memory, then this forgetting is accomplished with a similar rapidity to that shown in the loss of the terminal items when a filled delay is introduced immediately after presentation.

The more likely explanation of the results of Chapter IV would seem to be that subjects are not able to transfer much information to long-term memory beyond that which is processed during presentation. Although the findings on which this interpretation is made seem in line with a number of earlier studies (e.g. Brown, 1958; Hellyer, 1962; Sanders, 1961), the similarity of the present results to those of earlier studies is somewhat surprising. The main methodological difference between earlier studies, demonstrating a small improvement due to rehearsal opportunity before a filled delay, and the present series of experiments, lies in the model adopted in the present work. This led to postulating that short-term memory would typically only appear in the immediate free recall of the last presented items. Other studies which have used ordered recall would not be likely to measure a short-term component. Additionally, it cannot be known from earlier work where the improvement occurred, so that interpretation of the causes of the improvement are problematical. The present results provide a notable advance on interpretative possibilities by showing that subjects appear to rehearse terminal items during a pure delay and stabilise these items to some extent. They also show that after pure delay followed by an interpolated task, recall order does not appear to be important for the number of terminal items recalled and that the necessity of recalling items in the correct order may depress performance.

Before examining the issue of order information, it is convenient to conclude discussion of the retention of terminal items by reference to the full serial position curves. These curves are presented in Appendices O, P, Q, R, S, T and U.

It was anticipated that the method of presenting material in the experiments of Chapter IV, namely in three groups of five items, would have encouraged subjects to attempt to recall all of the last group of items from short-term memory. Although immediate recall of this terminal group was high (85% in Experiment V) it is apparent from examination of other free recall data that recall scores over the last five items of around 80% are possible (e.g. Glanzer & Meinzer, 1967; Murdock, 1962). Thus, the modified experimental design cannot be said to have led to any noticeable gain on the terminal group.

However, it is of interest to note that the recency effect of immediate free recall is not a constant number of items. Auditory presentation typically leads to a more pronounced recency effect and this point will be discussed later. However, other studies using auditory presentation have reported recall scores over the last five items of as low as 40% (e.g. Murdock, 1967b). The main point of this observation is that while numerous studies cited earlier have suggested that the recency effect of immediate free recall is independent of most experimental treatments such as presentation rate, list length, repetition and word frequency, studies apparently differing only on these dimensions differ in the amount of recency effect shown.

Although the total number of items recalled over the last group was not as high as anticipated, inspection of the serial position curves for the experiments of Chapter IV (see Appendices O,P,Q,R,S,T and U) suggests that the presentation of material in groups changed the slope of the serial position curve. Typically, the recency effect of immediate free recall is described by an exponential decline from the last presented item. The serial position curves of the present series of experiments show irregular functions, but, with the exception of Experiment I, clear separations of the last presented group of items from the middle group. In particular, the first item of the last group, item 11, is exceptionally well recalled. It is apparent from the serial position curves that this item is not invulnerable to the disrupting effects of the interpolated task so that there is little reason for assuming that it has a higher probability of transfer to long-term memory than other items. Additionally, there is little indication from Experiments IV and V, which scored items by both a free recall and an ordered recall criterion, that the serial position of this item is relatively well remembered. This is somewhat surprising since, although the pause introduced before the final group no doubt made the first item of this group distinctive (von Restorff, 1938), and possibly as a consequence made an "anchor point" for other items (Fiegenbaum & Simon, 1962), subjects were well aware that a pause preceded each group of items and so should have remembered the position of the 11th item very well.

The "bowing" of the serial position curves within the terminal group of items is also shown to some extent in the two earlier groups where there is some indication that the first item in each group, and to some extent the last item in each group, were better recalled than middle items. Drevenstedt (1970) has recently presented similar data from grouped material but the cause of this effect is not clear. The most obvious explanation is that breaking the presented sequence up into groups anchors serial position knowledge within the sequence. However, the bowing within each group of the serial position curves is much more marked in Experiment II, which did not require knowledge of serial position, than in Experiment I, where memory for the position of the first item of a group was very important for the recall of items because of the partial recall procedure. Quite possibly, this phenomenon simply reflects some additional rehearsal given because the distinctive position of an item suggests it may be easy to remember and this additional rehearsal reduces the amount of attention given to the following few items (Massaro, 1970, and cf. Tulving, 1969). However such a view would carry the implication of increased resistance to forgetting of the rehearsal favoured items and there is little evidence to support this. An attractive alternative notion is that distinctive cues (such as provided by the pauses) define the search set through memory. A restriction to examine selectively items near the beginning of each group should increase the probability of recall of such items over a random search strategy (McLaughlin, 1968; Shiffrin, 1970). Such an explanation would account for the failure of Experiment V to remove the primacy effect despite controlled rehearsal. Certainly the model of Atkinson & Shiffrin (1968) which views the length of residence of material in the response buffer as a determinant of the primacy effect would not seem able to handle the difference in transfer rates between initial items in a sequence and the last items during the pure delay.

The technique of grouping the presented material and the separate measures of item and order information discussed above may introduce a complicated debate on organisational processes in recall. Despite the importance attached to a distinction between item and order information by such writers as Brown (1959) and Crossman (1961), this issue has been surprisingly neglected. A majority of studies would seem to suggest that order information is important to the recall of item information: Rosenberg (1966) and Tulving (1962) have demonstrated a high correspondence between multi-trial recall orders, Kintsch (1970) has shown that items temporally adjacent at presentation are recalled in adjacent positions, Young (1968) has shown that subjects can be instructed to retrieve information on a temporal basis. However, the most impressive evidence that subjects remember material in the order in which it is presented, and that order information is necessary for remembering the item information, comes from studies using digit strings (e.g. Bower & Winzenz, 1969; Corballis, 1969; Donaldson & Glathe, 1969; Johnson, 1970). It would seem probable that digits are more likely to be retained in their presented order than other kinds of material since to remember ordinal information otherwise may be considered disfunctional. Possibly a similar case might be made for letter strings. Thus there may be some justification in assuming that the amount of information transmitted by the retention of digit strings, and possibly letter strings, is given by the amount of item information alone, whereas for other vocabularies the total information transmitted would be the amount of item information plus the amount of order information (see Chapter III). If Crossman's data (1961) is re-examined in this way, the exceptionally high information rates for digits and letters reduce to a figure very similar to that given for the other vocabularies used in Crossman's memory task.

This is not to deny that the retention of the order in which other material is presented may not be closely associated with the retention of item information. Indeed, in one recent study the authors concluded from their results ".... our preferred interpretation is that position knowledge of a spatial-temporal nature is such a fundamental dimension of memory that it is an integral part of the learning process" (Zimmerman & Underwood, 1968, p. 306). In a sense it is not too surprising that subjects should handle verbal material in a sequential order since this is compatible with most experience of using verbal skills. Thus, subjects typically report rows of letters in the same order as their reading habits would indicate : with English-speaking peoples from left to right (Corballis, 1964; Heron, 1957; Kimura, 1959), except when mirror-imaged letters are presented, when the order of report is from right to left (Harcum & Filion, 1963; Winnik & Dornbush, 1965). Hebrew readers, on the other hand, typically report tachistoscopically-presented material from right to left (e.g. Harcum & Friedman, 1963).

Although there is a certain amount of evidence of this kind that a sequential order of presentation of material may be compatible with the processing which subjects would perform on material, such observations are of a different order from the conclusions of Zimmerman & Underwood (1968) cited above. These authors suggest that temporal information about items is processed without any "cost" to the system: a temporal code about each item is part and parcel of what the subject stores about the material to be remembered even under instructions to process only item information (Tulving & Madigan, 1970). This conclusion is one which contradicts that made in Chapter IV and, since both studies used common English words, the basis for Zimmerman & Underwood's conclusions must be examined.

Perhaps the main reservation which should be entertained in interpreting the results of Zimmerman & Underwood is that, like Experiment VI reported in the previous chapter, it was a study involving some deception of the subject. Separate groups of subjects were informed that they should remember either item information or order information but all groups were required to recall order information. Unfortunately, Zimmerman & Underwood do not make reference to the possibility of subjects being aware of the purpose of the experiment. Since the study was conducted at an American university and the subjects were likely to have taken part as a course requirement, the possibility of communication between subjects must be considered seriously. It may be noted parenthetically that such problems were recognised in the deception study reported in Chapter IV and measures were taken to ensure that subjects were ignorant of the aims of the experiment. When subjects were invited to participate, they were asked - for purposes of excluding sophisticated subjects - whether any friends had commented recently on taking part in a psychological experiment. This is a far better method than a post-experimental interview (Berkowitz, 1967), since subjects may be reluctant to confess to "cheating" after they have completed the experiment, as this would mean that they had wasted the time of the experimenter.

However, if steps were taken to safeguard against this source of error, then the results of Zimmerman & Underwood are of interest and relevance to the present research. Their experimental design was quite different from that used in the experiments of Chapter IV since subjects were allowed up to 60 seconds to learn either 8 or 12 words printed on a card. Possibly under such circumstances subjects attempt to learn the words in a cumulative rehearsal manner, thus learning serial positions as they proceed (Corballis, 1969). Unfortunately, since serial position curves are not presented, this can only remain a likely explanation.

Support for the view that the serial position of items is learned by cumulative rehearsal comes from Experiment V, reported in the preceding chapter. In this study, which effectively discouraged cumulative rehearsal, the order in which items were presented was very poorly retained compared with the other experiments of the series. This would seem to constitute an additional consideration in favour of the earlier point made in Chapter IV that the necessity of retaining order information appeared to reduce the amount of item information retained. Examination of the serial position curves of Experiments II, III and IV for suggestive trends, fails to reveal any points beyond those already raised. However, there is some slight indication (shown in the recall profiles of Chapter IV) that the necessity of retaining order information may depress early items more than the terminal ones. Such a trend would be consistent with the two storage mechanisms model adopted in the present discussion, which states that early presented material is learned by rehearsal so that the need to pay attention to the order of items would involve some reduction in the rehearsal of item information.

A related issue to the independence of item and order information, as discussed above, is that of the forgetting rate for these two kinds of information. The data from Chapter IV indicated that order information may be forgotten more rapidly than item information and when item information is forgotten no order information remains. However, subjects are well able to recall item information in the absence of order information. Two recent studies, again using words for the memory task, have offered support for the first statement in suggesting that order information is forgotten more rapidly than item information (Murdock & vom Saal, 1967; McNicol, 1970).

Examination of the serial position curves (in Appendix O and seq.) fails to reveal any suggestive trends for selective forgetting of serial positions beyond those apparent in the recall profiles reported in the preceding chapter. However, it would seem that order information is worst retained in the middle group of items although this point was not made earlier. The percentage of items recalled in the wrong order over all experiments and conditions is : First group = 26%; Middle group = 36%; Last group = 24%. Such differences would be expected under a model which viewed item information as to some extent independent of order information and must, therefore, present some problems for theories which do not recognise any independence between item and order information (Bower & Winzenz, 1969; Bryden, 1967; Johnson, 1970; Zimmerman & Underwood, 1968).

Unfortunately, the data available does not offer much indication of how order information for word sequences is retained. Some of the results discussed so far have suggested that the retention of order information relies more than item information does on rehearsal during presentation. The main evidence for this comes from the results of experiment V which also presents some complicating findings.

Experiments III and IV noted a tendency for more order information to be lost with time than item information. This trend was not apparent in Experiment V, which in fact showed the pure delay alone condition to be markedly superior to the immediate recall condition when the results were marked to the ordered recall criterion, but less difference between the conditions when scoring was conducted to the free recall criterion.

These differences are apparently not accountable for by any simple explanation such as the data of Experiment V representing more short-term memory than long-term memory since there is a tendency in Experiment IV for the terminal group of items more than earlier items to suffer a larger loss of order information than item information with a filled delay. Additionally, if the Baddeley et al technique (1969) is used to estimate the short-term memory component in the two experiments, the values suggest that Experiment V did not measure more short-term memory than Experiment IV. In Experiment IV for ordered recall criterion scoring the value is 1.15 items, for free recall criterion scoring, 1.9 items, whereas for Experiment V the values are 1.3 items and 1.2 items for the two scoring methods respectively.

In the absence of convincing evidence to the contrary, it would seem possible that order information may be provided from various sources. First of all, some concept of recency may be provided by "time tags" (Winograd, 1968a, b; Yntema & Trask, 1963) which may not be rehearsed and decay with time. These may even provide confusing information if the material is not rehearsed before recall is attempted and the recall takes place in a non-sequential manner. Material which is rehearsed may find the order information provided by rhythmic grouping (Johnson, 1966; Ryan, 1969b) or chunking of various sorts (Rosenberg, 1966; Tulving, 1968). Different orders of rehearsal (long-term coding) may also provide multiple cues for order information (e.g. Ebenholtz, 1963; Jensen & Rohwer, 1965; Young, Patterson & Benson, 1963) by means of associative chaining and position learning for example. It is quite possible that Experiment V, in requiring fixed rehearsal of the material, prevented anything other than "time tags" existing so that post-presentation rehearsal may have covered the item information available and used the time tags to chunk the material in a way which allowed the order information to be more integrally related to the items.

Discussion of the unusual feature of Experiment V in showing a reminiscence effect for order information must not ignore the similarly large reminiscence effect for item information. It would seem unlikely that traditional explanations of the reminiscence effect are applicable to the present data (Buxton, 1943). Although reminiscence has been previously observed in short-term memory (Crawford, Hunt & Peak, 1966; Keppel & Underwood, 1967; Scheifer & Voss, 1969), the relevance of other studies is problematical since Experiment V differed methodologically, and did not show poorer immediate recall for item information than did Experiment IV. Neither were effects of proactive inhibition apparent in that the first experimental trial produced identical performance to the final trial. Perhaps more importantly, reminiscence occurred over immediate recall performance whereas other studies typically show reminiscence taking place in the forgetting curve which declines rapidly at first and then rises to a level approaching that of immediate recall. It would seem likely, therefore, that the reason for the unusual results of Experiment V must lie in the vocalisation at presentation.

A large number of studies have demonstrated that vocalisation at presentation may improve short-term memory. However, almost all these studies have examined the effects of vocalising to a visual presented stimulus and under such circumstances the improvement is closely parallel to that obtained when auditory presentation is compared with visual presentation (e.g. Conrad & Hull, 1968; Murray, 1966b; Woodhead, 1966b). A number of studies have demonstrated poorer performance after vocalisation at presentation (Allen, 1968; Bushke & Kintsch, 1970; Poulton & Brown, 1968) but almost all studies reporting serial position curves show that vocalisation leads to an improvement in the recall of terminal items, although early presented items may suffer some decrement. The possibility that subjects may pay less attention to terminal items with visual presentation (as suggested in the preceding chapter) has recently been addressed by Routh (1970, 1971) and support found for theories which postulate the existence of different sensory analysis systems (Crowder & Morton, 1969; Murdock & Walker, 1969; Neisser, 1967). Such theories argue that the recency effect of auditory presentation over visual presentation is provided by a pre-perceptual sensory store.

One recent theory of the nature of the auditory recency effect has some interesting implication for the vocalisation of aurally presented material. In a series of papers, Crowder & Morton (Crowder, 1969, 1970; Crowder & Morton, 1969; Morton, 1970; Morton & Holloway, 1970) describe a precategorical acoustic storage which is similar enough to the auditory sensory memory described in Chapter I as not to require further amplification. Aurally presented material which is held in this store for approximately 2 seconds can be knocked out by the auditory presentation of a redundant stimulus suffix, but this suffix effect only occurs when there is a physical match between the voice delivering the stimulus and the voice delivering the redundant suffix element. Most of the authors' work has stemmed from a similar observation that a response suffix - i.e. recalling a redundant element before the memory task - does not disrupt the pre-categorical acoustic storage because, presumably, the voice of the subject can be treated separately from the voice of the experimenter. However, most of these studies are difficult to interpret in view of the variable delays before subjects vocalise the response prefix. At times, too, Crowder & Morton's model is confusing. Thus, although the store is pre-categorical it must be post-attentional for any "attenuation" or "blocking" of the different voice from access to the acoustic store to occur. (Crowder & Morton, 1969, p. 370, p. 372). Additionally, Murdock (1967b) has claimed that the advantages of auditory presentation over visual presentation are to be found when an auditory probe is given for the item to be recalled. Murdock's experiment would not seem consistent with the stimulus suffix data. To be sure, some methodological points may provide room for manœuvre, but such apparently contradictory data should be borne in mind when assessing Crowder & Morton's work.

One possible explanation of the inability of subjects to ignore a redundant stimulus suffix, when it is presented in the same voice as the stimulus, is that the "blocking" of elements presented in a different voice does not in any meaningful sense reflect a control process of the subject. It may be that different material enters different stores so that there may be at least two pre-categorical acoustic stores. In such experiments as those reported by Crowder & Morton, only one of these stores would receive attention for processing.

In somewhat different circumstances there may exist evidence for independent acoustic stores. The early work of Cherry (1953) and of Moray (1959) suggested that non-attended auditory stimuli are not remembered at all. However, the attentional filter model which predicted such an effect has since been shown to be inadequate and, further, subjects can remember material presented to an unattended channel (Treisman, 1964 a,b,c). The work of Treisman would seem very relevant to the discussion of Crowder & Morton's results above, since subjects were performing a shadowing task (see Chapter I) and this involved presenting "different" auditory stimuli spoken by the same voice to the two ears. Crowder & Morton's model would seem to predict that both inputs would enter the same pre-categorical acoustic storage and so disrupt each other. However, the shadowed channel is not affected by the auditory input into the other ear (Broadbent, 1958). Crowder & Morton's model would, therefore, need to predict that the non-attended channel is "blocked" (Crowder & Morton, 1969). Again, such is not the case. Although there are a number of studies demonstrating that non-attended material does enter some kind of memory (Eriksen & Johnson, 1964; Norman, 1969b;Treisman, 1964a,b,c) some recent and compelling evidence has been offered by Glucksberg & Cowen (1970).

Glucksberg & Cowen (1970) demonstrated that digits presented amid non-attended verbal material were remembered but that recall performance decreased from 0-5 seconds down to approximately 5% correct detections in a negatively accelerated fashion. In addition to this cued detection rate which was obtained for various time lags after the digit stimuli, subjects were asked to report "whenever it appeared likely that a digit occurred" and this subjects were able to do at a correct detection rate of 5%. This condition provided a baseline of the number of unattended stimuli which were noticed by subjects.

Thus, it can be concluded that the Glucksberg & Cowen work shows total forgetting of unattended material after 5 seconds. Interestingly, the forgetting curve after 5 seconds remains at approximately 5% for a further 10 seconds showing the longer duration of attended stimuli. The main point of this experiment and similar studies is that unattended material may be retained for some time and apparently without any cost to the attended material.

Further support for the hypothesis that 2 auditory stimuli which differ in some way could be stored in an independent fashion may be provided by the work of Wickens, Born & Allen (1963) who showed a release from proactive inhibition with a change in the immediate memory task from digit strings to letter strings. This might be interpreted in terms of a change in memory stores used. However, it is clear that in this study the inhibitory effects on performance of similar kinds of material being presented over a number of trials cannot be readily reconciled with a view that immediate memory tasks measure output from a rehearsal buffer alone, nor with a view that the basis for categorisation of material for placement in different stores occurs at an early stage of processing. The Wickens, Born & Allen study must, therefore, be considered as showing perseveration of long-term memory material in a short-term memory task. This is of no embarrassment to the "two storage mechanisms" models if proactive inhibition effects do not occur on terminal items of long sequences. Unfortunately, the relevant data would not seem available.

The work of Bower & Winzenz (1969) is also relevant to the present argument since the authors suggest that, in their study of the Hebb effect, material which was regrouped when repeated on later trials was stored as a separate memory trace from the digit string initially presented and thus failed to add any additional strength to the initial string. Again the time period of memory with which this study was concerned places the separate stores at a somewhat different level than the pre-categorical acoustic storage discussed earlier.

In principle it would not seem unreasonable to suppose that different material may be stored and processed differently, but the lack of references to such a phenomenon suggests that if it does occur it may do so only under restricted circumstances. All of the studies cited above, which might be considered to have possibly demonstrated independent storing of different material, have used auditory presentation. It is of particular interest to note that one experiment reported by Bower & Winzenz (1969) used a visual presentation of a changed group digit string and found the typical Hebb effect. In this experiment it would seem that subjects may have recoded the visual sequence such that the group structure of the recoded string corresponded with that of the initial digit string. This would imply that recoding may be less likely to occur with auditory presentation than visual presentation. A somewhat similar argument has been made by others. Corballis (1966), Corballis & Loveless (1967) and Sherman & Turvey (1969) have argued that rehearsal is less likely to take place with auditory presentation than with visual. However, the basis for the view would seem to be only that auditory presented sequences may show less primacy than visually presented sequences.

Returning to the effects of vocalisation at presentation, as stated earlier, almost all the studies of this have used vocalisation to visually presented sequences. However, two experiments have been reported which have shown poorer recall with vocalisation to aurally presented sequences (Mackworth, 1964; Murdock, 1966). Mackworth (1964) used ordered recall and Murdock (1966) used a paired-associate task with the probe recall technique - thus requiring subjects to remember order information to the same degree as in Mackworth's experiment.

Experiment V cast some light on the effects of vocalising to aurally presented material by showing that this condition leads to a large loss of order information. Scoring the data from such an experiment to a free recall criterion shows no difference between the immediate recall of vocalised aurally presented material (Experiment V) and silently monitored aurally presented material (Experiment IV). An additional finding is that a rehearsal opportunity before the recall of vocalised aurally presented sequences leads to a considerable improvement in performance.

The hypothesis that auditory messages differing in some way may be stored separately may be relevant to this reminiscence effect. If the auditory stimulus were stored separately from the vocalised response made by the subject, then immediate recall might be complicated by the fact that effectively twice as many items had been "presented" as in a non-vocalised sequence. This would affect both the ability of subjects to recall the items and the order of the items. However, since meaningful words were used as the memory task, this argument would seem unlikely in recommending a pre-categorical or at least phonemic coding. Although this interpretation was rejected in Chapter IV, some recent studies have suggested that when rehearsal is made difficult (as was most certainly the case in Experiment V), then material may be coded at a phonemic level rather than a semantic one (Baddeley & Levy, 1971; Eagle & Ortoff, 1967; Gruneberg & Sykes, 1969). If this were the case, then post-presentation rehearsal might be expected to allow some recoding of the stored information. Such recoding could serve to reduce the material stored by combining the 2 separate acoustic representations of the presented stimuli into one meaningful item, but possibly fail to offer any gain in stability since such post-presentation recoding may require the use of the rehearsal buffer and the final outcome might be equivalent to that found in the immediate recall of unvocalised sequences. Examination of the stability of information in Experiment IV suggests that such might be the case. The effects of filled delay alone in Experiment IV led to a loss of 78 items compared with the immediate recall condition whereas in Experiment V pure delay plus filled delay produced 85 items less than the pure delay alone condition.

Such an interpretation as that outlined above is not a complete explanation of the results of Experiment V, but the number of points which might be discussed is so great that discussion is best limited to those aspects of the study which promise to repay further investigation. Perhaps one outstanding problem of the separate stores for different auditory material hypothesis is that it fails to account for the lack of any great forgetting due to filled delay alone in Experiment V. The recall scores for filled delay alone and for pure delay plus filled delay conditions were very similar in both the data marked to the ordered recall criterion (26% and 23% respectively) and that marked to the free recall criterion (46% in both cases).

Possibly the best explanation of this finding is that a certain amount of information is almost always transferred to a stable long-term memory during presentation. This may be a slight contradiction to the earlier argument that vocalisation to aurally presented sequences results in phonemic coding. However, the existence of stable information at all serial positions is apparent in the results of Chapter IV (see Appendix O and seq.). Even the last group of items in immediate recall is apparently not entirely contained in a transitory buffer store (see Experiment VI). It would seem likely that there exists a certain amount of stabilised information in all the experiments of the preceding chapter, in addition to which a varying amount of unstable information may be held. In Experiment V most of this unstable information may be of the phonemic kind described earlier.

This discussion would seem to question some of the assumptions made concerning the hypothesis of two-storage mechanisms in free recall. The main point is that the experiments of Chapter IV do not support the assumption that terminal items are held in short-term memory alone. The finding that an interpolated task before recall reduces the recency effect to the asymptote of the serial position curve of immediate free recall is not a new one (e.g. Glanzer & Cunitz, 1966; Postman & Phillips, 1965). Also, this finding is not an embarrassment to the model of Atkinson & Shiffrin (1968) since these authors argue that an interpolated task, presented after the last presented items, knocks information out of the buffer store in the same manner as items do during presentation of the to-be-remembered sequence. Thus, the duration of material in the buffer store is the same for terminal items as for earlier ones.

The problem with this interpretation is that if the length of residence in the rehearsal buffer is the main parameter of the transfer rate to long-term memory, then the post-presentation rehearsal should lead to all of the information in the rehearsal buffer being transferred to long-term memory. Since the transfer rate to long-term memory during post-presentation rehearsal appears to be approx. 1/5 of that during the presentation of the material, it would seem that the presentation of new information may involve more transfer to long-term memory than does the retention of old information. Perhaps the critical difference between these two transfer rates lies in the recognition of new information.

It would seem sensible to postulate some naming system between pre-categorical acoustic storage (i.e. the auditory sensory buffer) and the rehearsal buffer of short-term memory. This would not mean that subjects cannot respond to an auditory stimulus by simply repeating the sound, but that short-term memory will ordinarily represent a translation of the stimulus into an auditory representation from the subject's own naming system (see Experiment V, Conrad, 1964; Sperling, 1963, etc.) Such a view would explain why the short-term memory component of the serial position curve of immediate free recall is not dependent on the number of phonemes or syllables in a word but is limited to a fixed number of words (Craik, 1968 and possibly Murdock, 1961, if the latter study measured short-term memory alone). Thus, short-term memory may be described as post-recognitional. The level of recognition taking place would seem open to question. It would seem that it is such that it cannot allow semantic features of the presented material to be incorporated into the information embraced by the rehearsal buffer since semantic and associative features do not affect the last few items presented (Craik & Levy, 1970; Glanzer & Schwartz, 1971; Kintsch & Bushke, 1969). Probably, short-term memory ordinarily contains information recalled from long-term memory in the form of an acoustic-type translation of the presented message. Since the stimulus may be usually matched against long-term memory, it would seem feasible that this naming system allows long-term coding of material during presentation. If this were the case, then the recency effect should be less disrupted when the presented material is of high meaningfulness since it would contain a larger long-term memory component.

Glanzer & Schwartz (1971) have recently presented evidence in line with this view.

A recent study by Shulman (1970) gives support to the recognition model described above and reports results which would seem quite inconsistent with the assumptions of the recent two-storage mechanisms model outlined earlier. Shulman presented lists of 10 words to subjects and gave them instructions to expect a test word at the end of each trial. This probe word required their judgement as to whether it was identical to a word presented in the trial, or a synonym or a homonym of such a word. The number of correct detections made for each probe was very similar for the identical word and the homonym word probes but much lower for the synonym probe. This was the case at all serial positions. Further, all three correct detection serial position curves showed marked recency effects. This in itself would indicate that the recency effect is not made up of an acoustic short-term memory component and a semantic long-term memory component. However, Shulman also collected data on reaction times. Reaction times are shorter in recalling information from short-term memory than recalling information from long-term memory (Waugh, 1970), so that this data allows some check on the probability that information was not recalled from short-term memory when the synonym probe was used. Reaction times were shorter for late presented items with all three probes. This would seem additional evidence against a separate and exclusively acoustic coding of terminal items. Unfortunately, Shulman does not relate his work to the mass of studies which demonstrate different coding methods over the serial position curve. However, in view of the importance of Shulman's work, some attempt will be made to examine this in the following chapter.

The recognition model outlined above helps to give meaning to the results of chapter IV. The numerous observations that the primacy effect is due to cumulative rehearsal of material (e.g. Corballis, 1969; Fischler, Rundus & Atkinson, 1970; Rundus & Atkinson, 1970; Thurm & Glanzer, 1971) may be a misinterpretation of the processes operating during the presentation of a sequence. If long-term memory coding occurs through the naming process and slow presentation rates allow this naming process to proceed to a finer semantic/associative level of analysis, then it would follow that anything which restricts the amount of time subjects can allocate to this naming system would result in fewer dimensions for retrieval and so lead to poorer recall(cf. Brown & McNeill, 1966). Reducing interstimulus intervals would be one method of reducing the primacy effect (e.g. Bushke & Lim, 1967; Jahnke, 1968; Norman, 1966). One other method would be attempting to carry a large number of items in the rehearsal buffer. Viewed in this way it is apparent that cumulative rehearsal will result in a steady increase in the size of the rehearsal buffer until the interstimulus interval is filled with simply recognising each new item and adding this to the rehearsal buffer. It may be noted that the rehearsal of items during presentation would not seem to serve much purpose and may be a consequence of the current availability of items which subjects are irrationally afraid of losing. However, it may allow some coding of order information by aiding recency judgements and some associations to be formed between items, thus aiding the retention of both order and item information.

If this radical reinterpretation of the primacy effect is accepted, then it becomes apparent that maintaining items in the rehearsal buffer is not a particularly advantageous method of learning material. Also, it would explain why post-presentation rehearsal fails to add as much information to long-term memory as would be expected from the degree of information transfer during the presentation of material. Possibly, as Brown (1958) has suggested, the strengthening of material during post-presentation rehearsal may be in terms of some subjective reorganisation of the material (cf. Sanders, 1961). It would seem very likely from subjects' reports that the post-presentation rehearsal led to the selection of just one or two items for special attention because of some apparent associative potential. Processing of information according to such a criterion should lead to random strengthening of items in terms of serial position within the terminal group and a great loss of order information. This was demonstrated in the experiments of the preceding chapter.

The model outlined above carries many interesting predictions and receives a certain amount of support from various empirical studies. Since no further experiments are to be reported, fuller discussion of this model will be presented in the following chapter where recommendations and suggestions for future research are described.

Conclusions to the present chapter are presented in the summing up below.

Conclusions and Summary

The time period embraced by the research reported in the previous chapter produced a considerable amount of research relevant to the hypothesis that immediate free recall reflects both long-term and short-term memory. There is now much evidence that the recency effect of immediate free recall displays characteristics of short-term memory and all earlier presented items show themselves vulnerable to effects traditionally associated with long-term memory. Despite the popularity of models which postulate a short-term memory rehearsal buffer allowing the entry of material to long-term memory (Atkinson & Shiffrin, 1968; Craik, 1971; Waugh & Norman, 1965), tests of this model have not extended to examining the effects of post-presentation rehearsal. If the rehearsal buffer served an important function for learning, then it would be expected that post-presentation rehearsal should allow material held in the buffer to be transferred to long-term memory. The results of Chapter IV all demonstrated an improvement in the stability of terminal items following post-presentation rehearsal, but the increase in stability per unit time was considerably less than that occurring during the presentation of the to-be-remembered sequence. This observation and the fact that short-term memory would appear to be post-recognitional suggests that material may enter long-term memory during presentation. This entry could be made by matching the stimulus input against long-term memory and retrieving the sound of that item for entry into the rehearsal buffer. The rehearsal buffer may operate to reduce recall in so far as it takes up time in the interstimulus interval. The primacy effect would be seen as arising from the increasing size of the rehearsal buffer as the sequence progresses.

Under certain conditions involving the auditory presentation of material and limited opportunity for processing, it was suggested that different auditory messages may be stored separately. This may have occurred in Experiment V where subjects were required to vocalise to aurally presented material. Earlier studies showing this procedure to reduce recall ignore the fact that this procedure only reduces order information and does not lower performance on the number of items recalled. Indeed, vocalisation to the auditory stimuli led to a marked improvement in the number of items recalled when subjects were allowed a rehearsal opportunity before attempting recall. It was suggested that this rehearsal opportunity may have allowed the combining of two separate traces for the auditory stimulus and the vocalised response.

Examination of the full serial position curves did not provide much additional information relevant to the problems of the preceding chapter. However, the serial position curves did suggest that order information is not located at certain anchor points and thus gave credence to the view that a variety of cues are available for the knowledge of order information.

The following chapter will extend discussion to the work covered in the earlier chapters and suggest some research priorities for the future.

CHAPTER Vl

Retrospect and Prospect

In the introductory chapter it was suggested that the most striking characteristic of short-term memory is that it appears to be sustained by rehearsal so that even when material is presented visually, memory errors are acoustically related to the forgotten stimulus. The research reported in the succeeding chapters examined the basis for this argument and some possible effects of rehearsal. The purpose of the present chapter is not to summarise this work since summaries are presented at the end of each chapter, but rather to suggest the kind of research which would seem the most promising as a follow-up to this work. However, a general summary is given at the end of this chapter.

Chapter 11 described some analyses conducted on the listening error matrix and the memory error matrix for letters of the alphabet, reported by Conrad (1964). Perhaps the most important finding to emerge was that while the correlation between the two error matrices is very high (r_s = .64), when the correct detection rate (intelligibility) is calculated for each of the two matrices and correlated, no relationship is demonstrated (r_s = -.08). It was concluded that the concept of acoustic confusability does not allow prediction of which letters will be remembered in short-term memory but only of which items will be given as responses when forgetting occurs. A number of points concerning this finding require further discussion.

It has recently been pointed out by Sperling & Speelman (1970, p. 183) that Conrad's listening error matrix is not an adequate predictor of acoustic confusions in short-term memory: "Because the spectrum of speech itself is not flat - it is deficient in high frequencies - a masking noise with a flat frequency spectrum selectively destroys speech discriminations based on high frequencies (e.g. 2nd and 3rd formants) and leaves discriminations based on low frequencies (e.g. on the 1st formant) relatively intact. In memory tasks, subjects make both kinds of confusions, which implies that the spectrum of memory noise approximates to the spectrum of speech. Differences observed between errors made in listening and in memory tasks (Conrad, 1964) can be explained by the arbitrary selection of the flat-noise stimulus to produce the listening errors."

This would seem an excellent point but whether it would offer a complete explanation of the discrepancy between intelligibility in memory and intelligibility in listening must await further research. Examination of the Miller & Nicely (1955) data on listening errors by different noise bandwidths shows that the spectrum of masking noise used is indeed important for intelligibility. However, it would seem to affect the distribution of perceptual confusions to a similar extent. Further research would no doubt gain from a fine grained approach along the lines of distinctive feature analysis (Jacobson & Halle, 1956; Miller & Nicely, 1955; Wickelgren, 1965b, 1966 a, b) since there is some evidence in Miller & Nicely's own work that different bandwidths of masking noise may selectively impair certain distinctive features.

A second point concerning Conrad's (1964) data on memory errors is that this work was carried out without awareness that only the last few items of a presented sequence are likely to remain in short-term memory at the time of attempted recall. Given the short-term memory component limits reported in the preceding chapter of approximately 3 items, it would seem that half of the recalled sequence in Conrad's memory task should have reflected output from long-term memory. Since subjects were allowed written recall, it would seem possible that terminal items would be recalled first (see Chapter IV) so that most of the errors making up the memory error matrix should be provided by early presented items which cannot be retrieved from long-term memory. Current buffer store models as reviewed by Craik (1971) face embarrassment on two fronts by Conrad's results. First of all buffer store models which view the rehearsal buffer as containing items which are knocked out by later presented items (e.g. Atkinson & Shiffrin, 1968; Waugh & Norman, 1965) would predict forgetting as all or none in short-term memory and so could not handle systematic errors in short-term memory. Secondly, if acoustic confusions occur in long-term memory, then some contradiction is implied since long-term memory is putatively free of such effects (see Chapter V). It would be useful for this debate to have data on the incidence of acoustic confusions at various serial positions in Conrad's task.

Such memory studies as Conrad's raise an additional point relevant to the "two storage mechanisms" model. It is apparent from introspective observations and subjects' reports that we are able to rehearse six or seven items without great difficulty so that the limits placed on the size of the rehearsal buffer of approximately 3 items are somewhat puzzling. It would seem that the rehearsal buffer must include material which is in long-term memory.

Possibly other interpretations are feasible but these points would seem to support the model described in the preceding chapter of the rehearsal buffer being post-recognitional and based on information retrieval from long-term memory. This model allows material drawn from long-term memory to be acoustic in nature and so would not be embarrassed by the data of Conrad (1964). It must also allow for failure to retrieve from long-term memory and since forgetting increases with the number of items interpolated before recall (Waugh & Norman, 1965) this forgetting rate should be such as to explain forgetting in short-term memory.

Some evidence has already been presented against the view that short-term memory has as its main function the provision of a buffer store to feed in material to long-term memory at a regular rate since, if this were the case, post-presentation rehearsal should be more efficient at stabilising information than it is. Also, the observation that short-term memory is not limited to the number of phonemes presented (Craik, 1968; Murdock, 1961) but rather the number of meaningful units suggests that short-term memory has other functions. The main value and use of short-term memory would seem to be in the processing of redundant verbal material (i.e. speech) since this is the most common verbal activity. A buffer store would be of advantage in allowing some limited processing as an aid to prediction or the perception of redundancy in messages so that concepts could be stored. Rehearsal of material in short-term memory would allow a rapid recirculating of information without committing the subject to any method of analysis.

The "what-did-you-say?" phenomenon might be seen as a breakdown in the normal functioning of short-term memory because material is not fully attended to. In many respects short-term memory may then be viewed as a working memory for concept formation and problem solving (Hunter, 1964; Posner, 1967) rather than a mechanism for rote learning.

The data of Shulman (1970), discussed in the previous chapter, are particularly intriguing for this view in that Shulman demonstrated semantic and acoustic coding at all serial positions of a ten item sequence. It is possible that this study demonstrates that subjects can be flexible in their coding methods. It would be of interest to know, therefore, whether the two-dimensional coding of words in Shulman's experiment leads to any decrement in performance compared with a coding system which subjects generate for themselves. An additional point is that Shulman's data show very little indication of any primacy effects and the reason for this is not clear. Probe recall studies typically show an absence of any primacy effects but this is usually accounted for by the length of the sequences involved (Atkinson & Shiffrin, 1968) although criterion changes may be important (Murdock, 1968). In this case only 10 items were presented. Possibly, this reflects some attempt by the subjects to focus attention on word sounds rather than meanings and on late presented words in the expectation of maximising performance in the probe recall.

It would be expected on the recognition model described earlier that the primacy effect reflects the lack of cumulative rehearsal during presentation of early items and this allows the naming system to proceed to a more detailed semantic analysis. This hypothesis could be tested by applying Shulman's technique to word lists which show a primacy effect for the recognition of identical words. The expected results would be that a synonym probe would show a primacy effect whereas a homonym probe would not, but for all other serial positions the curves would be parallel. A primacy effect would seem readily introduced by simply biassing the probe item in favour of recall of early positions.

The acceptance of Shulman's result as being reliable for short-term memory is based on an assumption that no other techniques have adequately measured the semantic and acoustic components of memory. However, Shulman's work would be more convincing if it were demonstrated for example that synonym probes for high meaningful word lists produced more correct detections than low meaningful word lists.

As stated earlier, there is some evidence that the recency effect contains items which have been recognised by matching against long-term memory. Additionally, it may be the case that memory for items beyond the primacy effect is based upon predominantly acoustic type coding (as Shulman's work suggested). Thus, the recency effect would be provided by recall of item sounds and if these fail it must be assumed that the amount of semantic information must be similarly reduced. Observations that terminal items are differentially affected by certain variables to earlier items may be less difficult to integrate with Shulman's data and the recognition model described than it would appear at first sight.

The acoustic confusion effect in short-term memory (see Chapter I) may be a less reliable measure of the lack of semantic coding than is commonly supposed (e.g. Norman, 1969a). When subjects are not required to retain the order in which items are presented, acoustic similarity between items of the presented sequence appears to have either no effect or may even be mildly beneficial (Craik & Levy, 1970; Wickelgren, 1965b). As the research of Chapter IV shows, terminal items are remembered in the correct order in immediate recall better than earlier items. Apparently, in this respect at least, acoustically similar material produces effects in short-term memory akin to those of vocalisation-at-presentation to aurally presented regular material (see Chapter IV, Experiment V). Possibly, the mechanism is the same in that there is an overload of retrieval cues (Baddeley, 1968) when subjects attempt to recall each item. However, one other possibility is that subjects do not attempt to rehearse acoustically similar items in the usual way so that the recency effect for acoustically similar items would not be a result of sequential rehearsal of the last few items. The technique of observing rehearsal processes described by Rundus & Atkinson (1970) should prove useful in investigating this problem. However, Rundus & Atkinson do not stress the important point that all methods of making rehearsal overt must be validated when rehearsal and recall performance are dependent variables, in that the effects that such overt rehearsal may have cannot be assumed to produce equal effects for all methods of presentation, material and recall methods.

One other research question concerning acoustically similar material is whether such material encourages a greater degree of semantic coding than regular material. If acoustically similar material is difficult to rehearse sequentially, then subjects may spend more time on the semantic aspects of each item. Shulman's (1970) technique would allow examination of this question. One further issue is that if subjects do not sequentially rehearse acoustically similar material, it may be unlikely that any recency effect would be apparent after a rehearsal opportunity before recall. It would be profitable to use the experimental design of Chapter IV to examine different kinds of material after both filled and unfilled delay.

One point relating to the recency effect and the kind of coding on which this is based concerns the forgetting rate for semantic and acoustic type information. Shulman's methodology may be applied in a number of ways. Emphasis on either kind of information could be encouraged by the selective use of either homonym or synonym probes and the recency effect examined at various time lags. It would seem likely that semantic information is lost at a similar rate to acoustic type information (Shulman, 1970) so that some serious questioning of the nature of short-term memory would seem to be required.

The level of semantic coding in short-term memory may be fairly low since Tulving & Patterson (1968) have reported that highly related words which are treated as one chunk in long-term memory are recalled as separate units in short-term memory. This finding contrasts with that of Craik (1968) who found short-term memory for words to be more or less invariant when the number of syllables in the words was varied from 1 to 4. The difference between these two levels of analysis suggests some nice distinctions may be made in semantic coding. Research has yet to define what parameters are involved in this.

One final point concerning the recency effect is whether it can be rapidly stabilised or whether some forgetting is inevitable when terminal items are neglected. This might be investigated by encouraging subjects to use a long-term memory code before recalling terminal items. For example, words might be presented which had previously been part of a digit code such as "one is a bun, two is a shoe" reported by Miller, Galanter & Pribram (1960). If subjects were required to recall the digits associated with the presented words (i.e. recode terminal items by consulting the long-term store), then possibly the terminal items might become as resistant to forgetting as early presented items. It would also be of great interest to know whether the use of the rehearsal buffer in this way as a working memory would lead to any loss of items in the immediate recall situation. It may be noted parenthetically that an unreported experiment of the series in chapter lV examined the effects of requiring subjects to vocalise free associates to each word as it was presented. This led to very poor recall at all serial positions. Unfortunately, the effects of pure (unfilled) delay were not examined so that little comparison was possible with experiment V of chapter lV. Possibly, the effects of vocalising different words reduced any benefit which encouragement to code material semantically might provide, (Lindley 1966).

To summarise briefly, the possibility of semantic coding in short-term memory is a strong one and future research must be directed to assessing the level of coding which takes place and the effect of such coding on the size and the stability of the recency effect of immediate free recall.

The earlier discussion of acoustic coding at serial positions before the recency effect is an issue which has not been entirely neglected in that there have been a number of studies which have looked for evidence of acoustic coding in long-term memory (Baddeley 1966b, Bruce & Crowley 1970; Kintsch & Bushke 1969; Levy & Murdock 1968). Unfortunately, although some evidence has been found in these experiments for acoustic effects, there are few studies which have adopted methodologies which could be sensitive enough to tease out the dominant retrieval methods used. The tip-of-the-tongue phenomenon studied by Brown & McNeill (1966) and the methodology of Shulman (1970) provide notable exceptions and both suggest that acoustic retrieval may be a dominant coding dimension.

Doubtlessly, the method of coding material will depend on the nature of the material. Individual letters of the alphabet have little meaning so that it is difficult to conceive of an equivalent system operating to that of recognising individual words. Despite this, the results of such people as Glanzer & Cunitz (1966) with word sequences are apparently replicable, using digit sequences (e.g. Ellis & Anders 1969; Ellis & Hope 1968; Bower & Winzenz 1969). It would seem that early presented digits achieve their stability by becoming grouped whereas the last few digits are not handled in this way (Ryan 1969 a,b) and are easily disrupted by an interpolated task. Although this would suggest a parallel to the Tulving and Patterson study (1968) which used word sequences, apparently, under certain conditions at least, a number of terminal digits may be recalled as one chunk (Shepard & Sheenan 1965).

It is possible that if letters of the alphabet are remembered in groups, then the rhythmic structure provided by such a method (Neisser 1967) could lead to a greater preponderance of acoustic confusion and substitution errors over early and middle parts of the sequence than would be the case at terminal positions where items would not seem likely to be grouped. In other words, rhythmic grouping would seem to be one situation where any qualities of the letter arising from its recognition (e.g. possibly, position in the alphabet, frequency in the language) may not be retained in long-term memory. Research so far has been reluctant to address the question of how much information subjects have available about items. There would seem excellent reason for simply asking subjects to describe forgotten items and indicate why certain items must be rejected in a recognition task. Such an approach paying due regard to possible serial position differences should prove rewarding.

The possibility, discussed in chapter V, that auditory stimuli, differing in some way, may be stored separately would seem to represent an intriguing notion worth pursuing. A number of studies were felt to present evidence in line with this hypothesis which was used to offer one interpretation of the results of experiment V in chapter lV. The work of Crowder and Morton (1969) represents one area in which this possibility might be investigated (see chapter V). Morton (1970) argues that the superiority of aurally presented information over visually presented information occurs at the last three items because the auditory sensory buffer (precategorical acoustic storage) for the last presented items feeds information into the short-term memory rehearsal buffer. If such contradictory evidence as Murray (1967, experiment 111) is ignored, Morton's model suggests some interesting possibilities. The size of Morton's (1970) rehearsal buffer is limited to a fixed number of items so that there would seem little provision for the rehearsal buffer to accept additional information. Thus, the entry of information from precategorical acoustic storage should disrupt some items from the rehearsal buffer. The absence of any such effect suggests that the auditory information from the last few items may enter a separate store to the information for these items which is contained in the rehearsal buffer. This point would lend support to the argument made earlier that a redundant stimulus suffix spoken in a different voice to the presented sequence may not be blocked from entry to processing mechanisms but stored separately from the stimulus sequence. Since information from the precategorical acoustic store supplements information for terminal items even when the presented sequence is recalled in a serial order (Craik 1969) it would seem possible that relatively enduring memory may arise from such auditory sensory stores.

There are a number of possible lines of research: investigating whether precategorical acoustic storage can be "filled up" with different voices or whether each voice is stored separately. Memory for this information at various time lags would also be important for an indication of the level of processing which could take place. However, a more cautious beginning would be to investigate whether the necessity of remembering a differently voiced redundant suffix (a choice would be required) led to any decrement in the recall of the stimulus sequence. If it did, then a study of incidental retention using a recognition probe might provide a reasonable final test of the hypothesis.

In the work on the differences between auditory and visual presentation some attempt has been made at controlling obvious artefacts such as the amount of attention which subjects pay to items. (e.g. Routh 1970, 1971). It is a somewhat trite point, but while it is possible to control attention to some extent by requiring subjects to monitor information as it is presented, it is impossible to control subjects' thought processes. Further, there may be few and unreliable ways of estimating how much attention material is actually receiving. Recording of subjects' rehearsal strategies (Rundus & Atkinson 1970), monitoring of pupilliary responses (Kahneman, Onuska & Wolman 1968) and physiological correlates of arousal (Walker & Tarte 1963) cannot be fully satisfactory.

With all too many reported studies it is impossible to separate the effects of experimental treatments from cognitive effects due to anticipation of those treatments. Unfortunately, such a distinction is usually of vital importance. This point was made in the rationale for experiments V and Vl of chapter lV with reference to the effects which an interpolated task may have. These two experiments showed that while it is possible to control for possible effects due to the anticipation of an interpolated task, the level of control required could be such as to produce numerous complications. (In these experiments there was a reminiscence effect and substantial forgetting of order information.)

Crowder (1969) has recently presented evidence that subjects' anticipations of experimental treatments may be usually confounded with the effects of such treatments. He argued that long sequences produce smaller primacy effects than short sequences because subjects do not rehearse early items of long sequences as much as they do with short sequences.

In his experiment, one group of subjects received trials on
sequences of 9 items and one group of subjects received trials on sequences of variable length from 9 items to 30 items. The latter group showed markedly inferior performance on 9 item sequences over the first 4 serial positions, committing twice as many errors as the

former group on the first two items. Crowder (1969) interpreted these results in terms of the lack of cumulative rehearsal in the variable sequence length group. However, this is an empirical question not answered by Crowder's own experiment. Such a technique as that reported by him promises to allow powerful tests to be made of hypotheses concerning rehearsal strategies. Future replications of Crowder's study could usefully examine memory for both item and order information since Crowder's material consisted of digit strings and it may have been the daunting task of remembering the order of the material with the long strings which produced the effects reported. Certainly, the experiments of chapter lV indicate that the retention of order information is amenable to experimental treatments and possibly more readily so than the retention of item information.

Although it is not fully realistic to expect much advance methodologically in this area, there is no doubt that many studies would benefit from a consideration of possible confounding of cognitive effects and experimental treatments. This is particularly true of the effects of interpolated tasks where the influence may be on what subjects attempt to remember rather than on what is disrupted by the interpolated activity. Allocation of separate groups to different experimental treatments offers the highest probability of such confounding but designs which require subjects to perform every condition present problems of reduction in sensitivity where asymetrical transfer effects occur between conditions (Poulton 1966) besides possibly defining the experimental hypotheses for the subject. Fortunately, it is not always necessary to deceive subjects over the experimental treatments in order to assess cognitive effects.

The possibility of cognitive effects confounding with experimental treatments raises the issue of individual differences in memory tasks. There is little reason to assume that all subjects will evaluate the experimental task in the same way and demonstrate similar effects of experimental treatments. Indeed Corballis (1969) recorded subjects' overt rehearsals and concluded "...there were wide variations between subjects, making it unrealistic to average across subjects" (Corballis 1969, p. 43). While Corballis observed that some subjects rehearsed cumulatively and some did not, it would seem important to link rehearsal strategies in a causal manner to those dependent variables which are usually of interest in memory tasks - recall performance and the distribution of recall scores over serial positions. There is ample correlational evidence that the primacy effect reflects cumulative rehearsal (e.g. Fischler, Rundus & Atkinson 1970; Rundus & Atkinson 1970; Thurm & Glanzer 1971). As was suggested in chapter V, this may merely reflect the relative availability of early items and may not cause any increment in the probability of recall of these items, but rather reduce the probability of recall of later items since the interstimulus interval becomes filled with the rehearsal of early items. Perhaps to test either theory it might be wise to examine the effects of cumulative rehearsal for items after the primacy effect. To examine the effects of reduced time for processing due to cumulative rehearsal, vocalised cumulative rehearsal could be used with increasing interstimulus intervals to allow the amount of time for processing to be constant for each item. If cumulative rehearsal can account for most of the variance in the primacy effect then two primacy effects should appear. If the processing time per item is more important, then the asymptote of the serial position curve should be raised for all items.

Although the usefulness of recording overt rehearsal has yet to be investigated, it is apparent that there are large differences between subjects in their performance. The data of chapter 1V indicated that the differences between subjects was greater than the differences within subjects over trials. Such variance perhaps properly directs attention to the more influential of experimental treatments but does not necessarily aid our understanding of the kind of information processing. which is carried out on early and late presented items.

Possibly one day some subject will submit himself to massive in-depth research to map out his memory strategies, organizational schema and cognitive strudtures and so allow some clearer understanding of "simple memory" and its relationship to higher cognitive processes. In the meantime, until we have some clear operational definitions of what is important and can mount a suitable research programme, perhaps we should attempt to reduce individual differences amd make systematic studies of groups of subjects who differ in their performance over the serial position curve. This would represent the other alternative to Corballis'(1969) recommendation that individual subjects should be classified according to their apparent rehearsal strategies,

The development of verbal skills in the young child may provide some insight into memory processes but initial studies have produced conflicting findings (e.g. Bernbach 1967; Hagen, Meechan & Melbor 1970). In principle, there would seem no reason why the developing cognitive system of the child should not answer many of the present questions. The only caveat would be that humans may show remarkable flexibility in their behaviour (Conrad 1970, Levy 1971) and we should recognise that any model of memory based on uni-dimensional coding must represent a gross over-simplification of actuality and potential and so would be worth very little analytically.

Summary and Conclusions

The chapters of this thesis are presented in the order in which the ideas were conceived and executed. Necessarily, this has led to earlier conceptualisations being modified in discussion. It would seem convenient, therefore, to indicate some of the main points made by the work without reference to the historical order of presentation of these.

Recent developments in short-term memory have drawn attention to the existence of both long- and short-term memory in immediate free recall. These studies urge caution in the interpretation of much earlier short-term memory research where serial position curves are not presented and it is not possible to know where the experimental treatments were operating. Popular current models of the serial position curve define the recency effect as reflecting the operation of a short-term memory rehearsal buffer which feeds information into long-term memory (e.g. Atkinson & Shiffrin 1968).

Chapter lV examined the effects of post-presentation rehearsal and found that this led to some gain in the stability of terminal items of a list but that subjects were likely to forget the order in which these items were presented. Post-presentation rehearsal, while retaining terminal items does not appear to be an efficient system for transferring this material to long-term memory, since the rate at which information enters long-term memory at presentation would seem in the order of 5 times greater. Because of this and other evidence it was suggested that material may enter long-term memory at presentation to allow recognition of the material to be rehearsed in the buffer store. Information in both memories may be of a predominantly acoustic nature. In view of this, it was recommended that techniques should be used which may be sensitive to the nature of the coding of information in short-term memory and long-term memory such as probe words which subjects are required to recognise as being similar on some dimension to a presented item. In this way it may be possible to tease out what is forgotten in either memory and the rate at which different dimensions are lost.

There is a psssibility that Conrad's (1964) noted correlation between listening errors and memory errors may have been based on errors made in long-term memory. It was recommended that future research should clarify this. Chapter 11 reported a series of analyses concerned with evaluating Conrad's (1964) work. The listening error matrix was found to contain a marked response preference for the most frequent letters of the alphabet. More importantly, although such a correlation would be predicted, no correlation was found between the correct detection rates for letters in the memory error matrix and the listening error matrix. This may reflect the lack of correspondence between memory noise and the white noise used in the listening task but further research is needed to clarify this point. On the other hand, this may be further evidence that more than one dimension is relevant for memory of individual items. It was suggested that subjects may be able to describe features of forgotten letters by their rejection of alternatives. Such analysis qould help to direct future research in the investigation of coding dimensions.

It was found that vocalisation-at-presentation to aurally presented material does not necessarily lead to poorer recall. Order information was badly retained and a rehearsal opportunity before recall led to a marked improvement in performance. Although badly understood, this may reflect independent processing of auditory material which differs on some dimension. A number of published experiments were interpreted using this model and some testable hypotheses suggested.

The main recommendations for future research are that attempts should be made to separate cognitive effects arising from the anticipation of experimental treatments from the effects of those treatments and that serious effort should be made to map out the coding dimensions relevant in short-term memory and the rate of loss of these dimensions.

REFERENCES

Adams, H.F. (1915), A note on the effect of rhythm on memory. Psychological Review, 22, 289-297

Adams, J.A. (1967), Human Memory. Illinois: McGraw-Hill

Adams, J.A., Thorshiem, H.I., & McIntyre, J.S. (1969), Item length, acoustic similarity, and natural language mediation. Journal of Experimental Psychology, 80 (1), 39-46

Allen, M. (1968), Rehearsal strategies and response cueing as determinants of organization in free recall. Journal of Verbal Learning and Verbal Behavior, 7, 58-63

Alpern, M. (1952), Metacontrast: historical introduction. American Journal of Optometry, 29, 631-646

Alpern, M. (1953), Metacontrast. Journal of the Optical Society of America, 43, 648-657

Anderson, J.S. (1960), Poststimulus cuing in immediate memory, Journal of Experimental Psychology, 60, 216-221

Atkinson, R.C. & Shiffrin, R.M. (1968), Human memory: a proposed system and its control processes. In: K.W. Spence & J.T. Spence, The Psychology of Learning and Motivation. Advances in Research and Theory, Vol. 2, pp. 88-195

Averbach, E. & Corriell, A.S. (1961), Short-term memory in vision. Bell System Technical Journal, 40, 309-328

Averbach, E. & Sperling, G. (1961), Short-term storage of information in vision. In: C. Cherry, Information Theory. London: Butterworth, pp. 196-211

Baddeley, A.D. (1962), Some factors influencing the generation of random letter sequences.
Cambridge (England): Applied Psychology Research Unit, Mimeograph APU 422/62

Baddeley, A.D. (1966a), Short-term memory for word sequences as a function of acoustic, semantic and formal similarity.
Quarterly Journal of Experimental Psychology, 18, 362-365

Baddeley, A.D. (1966b), The influence of acoustic and semantic similarity on long-term memory for word sequences.
Quarterly Journal of Experimental Psychology, 302-309

Baddeley, A.D. (1968), How does acoustic similarity influence short-term memory ?
Quarterly Journal of Experimental Psychology, 20 (3), 249-264

Baddeley, A.D. (1970), Estimating the short-term component in free recall.
British Journal of Psychology, 61 (1), 13-15

Baddeley, A.D., Conrad, R. & Hull, A.J. (1965), Predictability and immediate memory for consonant sequences.
Quarterly Journal of Experimental Psychology, 17, 175-177

Baddeley, A.D. & Dale, H.C. (1966), The effect of semantic similarity on retroactive interference in long- and short-term memory.
Journal of Verbal Learning and Verbal Behavior, 5, 217-220

Baddeley, A.D. & Levy, B.A. (1971), Phonemic coding in short-term memory.
Journal of Experimental Psychology, 89, 132-138

Baddeley, A.D., Scott, D., Drynan, R. & Smith, J.C. (1969), Short-term memory and the limited capacity hypothesis.
British Journal of Psychology, 60, 51-55

Bakan, P. (1960), Response-tendencies in attempts to generate random binary series.
American Journal of Psychology, 73, 127-131

Barnett, C., Ellis, N.R., & Pryer, M.W. (1960), Serial position effects in superior and retarded subjects.
Psychological Reports, 7, 111-113

Bartlett, F.C. (1932), Remembering. Cambridge: Cambridge University Press.

Bartz, W.H. (1969), Repetition and the memory stores.
Journal of Experimental Psychology, 80 (1), 33-38

Bergstrom, J.A. (1907), The effects of changes in time variables in memorizing, together with some discussion of the techniques of memory experimentation.
American Journal of Psychology, 18, 206-238

Berkowitz, L. (1967), In: O. Larsen (Ed.), Violence and the Mass Media. New York: Harper & Row

Bernbach, H.A. (1967), The effect of labels on short-term memory for colors with nursery school children.
Psychonomic Science, 7, 149-150

Bjork, R.A. (1970), Repetition and rehearsal mechanisms in models for short-term memory. In: D.A. Norman, Models of Human Memory.
New York: Academic Press, pp. 307-330

Bousefield, W.A. (1953), The occurrence of clustering in the recall of randomly arranged associates.
Journal of General Psychology, 49, 229-240

Bousefield, W.A. & Cohen, B.H. (1955), The occurrence of clustering in the recall of randomly arranged words of different frequencies of usage.
Journal of General Psychology, 52, 83-95

Bower, G.H. (1967), A multi-component theory of the memory trace.
In: K.W. Spence & J.T. Spence (Eds), The Psychology of Learning and Motivation Advances in Research and Theory, Vol. 1, New York: Academic Press, 229-325

Bower, G.H. & Winzenz, D. (1969), Group structure, coding, and memory for digit series.
Journal of Experimental Psychology Monograph, 80 (2), Part 2, pp. 1-17

Brelsford, J.W. & Atkinson, R.C. (1968), Recall of paired-associates as a function of overt and covert rehearsal procedures.
Journal of Verbal Learning and Verbal Behavior, 7, 730-736

Bricker, P.D. & Chapanis, R. (1953), Do incorrectly perceived tachistoscopic stimuli carry some information ?
Psychological Review, 60, 181-188

Broadbent, D.E. (1957), A mechanical model for human attention and immediate memory.
Psychological Review, 64, 205-215

Broadbent, D.E. (1958), Perception and Communication. New York: Pergamon Press

Broadbent, D.E. (1963), The flow of information within the organism.
Journal of Verbal Learning and Verbal Behavior, 2, 34-39

Broadbent, D.E. (1965), Techniques in the study of short-term memory.
Acta Psychologica, 24, 220-233

Broadbent, D.E. (1967), Word-frequency effect and response bias.
Psychological Review, 74, 1-15

Broadbent, D.E. & Gregory, M. (1964), Stimulus set and response set: the alternation of attention.
Quarterly Journal of Experimental Psychology, 16, 309-317

Brown, J. (1954), The nature of set to learn and of intra-material interference in immediate memory.
Quarterly Journal of Experimental Psychology, 6, 141-148

Brown, J. (1958), Some tests of the decay theory of immediate memory.
Quarterly Journal of Experimental Psychology, 10, 12-21

Brown, J. (1959), Information, redundancy and decay of the memory trace.
In: The Mechanisation of Thought Processes. London: H.M.S.O.
National Physical Laboratory Symposium No. 10 (2) pp. 729-745

Brown, J. (1964), Short-term memory.
British Medical Bulletin, 20, 8-11

Brown, R. & McNeill, D. (1966), The "tip of the tongue" phenomenon.
Journal of Verbal Learning and Verbal Behavior, 5, 325-337

Bruce, D. & Crowley, J.J. (1970), Acoustic similarity effects on retrieval from secondary memory.
Journal of Verbal Learning and Verbal Behavior, 9, 190-196

Bruder, G.A. (1970), Analysis of differences between free and serial recall.
Journal of Experimental Psychology, 83 (2), 232-237

Bruner, J.S., Goodnow, J.J. & Austin, G.A. (1956), A Study of Thinking. London: Chapman & Hall.

Bryden, M.P. (1967), A model for the sequential organization of behaviour.
Canadian Journal of Psychology, 21, (1), 37-56

Bugelski, B.R. (1962), Presentation time, total time, and mediation in paired-associate learning.
Journal of Experimental Psychology, 63, 409-412

Bushke, H. & Kintsch, W. (1970), Rehearsal strategies and the serial-position curve in immediate free recall of ordered items.
Quarterly Journal of Experimental Psychology, 22, 347-352

Bushke, H. & Lim, H. (1967), Temporal and interactional effects in short-term storage.
Perception and Psychophysics, 2, 107-114

Buxton, C.E. (1943), The status of research in reminiscence.
Psychological Bulletin, 40, 313-340

Cardozo, B.L. & Leopold, F.F. (1963), Human code transmission: letters and digits compared on the basis of immediate memory error rates.
Ergonomics, 6, 133-141

Cattell, J. McK. (1885), Über die Zeit der Erkennung und Benennung von Schriftzeichen, Bildern und Farben.
Philosophische Studien, 2, 635-650

Chapanis, A. (1953), Random-number guessing behavior.
The American Psychologist, 8, 332 (Abstract)

Cherry, E.C. (1953), Some experiments on the recognition of speech with one and two ears.
Journal of the Acoustical Society of America, 25, 975-979

Cherry, E.C. (1955), On the validity of the application of communication theory to human operator problems.
Paper presented at a special technical meeting held at the Royal Empire Society, 19 September, 1955. Mimeograph.

Cherry, E.C. (1957), On Human Communication. Cambridge (Mass.): MIT Press

Clark, L.L., Lansford, T.E., & Dallenbach, K.M. (1960), Repetition and associative learning.
American Journal of Psychology, 73, 22-40

Clarke, F.R. (1957), Constant ratio rule for confusion matrices in speech communication.
Journal of the Acoustical Society of America, 29, 715-720

Cohen, B.H. (1963), Recall of categorised word lists.
Journal of Experimental Psychology, 66, 227-234

Cohen, R.L. (1970), Recency effects in long-term recall and recognition.
Journal of Verbal Learning and Verbal Behavior, 9 (2), 672-678

Conrad, R. (1957), Decay theory of immediate memory.
Nature, 179, 831-832

Conrad, R. (1958), Accuracy of recall using keyset and telephone dial and the effect of a prefix digit.
Journal of Applied Psychology, 42, 285-288

Conrad, R. (1959), Errors of immediate memory.
British Journal of Psychology, 50, 349-359

Conrad, R. (1960), Very brief delay of immediate recall.
Quarterly Journal of Experimental Psychology, 12, 45-47

Conrad, R.(1962), An association between memory errors and errors due to acoustic masking of speech.
Nature, 196, 1314-1315

Conrad, R. (1963), Acoustic confusions and memory span for words.
Nature, 197, 1029-1030

Conrad, R. (1964), Acoustic confusions in immediate memory.
British Journal of Psychology, 55 (1), 75-84

Conrad, R. (1967), Interference or decay over short retention intervals? Journal of Verbal Learning & Verbal Behavior, 6, 49-54.

Conrad, R. (1971), Short-term memory processes in the deaf. British Journal of Psychology, 61 (2), 179-195 ·

Conrad, R., Baddeley, A.D. & Hull, A.J. (1966) Rate of presentation and the acoustic similarity effect in short-term memory. Psychonomic Science, 5, 233-234.

Conrad, R., Freeman, P. R. & Hull, A. J. (1965) Acoustic factors versus language factors in short-term memory. Psychonomic Science, 3, 57-58.

Conrad, R. & Hille, B. A. (1957) Memory for long telephone numbers. Post Office Telecommunications Journal, 10, 37-39.

Conrad, R. & Hille, B. A. (1958) The decay theory of immediate memory and paced recall. Canadian Journal of Psychology, 12 (1), 1-6.

Conrad, R. & Hull, A. J. (1964) Information, acoustic confusion and memory span. British Journal of Psychology, 55 (4), 429-432.

Conrad, R. & Hull, A. J. (1968) Input modality and the serial position curve in short-term memory. Psychonomic Science, 10, 135-136.

Corballis, M. C. (1964) Binochular interactions in letter recognition. Australian Journal of Psychology, 16, 38-47.

Corballis, M. C. (1966) Rehearsal and decay in immediate recall of visually and aurally presented items. Canadian Journal of Psychology, 20, (1), 43-51.

Corballis, M. C. (1969) Patterns of rehearsal in immediate memory. British Journal of Psychology, 60 (1), 41-49.

Corballis, M. C. & Loveless, T. (1967) The effect of input modality on short-term serial recall. Psychonomic Science, 7, 275-276.

Craig, J. R. & Bartz, W. H. (1969) Repetition effects and the ordered recall of categorical serial lists. Psychonomic Science, 14 (2), 67-68.

Craik, F.I.M. (1968) Two components in free recall. Journal of Verbal Learning & Verbal Behavior, 7, 996-1004.

Craik, F.I.M. (1969) Modality effects in short-term storage. Journal of Verbal Learning & Verbal Behavior, 8, (5), 658-664.

Craik, F.I.M. (1970) The fate of primary memory items in free recall. Journal of Verbal Learning & Verbal Behavior, 9 (2), 143-148.

Craik, F.I.M. (1971) Primary memory.
British Medical Bulletin, 27 (3), 232-236.

Craik, F.I.M. & Levy,B.(1970) Semantic and acoustic information in primary memory. Journal of Experimental Psychology, 86, 77-82.

Crannel, C. W. & Parrish, J. M. (1957) A comparison of immediate memory span for digits, letters and words.
Journal of Psychology, 44, 319-327.

Crawford, J., Hunt, E. & Peak, G. (1966) Inverse forgetting in short-term memory. Journal of Experimental Psychology, 72 (3), 415-422.

Crossman, E. R. F. W. (1961) Information and serial order in human immediate memory. In: C.Cherry, Information Theory. London: Butterworths, 147-159.

Crowder, R. G. (1969a) Improved recall for digit with delayed recall cues. Journal of Experimental Psychology, 82, 258-262.

Crowder, R. G. (1969b) Behavioral strategies in immediate memory.
Journal of Verbal Learning & Verbal Behavior, 8, 524-528.

Crowder, R. G. (1970) The role of one's own voice in immediate memory. Cognitive Psychology, 1, 157-178.

Crowder, R. G. & Morton, J. (1969) Pre-categorical acoustic storage (PAS). Perception & Psychophysics, 5(6), 365-373.

Dale, H. C. A. (1964) Retroactive interference in short-term memory.
Nature, 203, 1408.

Dale, H. C. A. & Gregory, M. (1966) Evidence of semantic coding in short-term memory. Psychonomic Science, 5, 75-76.

Dalrymple-Alford, E. C. (1967) Repetition and immediate memory.
British Journal of Psychology, 58 (1&2), 63-67.

Deese, J. & Kaufman, R. A. (1957) Serial effects in recall of unorganised and sequentially organised verbal material.
Journal of Experimental Psychology, 54, 180-187.

Donaldson, W. & Glathe, H. (1969) Recognition memory for item and order information.
Journal of Experimental Psychology, 82 (3), 557-560.

Drevenstedt, J. (1970) Modifiability of the serial position curve in immediate recall. Psychonomic Science, 19 (4), 231-233.

Eagle, M. & Ortoff, E. (1967) The effects of level of attention upon "phonetic" recognition errors.
Journal of Verbal Learning & Verbal Behavior, 6, 226-231.

Ebbinghaus, H. (1885) Translation by H. Ruyer & C. E. Bussenius, Memory. New York: Columbia University Teachers' College (1913).

Ebenholtz, S. M. (1963) Serial learning: position learning and sequential associations.
Journal of Experimental Psychology, 66, 353-362.

Ellis, N.R. & Anders,T.R. (1969) Effects of interpolated recall on short-term memory. Journal of Experimental Psychology, 79(3), 568-569.

Ellis, N. R. & Hope, R. (1968) Memory processes and the serial position curve. Journal of Experimental Psychology, 77, 613-619.

Erdmann, B. & Dodge, R. (1898) Psychologische Untersuchungen über das Lesen. Halle: M. Niemeyer. (cited by Kintsch, 1970).

Eriksen, C. W. & Collins, J. F. (1964) Backward masking in vision. Psychonomic Science, 1, 101-102.

Eriksen, C. W. & Johnson, H. J. (1964) Storage and decay characteristics of non-attended auditory stimuli.
Journal of Experimental Psychology, 68, 28-36.

Eriksen, C. W. & Steffy, R. A. (1964) Short-term memory and retroactive interference in visual perception.
Journal of Experimental Psychology, 68, 423-434.

Estes, W. K. (1965) A technique for assessing variability of perceptual span. Proceedings of the National Academy of Sciences, 54, 403-7.

Estes, W. K. & Taylor, H. A. (1966) Visual detection in relation to display size and redundancy of critical elements.
Perception & Psychophysics, 1, 9-16.

Fiegenbaum, E. A. (1967) In: D. P. Kimble (Ed.), Learning, Remembering and Forgetting, Vol.II: The Organization of Recall. New York: New York Academy of Sciences. (p.115).

Fiegenbaum, E. A. & Simon, H. A. (1962) A theory of the serial position effect. British Journal of Psychology, 53, 307-320.

Fischler, I., Rundus, D. & Atkinson, R. C. (1970) Effects of overt rehearsal procedures on free recall. Psychonomic Science, 19

Fitts, P. M. & Switzer, G. (1962) Cognitive aspects of information processing. I. The familiarity of S-R sets and subsets. Journal of Experimental Psychology, 63, 321-329.

Fraser, D. C. (1958) Decay of immediate memory with age. Nature, 182, 1163.

Gilson, E. Q. & Baddeley, A. D. (1969) Tactile short-term memory. Quarterly Journal of Experimental Psychology, 21, 180-184.

Glanzer, M. & Clarke, W. H. (1964) The verbal loop hypothesis: binary numbers. Journal of Verbal Learning & Verbal Behaviour, 2, 301-309.

Glanzer, M. & Cunitz, A. R. (1966) Two storage mechanisms in free recall. Journal of Verbal Learning & Verbal Behavior, 5, 351-360.

Glanzer, M., Gianutsos, R. & Dubin, S. (1969) The removal of items from short-term storage. Journal of Verbal Learning & Verbal Behavior, 8, 435-447.

Glanzer, M. & Schwartz, A. (1971) Mnemonic structure in free recall. Differential effects on STS and LTS. Journal of Verbal Learning & Verbal Behavior, 10, 194-198.

Glickman, S. E. (1961) Perseverative neural processes and consolidation of the memory trace. Psychological Bulletin, 58, 218-233.

Glucksberg, S. & Cowen, N. (1970) Memory for non-attended auditory material. Cognitive Psychology, 1, 149-156.

Groninger, L. D. (1966) Natural language mediation and covert rehearsal in short-term memory. Psychonomic Science, 5, 135-136.

Gruneberg, M. M. & Sykes, R. N. (1969) Acoustic confusions in long-term memory. Acta Psychologica, 31, 293-296.

Guilford, J. P. (1936) The determination of item difficulty when chance success is a factor. Psychometrika, 1, 259-264.

Guthrie, E. R. (1933) Association as a function of time interval. Psychological Review, 40, 355-367.

Haber, R. N. (1964a) A replication of selective attention and coding in visual perception. Journal of Experimental Psychology, 67, 402-404.

Haber, R. N. (1964b) The effects of coding strategy on perceptual memory. Journal of Experimental Psychology, 68, 357-362.

Haber, R. N. (1965) Effect of prior knowledge of the stimulus on word recognition processes. Journal of Experimental Psychology, 69, 282-286.

Haber, R. N. (1966) Nature of the effect of set on perception. Psychological Review, 73, 335-351.

Hagen, J. W., Meacham, J. A. & Mesibov, G. (1970) Verbal labeling, rehearsal, and short-term memory. Cognitive Psychology, 1, 47-58.

Hall, J. F. (1966) The Psychology of Learning. New York: J. B. Lippincott Co.

Halle, M. (1964) On the basis of phonology. In: J.A.Fodor & J.J.Katz (Eds.), The Structure of Language: Readings in the Philosophy of Language. New Jersey: Prentice-Hall.

Harcum, E. R. & Filion, R. D. (1963) Effects of stimulus reversals on lateral dominance in word recognition. Perceptual and Motor Skills, 17, 779-794.

Harcum, E. R. & Friedman, S. M. (1963) Reversal reading by Israeli observers of visual patterns without intrinsic directionality. Canadian Journal of Psychology, 17, 361-369.

Harris, C. S. & Haber, R. N. (1963) Selective attention and coding in visual perception. Journal of Experimental Psychology, 65, 328-333.

Harrison, G. J. (1967) Some additive results in short-term memory. In: A.F.Sanders (Ed.), Attention and Performance. Amsterdam: North-Holland Publ. Co.

Hebb, D. O. (1949) The Organisation of Behavior: A Neuropsychological Theory. New York: Wiley.

Hebb, D. O. (1961) Distinctive features of learning in the higher animal. In: J.F.Delafresnaye (Ed.), Brain Mechanisms & Learning. London: Oxford University Press. (Pp. 37-46).

Hellyer, S. (1962) Frequency of stimulus presentation and short-term decrement in recall. Journal of Experimental Psychology, 64, 650

Heron, A. (1962) Immediate memory in dialling performance with and without simple rehearsal. Quarterly Journal of Experimental Psychology, 14, 94-103.

Heron, W. (1957) Perception as a function of retinal locus and attention. American Journal of Psychology, 70, 38-48.

Hick, W. E. (1952) On the rate of gain of information. Quarterly Journal of Experimental Psychology, 4, 11-26.

Hintzman, D. L. (1965) Classification and aural coding in short-term memory. Psychonomic Science, 3, 161-162.

Hintzman, D. L. (1967) Articulatory coding in short-term memory. Journal of Verbal Learning & Verbal Behavior, 6, 312-316.

Hintzman, D. L. (1968) Exploration with a discrimination net model for paired-associate learning. Journal of Mathematical Psychology, 5, 123-162.

Howe, M. J. A. (1965) Intra-list differences in short-term memory. Quarterly Journal of Experimental Psychology, 17, 338-342.

Howe, M. J. A. (1967) Consolidation in short-term memory as a function of rehearsal. Psychonomic Science, 7 (10), 355-356.

Howes, D. H. & Solomon, R. C. (1951) Visual duration threshold as a function of word probability. Journal of Experimental Psychology, 41, 401-410

Hull, C. L. (1943) Principles of Behavior. New York: Appleton-Century-Crofts.

Hunter, I. M. L. (1964) Memory. Harmondsworth: Penguin Books.

Jacobs, J. (1887) Experiments in prehension. Mind, 12, 75-79.

Jacobson, R. & Halle, M. (1956) Fundamentals of Language. The Hague: Mouton & Co.

Jahnke, J. C. (1968) Delayed recall and the serial position effect of short-term memory. Journal of Experimental Psychology, 76 (4), 618-622.

James, W. (1890) The Principles of Psychology, Vol.I. New York: Holt. (Chapter 16, p. 643).

Jenkins, J. G. & Dallenbach, K. M. (1924) Oblivescence during sleep and waking. American Journal of Psychology, 35, 605-612.

Jensen, A. R. & Rohwer, W. D. (1965) What is learned in serial learning. Journal of Verbal Learning & Verbal Behavior, 4, 62-72.

Johnson, N. F. (1966) The influence of associations between elements of structured verbal responses. Journal of Verbal Learning & Verbal Behavior, 5, 368-374.

Johnson, N. F. (1970) The role ofcchunking and organization in the process of recall. The Psychology of Learning & Motivation, 4, 171-247.

Kahneman, D., Onuska, L. & Wolman, R. (1968) Effects of grouping on the pupilliary response in a short-term memory task. Quarterly Journal of Experimental Psychology, 20, 309-311.

Karlin, J. E. (1958) All-numeral dialling: would users like it? Bell Laboratory Records, 36, 284-288.

Kausler, D.H. (Ed.) (1966) Readings in Verbal Learning: Contemporary Theory and Research. New York: Wiley.

Keppel, G. & Underwood, B. J. (1967) Reminiscence in the short-term retention of paired-associate lists. Journal of Verbal Learning & Verbal Behavior, 6, 375-382.

Kimble, D. P. (Ed.), (1967) Learning, Remembering and Forgetting. Vol.II. The Organisation of Recall. New York: New York Academy of Sciences, (Pp. 91-95).

Kimura, D. (1959) The effect of letter position on recognition. Canadian Journal of Psychology, 13, 1-10.

Kintsch, W. (1970) Models for free recall and recognition. In: D.A.Norman, Models of Human Memory. New York: Academic Press.

Kintsch, W. & Buschke, H. (1969) Homophones and synonyms in short-term memory. Journal of Experimental Psychology, 80, 403-407.

Klemmer, E. T. (1961) The perception of all patterns produced by a seven line matrix. Journal of Experimental Psychology, 61, 274-282.

Klemmer, E. T. (1964) Does recoding from binary to octal improve the perception of binary patterns? Journal of Experimental Psychology, 67, 19-21.

Landauer, T. K. (1962) Rate of implicit speech. Perceptual and Motor Skills, 15, 646 .

Lawrence, D. H. & Laberge, D. L. (1956) Relationship between recognition accuracy and order of reporting stimulus dimensions. Journal of Experimental Psychology, 51, 12-18.

Lepley, W. M. (1934) Serial reactions considered as conditioned reactions. Psychological Monographs, 46 (1), Whole No. 205.

Lindley, R. H. (1966) Words and pronunciation as coding aids. Psychonomic Science, 6, 395-396.

Mackworth, J. F. (1962a) Presentation rate and immediate memory. Canadian Journal of Psychology, 16, 42-47.

Mackworth, J. F. (1962b) The effect of display time upon the recall of digits. Canadian Journal of Psychology, 16, 48-55.

Mackworth, J. F. (1962c) The visual image and the memory trace. Canadian Journal of Psychology, 21, 37-56.

Mackworth, J. F. (1963) The relation between the visual image and post-perceptual immediate memory. Journal of Verbal Learning & Verbal Behavior, 2, 75-85.

Mackworth, J. F. (1964) Auditory short-term memory. Canadian Journal of Psychology, 18, 292-303.

Mackworth, J. F. (1965) Presentation rate, repetition, and organization in auditory short-term memory. Canadian Journal of Psychology, 19(4), 304-315.

Madigan, S. A. & McCabe, L. (1971) Perfect recall and total forgetting: A problem for models of short-term memory. Journal of Verbal Learning & Verbal Behaviour, 10, 101-106.

Marks, M. R. & Jack, O. (1952) Verbal context and memory span for meaningful material. American Journal of Psychology, 65, 298-300.

Massaro, S. W. (1970) Perceptual processes and forgetting in memory tasks. Psychological Review, 77 (6), 557-567.

Matthews, W. A. & Hoggart, K. (1970) Associative grouping and free recall. British Journal of Psychology, 61 (3), 345-357.

Mayzner, M. S., Abrevaya, E. L., Frey, R. E., Kaufman, H. G. & Schoenberg, K. M. (1964) Short-term memory in vision. Psychonomic Science, 1, 225-226.

Mayzner, M. S. & Schoenberg, K. M. (1965) Short-term retention and presentation rate. Psychonomic Science, 2, 111-112.

McClean, R. S. & Gregg, L. W. (1967) Effects of induced chunking on temporal aspects of serial recitation. Journal of Experimental Psychology, 74, 455-459.

McGeoch, J. A. (1932) Forgetting and the law of disuse. Psychological Review, 39, 352-370.

McGeoch, J. A. (1942) The Psychology of Human Learning. New York: Longmans.

McGeoch, J. A. & Irion, A. L. (1952) The Psychology of Human Learning. New York: Longmans, Green (2nd edition).

McLaughlin, J. P. (1968) Recall and recognition measures of the von Restorff effect in serial learning. Journal of Experimental Psychology, 78(1), 99-102.

McNicol, D. (1970) Progressive decay of the memory trace. Psychonomic Science, 20(4), 196

McNulty, J. A. (1966) The measurement of "adopted chunks" in free recall learning. Psychonomic Science, 4, 71-72.

McReynolds, P. & Acker, M. (1959) Serial learning under conditions of rapid presentation of stimuli.
American Journal of Psychology, 72, 589-592.

Mechanic, A. (1964) The responses involved in the rote learning of verbal material.
Journal of Verbal Learning and Verbal Behavior, 3, 30-36.

Melton, A. W. (1963) Implications of short-term memory for a general theory of memory.
Journal of Verbal Learning and Verbal Behavior, 2, 1-21.

Mewhort, D. J., Merikle, P. M. & Bryden, M. P. (1969) On the transfer from iconic to short-term memory.
Journal of Experimental Psychology, 81(1), 89-94.

Miller, G. A. (1956a) The magical number seven, plus or minus two: some limits on our capacity for processing information.
Psychological Review, 63, 81-97.

Miller, G. A. (1965b) Information and memory.
Scientific American, (August), 419, 1-6.

Miller, G. A. (1958) Free recall of redundant strings of letters.
Journal of Experimental Psychology, 56, 485-491.

Miller, G. A., Galanter, E. & Pribram, K. H. (1960) Plans and the Structure of Behavior. New York: Holt, Rinehart & Winston.

Miller, G. A. & Nicely, P. E. (1955) An analysis of perceptual confusions among some English consonants.
Journal of the Acoustical Society of America, 27, 338-352.

Miller, G. A. & Selfridge, J. A. (1950) Verbal context and the recall of meaningful material.
American Journal of Psychology, 63, 176-185.

Moray, N. (1959) Attention in dichotic listening; affective cues and the influence of instructions.
Quarterly Journal of Experimental Psychology, 11, 56-60.

Mortenson, F. J. & Loess, H. (1964) The effect of very brief interpolated activity on short-term retention.
Perceptual and Motor Skills, 18, 797-803.

Morton, J. A. (1964) A model for continuous language behaviour.
Language and Speech, 7, 40-70.

Morton, J. A. (1968) A retest of the response-bias explanation of the word frequency effect. The British Journal of Mathematical & Statistical Psychology, 21(1), 21-33.

Morton, J. A. (1970) A functional model for memory. In: D.A.Norman (Ed.), Models for Human Memory. New York: Academic Press (Pp.203-254).

Morton,J. A. & Holloway, C. M. (1970) Absence of a cross-modal "suffix effect" in short-term memory. Quarterly Journal of Experimental Psychology, 22, 167-176.

Moser, H. M. & Fotheringham, W. C. (1960) Number telling. Technical Report No. 58, R F Project 1080. Ohio State University Research Foundation.

Müller, G. E. & Schumann, F. (1894) Experimentelle Beiträge zur Untersuchung des Gedächtnisses. Zeitschrift für Psychologie, 6, 81-190, 257-339 (cited by Kintsch, 1970).

Murdock, B. B. (1961) The retention of individual items. Journal of Experimental Psychology, 62, 618-625.

Murdock, B. B. (1962) The serial position effect of free recall. Journal of Experimental Psychology, 64, 482-488.

Murdock, B. B. (1963) Interpolated recall in short-term memory. Journal of Experimental Psychology, 66, 525-532.

Murdock, B. B. (1965) Effects of a subsidiary task on short-term memory. British Journal of Psychology, 56, 413-420.

Murdock, B. B. (1966) Visual and auditory stores in short-term memory. Quarterly Journal of Experimental Psychology, 18, 206-211.

Murdock,B. B. (1967a) Some recent developments in short-term memory. British Journal of Psychology, 58(3&4), 421-433.

Murdock, B. B. (1967b) Auditory and visual stores in short-term memory. Acta Psychologica, 27, 316-324.

Murdock, B. B. (1968) Serial order effects in short-term memory. Journal of Experimental Psychology Monograph, 76 (4),2, 1-15.

Murdock, B. B. & vom Saal, W. (1967) Transpositions in short-term memory. Journal of Experimental Psychology, 74, 137-143.

Murdock, B. B. & Walker, K. D. (1969) Modality effects in free recall. Journal of Verbal Learning & Verbal Behavior, 8(5), 665-676.

Murray, D. J. (1966a) Intralist interference and rehearsal time in short-term memory. Canadian Journal of Psychology, 20(4), 413-426.

Murray, D. J. (1966b) Vocalisation-at-presentation and immediate recall with varying recall methods. Quarterly Journal of Experimental Psychology, 18, 9-18.

Neisser, U. (1967) Cognitive Psychology. New York : Appleton-Century-Crofts.

Norman, D. A. (1966) Acquisition and retention in short-term memory. Journal of Experimental Psychology, 72, 369-381.

Norman, D. A. (1969a) Memory and Attention: An Introduction to Human Information Processing. New York: Wiley.

Norman, D. A. (1969b) Memory while shadowing. Quarterly Journal of Experimental Psychology, 21, 85-93.

Norman, D. A. (Ed.) (1970) Models of Human Memory. New York: Academic Press.

Oberly, H. S. (1928) A comparison of the spans of "attention" and memory. American Journal of Psychology, 40, 295-302.

Pavlov, I. P. (1928) Lectures on Conditioned Reflexes (translated by W.H.Gantt.) New York: International Publishers.

Penfield, W. & Milner, B. (1958) Memory deficit produced by bilateral lesions in the hippocampal zone. American Medical Association Archives of Neurology & Psychiatry, 79, 475-497.

Peterson, L. R. (1966a) Short-term memory. Scientific American, 215 (July) (1), 90-95.

Peterson, L.R. (1966b), Short-term verbal memory and learning.
Psychological Review, 73, (3), 193-207

Peterson, L.R. & Peterson, M.J. (1959), Short-term retention of individual verbal items.
Journal of Experimental Psychology, 58, 193-198

Pierie, J.R. & Karlin, J.E. (1957), Reading rates and the information rate of a human channel.
Bell Systems Technical Journal, 36, 497-516

Pillsbury, W.B. & Sylvester, A. (1940), Retroactive and proactive inhibition in immediate memory.
Journal of Experimental Psychology, 27, 532-545

Pollack, I. (1953), The assimilation of sequentially encoded information.
American Journal of Psychology, 66, 421-435

Pollack, I., Johnson, L.D. & Knaff, R.P. (1959), Running memory span.
Journal of Experimental Psychology, 57, 137-146

Posner, M.I. (1964), Rate of presentation and order of recall in immediate memory.
British Journal of Psychology, 55, 303-306

Posner, M.I. (1967), Short-term memory systems in human information processing.
Acta Psychologica, 27, 267-284

Posner, M.I. & Rossman, E. (1965), Effect of size and location of informational transform upon short-term retention.
Journal of Experimental Psychology, 70, 496-505

Postman, L. (1961), The present status of interference theory.
In: C.N. Cofer (Ed.), Verbal Learning and Verbal Behavior. New York: McGraw-Hill, pp. 152-179

Postman, L. & Adams, P.A. (1957), Studies in incidental learning.
Vll Effects of frequency of exercise and length of list.
Journal of Experimental Psychology, 56, 86-94

Postman, L. & Phillips, L.W. (1965), Short-term temporal changes in free recall.
Quarterly Journal of Experimental Psychology, 17, 132-138

Poulton, E.C. (1958), Copying behind during dictation.
Quarterly Journal of Experimental Psychology, 10, 48-55

Poulton, E.C. (1966), Engineering psychology,
Annual Review of Psychology, 17, 177-200

Poulton, E.C. & Brown, C.H. (1968), Memory after reading aloud and reading silently,
British Jourhal of Psychology, 58, 219-222

Raymond, B. (1969), Short-term storage and long-term storage in free recall.
Journal of Verbal Learning and Verbal Behavior, 8, 567-574

von Restorff, H. (1938), Über die Wirkung von Bereichsbilgung im Spurenfeld.
PsychologischeForschung, 18, 299-324
See E.A. Goss & C.F. Nodine. Paired-Associates Learning. New York: Academic Press, 1965

Rogov, A.I. (1964), Formation and dynamics of topic clusters in free recall.
Soviet Psychology and Psychiatry, 2, 19-26

Rosenberg, S. (1966), Clustering and repeated trials.
Journal of General Psychology, 74, 89-96

Routh, D.A. (1970), "Trace strength",modality and the serial position curve in immediate memory.
Psychonomic Science, 18 (6), 355-357

Routh, D:A. (1971), Independence of the modality effect and amount of silent rehearsal in immediate serial recall.
Journal of Verhal Learning and Verbal Behavior, 10, 213-218

Rundus, D. & Atkinson, R.C. (1970), Rehearsal processes in free recall: a procedure for direct observation.
Journal of Verbal Learning and Verbal Behavior, 9, 99-105

Ryan, J. (1969a), Grouping and short-term memory: different means and patterns of grouping.
Quarterly Journal of Experimental Psychology, 21, 137-147

Ryan, J. (1969b), Temporal grouping, rehearsal and short-term memory.
Quarterly Journal of Experimental Psychology, 16, 1-10

Sampson, H. (1964), Immediate memory and simultaneous visual stimulation.
Quarterly Journal of Experimental Psychology, 16, 1-10

Sampson, J.R. (1969), Influence of rehearsal on serial-position effects in immediate free recall.
Psychological Reports, 25, 893-894

Sampson, H. & Spong, P. (1961a), Binocular fixation and immediate memory.
British Journal of Psychology, 52, 239-248

Sampson, H. & Spong, P. (1961b), Handedness, eye-dominance and immediate memory.
Quarterly Journal of Experimental Psychology, 13, 173-180

Sanders, A.F. (1961), Rehearsal and recall in immediate memory.
Ergonomics, 4, 29-34

Savin, H.B. (1963), Word-frequency effect and errors in the perception of speech.
Journal of the Acoustical Society of America, 35, 200-206

Scheifer, C.J. & Voss, J.F. (1969), Reminiscence in short-term memory.
Journal of Experimental Psychology, 80 (2), 262-270

Schwartz, M. & Bryden, M. (1966), Retrieval and the effects of changing elements of a repeating sequence.
Paper presented at the meetings of the Canadian Psychological Association, June, 1966. Cited by Bower, G.H. & Winzenz, D. (1969)

Selzer, L.K. & Wickelgren, W.A. (1963), Number of items presented and recalled as determinants of short-term recall.
Nature, 200, 1239-1241

Severin, F.T. & Rigby, M.K. (1963), Influence of digit grouping on memory for telephone numbers.
Journal of Applied Psychology, 47, 117-119

Shannon, C.E. & Weaver, W. (1949), The Mathematical Theory of Communication. Urbana, I.K.: University of Illinois Press.

Shepard, R.N. & Sheenan, M.M. (1965), Immediate recall of numbers containing a familiar prefix or postfix.
Perceptual and Motor Skills, 21 (1), 263-273

Sherman, M.F. & Turvey, M.T. (1969), Modality differences in short-term serial memory as a function of presentation rate.
Journal of Experimental Psychology, 80, 335-338

Shiffrin, R.M. & Atkinson, R.C. (1969), Storage and retrieval processes in long-term memory.
Psychological Review, 76, 179-193

Shulman, H.G. (1970), Encoding and retention of semantic and phonemic information in short- term memory.
Journal of Verbal Learning and Verbal Behavior, 9, 499-508

Sinks, W.S. (1959), New numbers for tomorrow's telephones.
Bell Telephones Magazine. 38, 6-15

Skinner, B.F. (1942), The processes involved in the repeated guessing of alternatives.
Journal of Experimental Psychology, 30, 495-503

Solomon, R.L. & Howes, D.H. (1951), Word probability, personal values and visual duration thresholds.
Psychological Review, 58, 256-270

Sperling, G. (1960), The information available in brief visual presentations.
Psychological Monographs, 74, [illegible], No. 11

Sperling, G. (1963), A model for visual memory tasks.
Human Factors, 5, 19-31

Sperling, G. (1967), Successive approximations to a model for short-term memory.
Acta Psychologica, 27, 285-292

Sperling, G. & Speelman, R.G. (1970), Acoustic similarity and auditory short-term memory: experiments and a model.
In: D.A. Norman, Models of Human Memory. New York: Academic Press, pp. 151-202

Summerfield, A. & Legge, D. (1960), Perception and information theory.
Bulletin of the British Psychological Society, 42, 23-28

Tell, P.M. (1971), Influence of vocalization on short-term memory. Journal of Verbal Learning and Verbal Behavior, 10, 149-156

Thorndike, E.L. & Lorge, I. (1944), The Teachers' Word Book of 30,000 Words. New York: Columbia University Press.

Thorpe, C.E. & Rowland, C.E. (1965), The effect of "natural" grouping of numerals on short-term memory. Human Factors, February, 1965, 38-44

Thurm, A.T. & Glanzer, M. (1971), Free recall in children: long-term store vs short-term store. Psychonomic Science, 23 (2), 175-176

Tinker, M.A. (1928), The relative legibility of the letters, the digits, and of certain mathematical signs. Journal of General Psychology, 1, 472-495

Treisman, A.M. (1964a), Monitoring and the storage of irrelevant messages in selective attention. Journal of Verbal Learning and Verbal Behavior, 3, 449-459

Treisman, A.M. (1964b), Selective attention in man. British Medical Bulletin, 20, 12-16

Treisman, A:M. (1964c), The effect of irrelevant material on the efficiency of selective listening. American Journal of Psychology, 77, 533-546

Tulving, E. (1962), Subjective organization in free recall of unrelated words. Psychological Review, 69, 344-354

Tulving, E. (1966), Subjective organization and effects of repetition in multitrial free recall learning. Journal of Verbal Learning and Verbal Behavior, 5, 193-197

Tulving, E. (1968), Theoretical issues in free recall. In: T. Dixon & D. Horton (Eds.), Verbal Behavior and General Behavior Theory. Englewood Cliffs: New Jersey: Prentice Hall pp. 2-36

Tulving, E. (1969), Retrograde amnesia in free recall. Science, 164, 88-91

Tulving, E. & Colotla, V.A. (1970), Free recall of trilingual lists.
Cognitive Psychology, 1, 86-98

Tulving, E. & Madigan, S.A. (1970), Memory and verbal learning.
Annual Review of Psychology, 21, 437-484

Tulving, E. & Patkau, J.E. (1962), Concurrent effects of contextual constraint and word frequency on immediate recall and learning of verbal material.
Canadian Journal of Psychology, 16, 83-95

Tulving, E. & Patterson, R.D. (1968), Functional units and retrieval processes in free recall.
Journal of Experimental Psychology, 77, 239-248

Tune, G.S. (1964), Response preferences: a review of some relevant literature.
Psychological Bulletin, 61 (4), 286-302

Underwood, B.J. & Schultz, R.W. (1960), Meaningfulness and Verbal Learning. Philadelphia: Lippincott.

Walker, E.L. & Tarte, R.D. (1963), Memory storage as a function of arousal and time with homogeneous and heterogeneous lists.
Journal of Verbal Learning and Verbal Behavior, 2, 113-119

Warrington, E.K., Kinsbourne, M. & James, M. (1966), Uncertainty and transitional probability in the span of apprehension.
British Journal of Psychology, 57, 7-16

Wason, P.C. (1960), On the failure to eliminate hypotheses in a conceptual task.
Quarterly Journal of Experimental Psychology, 12, 129-140

Waugh, N.C. (1962), Immediate memory as a function of repetition.
Journal of Verbal Learning and Verbal Behavior, 1, 95-99

Waugh, N.C. (1970), Retrieval time in short-term memory.
British Journal of Psychology, 61 (1), 1-12

Waugh, N.C. & Norman, D.A. (1965), Primary memory.
Psychological Review, 72, 89-104

Welch, G.B. & Burnett, C.T. (1924), Is primacy a factor in association-formation ?
American Journal of Psychology, 35, 396-401

Welford, A.T. (1968), Fundamentals of Skill. London: Methuen.

Wickelgren, W.A. (1964), Size of rehearsal group and short-term memory.
Journal of Experimental Psychology, 68, (4), 413-419

Wickelgren, W.A. (1965a), Acoustic similarity and intrusion errors in short-term memory.
Journal of Experimental Psychology, 70, 102-108

Wickelgren, W.A. (1965b), Short-term memory for phonemically similar lists.
American Journal of Psychology, 78, 567-574

Wickelgren, W.A. (1965c), Distinctive features and errors in short-term memory for English vowels.
Journal of the Acoustic Society of America, 38, 583-588

Wickelgren, W.A. (1966a), Distinctive features and errors in short-term memory for English consonants.
Journal of the Acoustical Society of America, 39, 388-398

Wickelgren, W.A. (1966b), Short-term recognition memory for single letters and phonemic similarity of retroactive interference.
Quarterly Journal of Experimental Psychology, 18, 55-62

Wickelgren, W.A. (1969), Auditory or articulatory coding in verbal short-term memory.
Psychological Review, 76 (2), 232-235

Wickens, D.D., Born, D.G. & Allen, C.K. (1963), Proactive inhibition and item similarity in short-term memory.
Journal of Verbal Learning and Verbal Behavior, 2, 440-445

Wiener, N. (1948), Cybernetics. New York: Technological Press of M. I. T. (Wiley)

Winer, B.J. (1970), Statistical Principles in Experimental Design. New York: McGraw-Hill, International Student Edition

Winnick, W.A. & Dornbush, R.L. (1965), Pre- and post-exposure processes in tachistoscopic identification.
Perceptual and Motor Skills, 20, 107-113

Winograd, E. (1968a), List differentiation as a function of frequency and retention interval.
Journal of Experimental Psychology Monograph Supplement, 72 (2), Part 2

Winograd, E. (1968b), Retention of list differentiation and word frequency.
Journal of Verbal Learning and Verbal Behavior, 7, 859-863

Woodhead, M. M. (1966a), Varying the number of alternatives in short-term recall.
British Journal of Psychology, 57 (1&2), 45-52

Woodhead, M.M. (1966b), Simple rehearsal strategies for short-term recall.
Psychonomic Science, 6 (8), 385-386

Woodworth, R.S. (1938), Experimental Psychology, New York: Holt

Wooldridge, E.E. (1963), The Machinery of the Brain. Illinois: McGraw-Hill

Yntema, D.B. & Mueser, G.E. (1960), Remembering the present state of a number of variables.
Journal of Experimental Psycholoogy, 60, 18-22

Yntema, D.B. & Mueser, G.E. (1962), Keeping track of variables that have few or many states.
Journal of Experimental Psychology, 63, 391-395

Yntema, D.B. & Trask, F.P. (1963), Recall as a search process.
Journal of Verbal Learning and Verbal Behavior, 2, 65-74

Young, R.K. (1968), Serial learning. In: Dixon, T.R. & Horton, D.L. D.L. (Eds.), Verbal Learning and General Behavior Theory.
Englewood Cliffs: New Jersey: Prentice-Hall, pp. 122-148

Young, R.K., Patterson, J. & Benson, W.M. (1963), Backward serial learning.
Journal of Verbal Learning and Verbal Behaviour, 1, 335-338

Zimmerman, J. & Underwood, B.J. (1968), Ordinal position knowledge within and across lists as a function of instructions in free recall learning.
Journal of General Psychology, 79, 301-307

List of Appendices

APPENDIX A

CONRAD'S LISTENING ERROR MATRIX.

R. Conrad
(1964)

APPENDIX. LISTENING ERRORS, FULL ALPHABET

Stimulus letter

Response letter	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
A	.	25	9	24	18	9	35	77	19	151	200	134	45	126	478	9	8	23	22	17	28	22	79	8	21	22	
B	2	.	171	197	107	2	142	15	13	30	11	3	11	10	4	75	94	—	2	84	33	168	4	2	3	25	
C	2	32	.	19	24	4	19	7	3	10	4	—	4	5	—	35	30	—	2	42	4	20	1	5	5	3	
D	4	125	71	.	166	1	104	4	12	21	6	3	11	7	—	34	47	2	—	43	11	105	4	2	6	11	
E	8	271	195	252	.	11	208	31	100	9	16	7	59	77	9	111	66	6	6	163	65	119	11	19	5	6	
F	10	6	4	4	4	.	3	55	2	12	30	25	13	8	6	2	–	4	336	4	4	3	4	238	5	81	
G	4	40	22	47	34	—	.	2	9	8	5	—	3	3	1	18	39	—	3	12	33	37	2	2	1	1	
H	27	3	15	13	22	26	3	.	1	15	28	7	9	15	34	6	16	4	43	12	2	5	14	28	1	32	
I	1	2	5	2	14	5	4	3	.	14	6	51	52	30	23	1	5	188	21	6	5	3	5	4	78	5	
J	10	5	6	3	1	1	12	8	—	.	158	9	4	2	7	8	7	1	2	3	8	10	8	3	20	35	
K	46	2	7	6	—	7	—	15	7	64	.	16	9	17	21	6	12	7	7	6	1	5	10	3	6	28	
L	69	6	2	3	4	16	6	9	35	65	42	.	32	25	73	4	6	57	38	1	2	3	32	4	61	41	
M	106	10	14	5	13	22	22	9	31	42	73	83	.	334	24	2	7	22	21	3	6	4	17	9	30	41	
N	234	13	21	20	35	32	31	40	47	104	127	51	512	.	59	6	6	40	38	9	12	20	28	14	47	55	
O	116	10	5	10	18	22	26	16	31	80	80	122	15	30	.	9	8	41	26	36	15	20	76	6	15	50	
P	7	162	350	201	172	11	167	21	12	18	39	2	31	23	4	.	231	—	5	505	16	91	2	5	3	31	
Q	3	43	90	59	52	—	103	16	8	12	8	1	3	6	1	215	.	1	1	90	41	26	5	2	3	9	
R	13	3	3	3	13	14	10	4	104	17	20	136	43	12	15	1	9	.	15	4	2	5	7	9	162	28	
S	20	2	18	9	17	488	4	151	3	38	34	22	23	11	18	2	9	5	.	7	3	3	5	391	10	111	
T	3	143	232	158	124	14	116	20	9	11	13	1	12	11	4	281	175	6	8	.	11	50	8	5	2	10	
U	10	106	74	90	125	2	189	26	50	23	24	1	22	23	11	79	112	3	5	29	.	347	13	13	4	8	
V	4	122	61	147	55	1	135	13	6	15	18	—	8	11	—	34	35	1	1	22	79	.	2	—	6	15	
W	4	31	5	23	7	9	4	4	17	5	11	6	8	11	1	6	3	2	2	2	17	19	.	1	14	91	
X	1	1	6	3	6	245	1	163	1	5	12	9	2	1	1	2	1	2	184	2	2	1	2	.	2	56	
Y	7	5	7	1	5	7	11	3	86	98	25	62	39	11	7	1	2	32	5	7	4	5	2	4	.	22	
Z	4	1	5	3	4	40	4	21	2	115	52	6	7	3	3	3	5	2	9	—	4	6	6	22	21	.	
	715	1169	1398	1302	1040	989	1359	733	608	982	1042	757	977	812	804	950	933	449	802	1109	408	1097	347	799	531	817	22,929

Total no. letters presented = 37,440.

APPENDIX B

TINKER'S MOST PROBABLE SHAPE CONFUSIONS

(TINKER, 1928)

TABLE 4

CONFUSABILITY OF THE DIFFERENT CHARACTERS (SECOND SERIES—WHICH INCLUDED CAPITALS)

haracter	No. times read wrong	Characters confused with: Amount of that confusion in per cent
A	70	△, 57; X, 10; S, 6; (27)*
B	60	R, 12; H, 10; Q, 8; DE, 7; 8, 5; (51)
C	46	G, 26; L, 13; O, 11; U, 7; (43)
D	29	B, 21; Q, 14; O, 10; (55)
E	65	F, 15; L, 14; HIU%, 6; (47)
F	61	P, 28; I√, 13; E, 8; T, 7; Y, 6; (25)
G	65	6, 17; CO, 14; 0, 9; ○Q, 8; (30)
H	46	B, 28; UR, 13; N, 9; P, 6; (31)
I	77	1, 60; (40)
J	40	1, 20; 3, 15; I, 13; 7, 7; (45)
K	46	R, 22; Z, 8; Σ%, 7; (56)
L	48	1, 29, I, 17; □, 10; √, 8; ZU, 6; (24)
M	30	WN, 10; (80)
N	35	S, 23; X, 20; %, 11; M△, 8; (30)
O	31	0, 29; Q, 16; □○, 10; (35)
P	34	F, 41; ±, 9; (50)
Q	42	O, 60; 0, 10; ○, 7; (23)
R	65	B, 28; H, 18; 8P, 6; (48)
S	52	8, 42; %, 17; N, 6; (35)
T	55	?, 20; I, 16; Y, 13; F, 11; 7, 9; 1, 5; (26)
U	37	IL, 14; 1, 11; GGT, 8 (37)
V	51	√, 37; Y, 19; (44)
W	17	=, 17; M, 11; (72)
X	29	N, 24; %, 17; Y, 10; (49)
Y	32	√, 28; V, 19; X, 16; (37)
Z	22	7, 18; X8, 14; (54)
1	55	I, 40; J, 22; +, 5; (33)
2	50	3, 20; %, 10; ZΣ, 8; J, 6; (48)
3	47	2, 13; 9, 11; 5, 9; (67)
4	51	1, 20; I, 12; J+, 8; 5?, 6; (40)
5	60	3%, 13; S6, 8; Z2, 7; (44)
6	47	0, 23; 89, 12; G, 7; (46)
7	39	?, 28; Y÷+, 7; (51)
8	57	S, 18; 36, 12; 5, 9; R9%, 5; (34)
9	36	0, 19; %, 11; Q58, 8; (46)
0	72	9, 26; 6, 22; 8, 8; S, 6; (38)
Σ	40	Z, 30; 2, 15; ±, 13; X, 10; %, 7; (25)
÷	58	=, 28; ±, 20; +, 17; □, 12; %, 10; (13)
=	30	±, 43; ÷, 17; (40)
+	47	÷, 38; ±, 11; □, 8; √△, 6; (31)
±	48	=, 22; ÷, 18; +, 16; %, 6; (38)
□	35	+, 29; ÷, 11; ○, 8; (52)
△	33	A, 27; X, 9; (64)
○	33	□, 27; ÷, 18; O, 12; =, 9; (34)
?	35	7, 17; ÷, 11; 2+, 8; (56)
%	52	÷, 21; ±, 10; =S, 7; Q5+, 6; (36)
√	42	Y, 24; ÷, 14; V, 10; 2, 9; ?%, 7; (29)

*The numbers in parentheses indicate percentages of scattering errors.

APPENDIX D

SIMPLE EFFECTS, for the Experiments of Chapter IV, and showing tests of significance between the different conditions. Values of the F ratios are shown along with significance levels.

The error terms in the analyses of variance computed for each experiment were used for the calculation of F ratios on the simple effects for each experiment, (after Winer, 1970, p.340).

The following legend is used:

A_1B_1 = Pure delay and recall request

A_2B_1 = Immediate recall request

A_1B_2 = Pure delay, filled delay and recall request

A_2B_2 = Filled delay and recall request

C_1 = First group of presented items

C_2 = Middle group of presented items

C_3 = Last group of presented items

Conditions	Expt. I.	Expt. II.	Expt. III. Group Recall Criterion
$A_1B_1 - A_2B_1$	N S	N S	N S
$A_1B_2 - A_2B_2$	N S	9.28 p<.01	N S
$A_1B_1 - A_1B_2$	6.63 p<.05	2.58 p<.10	5.36 p<.05
$A_2B_1 - A_2B_2$	6.63 p<.05	24.84 p<.01	1.53 N S
At C_1 :-			
$A_1 - A_2$	N S	2.79 N S	N S
$B_1 - B_2$	N S	N S	N S
$A_1B_1 - A_2B_1$	N S	N S	4.41 p<.05
$A_1B_1 - A_1B_2$	1.51 N S	N S	N S
$A_1B_1 - A_2B_2$	N S	3.58 p<.10	N S
$A_2B_1 - A_1B_2$	1.51 N S	N S	N S
$A_2B_1 - A_2B_2$	N S	3.58 p<.10	3.91 p<.10
$A_1B_2 - A_2B_2$	1.11 N S	5.59 p<.05	N S
At C_2 :-			
$A_1 - A_2$	N S	N S	N S
$B_1 - B_2$	2.22 NS	N S	N S
$A_1B_1 - A_2B_1$	N S	N S	N S
$A_1B_1 - A_1B_2$	N S	N S	N S
$A_1B_1 - A_2B_2$	N S	N S	N S
$A_2B_1 - A_1B_2$	1.51 N S	N S	N S
$A_2B_1 - A_2B_2$	N S	1.75 N S	N S
$A_1B_2 - A_2B_2$	N S	1.51 N S	N S
At C_3 :-			
$A_1 - A_2$	N S	1.45 N S	N S
$B_1 - B_2$	22.25 p<.01	41.20 p<.01	46.43 p<.01
$A_1B_1 - A_2B_1$	N S	N S	N S
$A_1B_1 - A_1B_2$	7.89 p<.01	14.30 p<.01	16.62 p<.01
$A_1B_1 - A_2B_2$	14.91 p<.01	29.05 p<.01	24.42 p<.01
$A_2B_1 - A_1B_2$	7.89 p<.01	13.60 p<.01	22.04 p<.01
$A_2B_1 - A_2B_2$	14.91 p <.01	28.04 p <.01	30.91 p<.01
$A_1B_2 - A_2B_2$	N S	2.58 N S	N S

Conditions	Expt. IV. Ordered Recall Criterion	Expt. IV. Free Recall Criterion	Expt. V. Ordered Recall Criterion	Expt. V. Free Recall Criterion
$A_1B_1 - A_2B_1$	5.46 $p<.05$	4.75 $p<.05$	10.10 $p<.01$	10.08 $p<.01$
$A_1B_2 - A_2B_2$	N S	2.29 $p<.10$	N S	N S
$A_1B_1 - A_1B_2$	2.38 $p<.10$	N S	15.39 $p<.01$	20.24 $p<.01$
$A_2B_1 - A_2B_2$	15.04 $p<.01$	22.32 $p<.01$	N S	1.48 N S
At C_1: -				
$A_1 - A_2$	6.25 $p<.05$	3.18 $p<.10$	N S	N S
$B_1 - B_2$	N S	N S	N S	N S
$A_1B_1 - A_2B_1$	3.72 $p<.10$	3.29 $p<.10$	N S	1.91 N S
$A_1B_1 - A_1B_2$	N S	N S	3.33 $p<.10$	7.12 $p<.05$
$A_1B_1 - A_2B_2$	1.39 N S	1.46 N S	N S	N S
$A_2B_1 - A_1B_2$	5.56 $p<.05$	1.72 N S	N S	1.66 N S
$A_2B_1 - A_2B_2$	N S	N S	3.00 $p<.10$	N S
$A_1B_2 - A_2B_2$	2.58 N S	N S	6.01 $p<.05$	5.73 $p<.05$
At C_2 : -				
$A_1 - A_2$	N S	N S	3.03 N S	8.20 $p<.01$
$B_1 - B_2$	N S	N S	2.60 N S	4.90 $p<.05$
$A_1B_1 - A_2B_1$	N S	N S	12.01 $p<.01$	12.88 $p<.01$
$A_1B_1 - A_1B_2$	N S	N S	11.39 $p<.01$	9.79 $p<.01$
$A_1B_1 - A_2B_2$	N S	N S	5.62 $p<.05$	12.88 $p<.01$
$A_2B_1 - A_1B_2$	N S	N S	N S	N S
$A_2B_1 - A_2B_2$	N S	2.29 $p<.10$	N S	N S
$A_1B_2 - A_2B_2$	N S	1.46 N S	N S	N S
At C_3 : -				
$A_1 - A_2$	N S	N S	14.00 $p<.01$	2.65 N S
$B_1 - B_2$	51.83 $p<.01$	34.17 $p<.01$	27.10 $p<.01$	13.76 $p <.01$
$A_1B_1 - A_2B_1$	7.18 $p<.01$	1.46 N S	7.92 $p<.01$	N S
$A_1B_1 - A_1B_2$	10.34 $p<.01$	6.35 $p<.05$	15.38 $p<.01$	4.10 $p<.10$
$A_1B_1 - A_2B_2$	18.38 $p<.01$	20.58 $p<.01$	40.77 $p<.01$	14.24 $p<.01$
$A_2B_1 - A_1B_2$	34.74 $p<.01$	13.91 $p<.01$	N S	2.17 N S
$A_2B_1 - A_2B_2$	48.53 $p<.01$	33.02 $p<.01$	12.66 $p<.01$	10.37 $p<.01$
$A_1B_2 - A_2B_2$	N S	4.07 $p<.10$	6.07 $p<.05$	3.06 $p<.10$

APPENDIX E

EXPERIMENT I

RAW SCORES

EXPERIMENTAL CONDITION	GROUPS	Ss.	1	5	9	13	17	21	25	29	33	TOTAL	%
A1 B1 PURE DELAY	FIRST		2	2	2	2	3	1	5	1	3	21	47
	MIDDLE		2	2	3	3	0	1	3	3	2	19	42
	LAST		5	3	2	5	3	2	3	5	5	33	73
	TOTAL		9	7	7	10	6	4	11	9	10	73	54
		Ss.	2	6	10	14	18	22	26	30	34		
A2 B1 IMMEDIATE RECALL	FIRST		2	4	0	5	3	3	2	2	0	21	47
	MIDDLE		2	3	4	0	3	3	5	0	0	20	44
	LAST		1	5	3	3	5	4	5	2	5	33	73
	TOTAL		5	12	7	8	11	10	12	4	5	74	55
		Ss.	3	7	11	15	19	23	27	31	35		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		4	2	3	1	0	2	2	0	0	14	31
	MIDDLE		3	3	2	2	0	0	1	1	1	13	29
	LAST		3	3	2	1	1	1	3	1	2	17	38
	TOTAL		10	8	7	4	1	3	6	2	3	44	32
		Ss.	4	8	12	16	20	24	28	32	36		
A2 B2 FILLED DELAY	FIRST		4	0	4	0	2	2	2	3	3	20	44
	MIDDLE		1	3	2	1	1	3	0	1	2	14	31
	LAST		3	0	0	1	1	0	1	3	2	11	24
	TOTAL		8	3	6	2	4	5	3	7	7	45	34

APPENDIX F

EXPERIMENT II

RAW SCORES

EXPERIMENTAL CONDITION	GROUPS	Ss. 1	5	9	13	17	21	25	29	33	37	41	TOTAL	%
A1 B1 PURE DELAY	FIRST	7	6	8	4	13	7	11	8	9	10	5	88	53
	MIDDLE	6	2	10	8	6	9	4	6	4	3	7	65	39
	LAST	15	13	12	15	15	11	4	14	10	13	13	135	82
	TOTAL	28	21	30	27	34	27	19	28	23	26	25	288	58
		Ss. 2	6	10	14	18	22	26	30	34	38	42		
A2 B1 IMMEDIATE RECALL	FIRST	8	12	6	10	7	8	9	8	7	7	6	88	53
	MIDDLE	8	4	9	4	12	5	6	10	4	3	7	72	44
	LAST	10	9	14	12	14	11	14	11	11	13	15	134	81
	TOTAL	26	25	29	26	33	24	29	29	22	23	28	294	59
		Ss. 3	7	11	15	19	23	27	31	35	39	43		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST	8	9	5	8	9	8	12	8	9	9	8	93	56
	MIDDLE	3	8	4	7	5	9	9	5	9	6	6	71	43
	LAST	11	10	5	11	7	9	8	6	8	12	8	95	57
	TOTAL	22	27	14	26	21	26	29	19	26	27	22	259	52
		Ss. 4	8	12	16	20	24	28	32	36	40	44		
A2 B2 FILLED DELAY	FIRST	6	9	10	4	7	5	6	3	4	9	5	68	41
	MIDDLE	4	8	6	6	6	5	5	5	4	5	4	58	35
	LAST	10	9	4	5	8	8	8	8	6	6	6	78	47
	TOTAL	20	26	20	15	21	18	19	16	14	20	15	204	41

APPENDIX G

EXPERIMENT III

RAW SCORES GROUP RECALL CRITERION

EXPERIMENTAL CONDITION	GROUPS	Ss.										TOTAL	%
		Ss.	1	5	9	13	17	21	25	29	33	37		
A1 B1 PURE DELAY	FIRST		7	6	5	2	3	3	7	6	6	7	52	52
	MIDDLE		2	6	3	1	0	2	0	2	8	3	27	27
	LAST		8	8	10	7	8	5	8	10	10	2	76	76
	TOTAL		17	20	18	10	11	10	15	18	24	12	155	51
		Ss.	2	6	10	14	18	22	26	30	34	38		
A2 B1 IMMEDIATE RECALL	FIRST		5	4	5	3	6	4	1	2	2	3	35	35
	MIDDLE		5	1	3	2	7	2	1	4	0	1	26	26
	LAST		6	10	8	8	10	8	9	9	8	5	81	81
	TOTAL		16	15	16	13	23	14	11	15	10	9	142	47
		Ss.	3	7	11	15	19	23	27	31	35	39		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		8	4	5	3	5	3	5	2	5	4	44	44
	MIDDLE		4	0	1	1	3	1	4	4	4	3	25	25
	LAST		4	5	5	2	6	5	2	3	7	4	43	43
	TOTAL		16	9	11	6	14	9	11	9	16	11	112	37
		Ss.	4	8	12	16	20	24	28	32	36	40		
A2 B2 FILLED DELAY	FIRST		7	4	8	6	4	4	5	3	6	4	51	51
	MIDDLE		2	1	5	5	5	3	4	1	2	4	32	32
	LAST		4	2	7	5	4	0	4	1	5	4	36	36
	TOTAL		13	7	20	16	13	7	13	5	13	12	119	40

FREE RECALL CRITERION

	A1 B1		A2 B1		A1 B2		A2 B2	
GROUPS	TOTAL	PERCENT	TOTAL	PERCENT	TOTAL	PERCENT	TOTAL	PERCENT
FIRST	55	55	40	40	48	48	56	56
MIDDLE	34	34	27	27	36	36	35	35
LAST	78	78	83	83	53	53	38	38
TOTAL	167	56	150	50	137	46	129	43

APPENDIX H

EXPERIMENT IV

RAW SCORES ORDERED RECALL CRITERION

EXPERIMENTAL CONDITION	GROUPS	Ss.	1	5	9	13	17	21	25	29	33	37	TOTAL	%
A1 B1 PURE DELAY	FIRST		2	3	7	2	5	3	2	7	5	2	38	25
	MIDDLE		1	1	5	9	3	1	2	3	2	0	27	18
	LAST		5	7	5	7	8	3	5	7	7	11	75	50
	TOTAL		18	11	17	18	16	7	9	17	14	13	140	31
		Ss.	2	6	10	14	18	22	26	30	34	38		
A2 B1 IMMEDIATE RECALL	FIRST		4	2	8	6	4	10	6	6	6	4	56	37
	MIDDLE		6	1	7	0	4	3	2	1	5	2	31	21
	LAST		14	7	9	8	11	15	7	9	5	15	100	66
	TOTAL		24	10	24	14	19	28	15	16	16	21	187	42
		Ss.	3	7	11	15	19	23	27	31	35	39		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		3	6	0	0	5	5	3	4	4	4	34	21
	MIDDLE		2	2	1	3	4	1	4	2	6	5	30	20
	LAST		9	2	1	1	4	8	4	5	4	7	45	30
	TOTAL		14	10	2	4	13	14	11	11	14	16	109	24
		Ss.	4	8	12	16	20	24	28	32	36	40		
A2 B2 FILLED DELAY	FIRST		4	3	8	3	4	6	6	4	7	4	49	32
	MIDDLE		3	2	2	4	3	5	3	0	0	3	25	17
	LAST		6	4	1	1	2	3	10	2	1	5	35	23
	TOTAL		13	9	11	8	9	14	19	6	8	12	109	24

APPENDIX I

EXPERIMENT IV

RAW SCORES FREE RECALL CRITERION

EXPERIMENTAL CONDITION	GROUPS	Ss.	1	5	9	13	17	21	25	29	33	37	TOTAL	%
A1 B1 PURE DELAY	FIRST		3	7	8	2	6	3	5	7	5	4	50	33
	MIDDLE		2	4	9	9	0	6	4	4	3	4	45	30
	LAST		15	11	8	9	10	5	10	10	10	14	102	68
	TOTAL		20	22	25	20	16	14	19	21	18	22	197	44
		Ss.	2	6	10	14	18	22	26	30	34	38		
A2 B1 IMMEDIATE RECALL	FIRST		7	4	10	6	6	10	6	7	7	5	68	45
	MIDDLE		8	6	8	2	5	3	3	4	7	5	51	34
	LAST		14	9	11	10	13	15	11	10	6	15	114	76
	TOTAL		29	19	29	18	24	28	20	21	20	25	233	52
		Ss.	3	7	11	15	19	23	27	31	35	39		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		4	8	4	0	8	7	5	7	6	6	55	37
	MIDDLE		4	5	4	5	5	3	4	4	6	8	48	32
	LAST		9	6	5	4	6	11	7	9	10	10	77	51
	TOTAL		17	19	13	9	19	21	16	20	22	24	180	40
		Ss.	4	8	12	16	20	24	28	32	36	40		
A2 B2 FILLED DELAY	FIRST		7	4	8	4	5	6	7	6	9	6	62	41
	MIDDLE		5	3	3	6	4	4	3	3	1	4	36	24
	LAST		7	7	4	5	3	7	10	4	4	6	57	38
	TOTAL		19	14	15	15	12	17	20	13	14	16	155	34

APPENDIX J

EXPERIMENT IV

RAW SCORES ORDERED RECALL FROM ITEMS PROVIDED

EXPERIMENTAL CONDITION	GROUPS	Ss.	1	5	9	13	17	21	25	29	33	37	TOTAL	%
A1 B1 PURE DELAY	FIRST		2	1	2	1	3	1	1	3	3	2	19	38
	MIDDLE		4	0	2	1	4	0	2	1	3	0	17	34
	LAST		5	2	3	1	2	3	2	1	3	4	26	52
	TOTAL		11	3	7	3	9	4	5	5	9	6	62	41
		Ss.	2	6	10	14	18	22	26	30	34	38		
A2 B1 IMMEDIATE RECALL	FIRST		0	2	2	4	4	4	4	3	2	1	26	52
	MIDDLE		2	4	1	4	2	2	1	2	0	4	22	44
	LAST		4	1	3	3	5	3	2	3	5	5	34	68
	TOTAL		6	7	6	11	11	9	7	8	7	10	82	55
		Ss.	3	7	11	15	19	23	27	31	35	39		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		3	1	1	0	2	2	2	0	3	1	15	30
	MIDDLE		0	1	1	1	3	2	3	2	3	5	21	42
	LAST		3	0	0	1	3	2	4	0	2	2	17	34
	TOTAL		6	2	2	2	8	6	9	2	8	8	53	35
		Ss.	4	8	12	16	20	24	28	32	36	40		
A2 B2 FILLED DELAY	FIRST		3	2	3	2	2	2	2	2	3	3	24	48
	MIDDLE		0	1	2	1	3	1	0	0	2	1	11	22
	LAST		1	2	1	2	1	2	1	2	1	0	13	26
	TOTAL		4	5	6	5	6	5	3	4	6	4	48	32

APPENDIX K

EXPERIMENT V

RAW SCORES ORDERED RECALL CRITERION

EXPERIMENTAL CONDITION	GROUPS	Ss.	1	5	9	13	17	21	25	29	33	37	TOTAL	%
A1 B1 PURE DELAY	FIRST		7	6	10	3	0	1	3	2	5	3	40	27
	MIDDLE		10	5	6	4	5	5	4	5	7	5	56	37
	LAST		14	10	13	15	8	4	11	11	12	10	108	72
	TOTAL		31	21	29	22	13	10	18	18	24	18	204	45
		Ss.	2	6	10	14	18	22	26	30	34	38		
A2 B1 IMMEDIATE RECALL	FIRST		4	5	5	1	2	1	2	2	4	2	28	19
	MIDDLE		2	7	0	1	1	1	1	1	3	1	18	12
	LAST		10	11	5	9	5	10	3	9	8	7	77	51
	TOTAL		16	23	10	11	8	12	6	12	15	10	123	27
		Ss.	3	7	11	15	19	23	27	31	35	39		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		1	0	0	3	1	3	3	5	3	1	20	13
	MIDDLE		2	0	0	2	1	1	8	1	0	4	19	13
	LAST		7	3	10	6	8	8	4	6	7	6	65	43
	TOTAL		10	3	10	11	10	12	15	12	10	11	104	23
		Ss.	4	8	12	16	20	24	28	32	36	40		
A2 B2 FILLED DELAY	FIRST		2	4	13	4	3	3	3	5	5	5	47	31
	MIDDLE		2	1	8	3	4	0	1	2	6	3	30	20
	LAST		0	7	8	7	4	0	1	3	4	4	38	25
	TOTAL		4	12	29	14	11	3	5	10	15	12	115	26

APPENDIX L

EXPERIMENT V

RAW SCORES FREE RECALL CRITERION

EXPERIMENTAL CONDITION	GROUPS	Ss.	1	5	9	13	17	21	25	29	33	37	TOTAL	%
A1 B1 PURE DELAY	FIRST		12	6	10	5	4	9	6	5	8	6	71	47
	MIDDLE		12	9	6	4	10	11	13	9	10	8	92	61
	LAST		14	12	14	15	12	9	13	12	14	12	127	85
	TOTAL		38	27	30	24	26	29	32	26	32	26	290	64
		Ss.	2	6	10	14	18	22	26	30	34	38		
A2 B1 IMMEDIATE RECALL	FIRST		6	8	9	4	5	3	6	4	6	5	56	37
	MIDDLE		3	9	4	6	5	6	6	3	5	6	53	35
	LAST		14	15	9	15	9	13	9	13	14	10	121	81
	TOTAL		23	32	22	25	19	22	21	20	25	21	230	51
		Ss.	3	7	11	15	19	23	27	31	35	39		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		5	3	4	3	1	6	3	8	5	4	42	28
	MIDDLE		6	7	1	12	4	2	10	4	5	7	58	39
	LAST		14	6	15	9	11	11	8	11	8	12	105	70
	TOTAL		25	16	20	24	16	19	21	23	18	23	205	46
		Ss.	4	8	12	16	20	24	28	32	36	40		
A2 B2 FILLED DELAY	FIRST		4	7	13	5	5	3	5	10	9	7	68	45
	MIDDLE		5	3	9	4	7	2	5	6	7	5	53	35
	LAST		7	10	12	11	8	10	6	6	8	8	86	57
	TOTAL		16	20	34	20	20	15	16	22	24	20	207	46

APPENDIX M

EXPERIMENT VI

RAW SCORES

ORDERED RECALL CRITERION

EXPT. CONDITION	GROUPS Ss.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	TOTAL	%
A1 B1 PURE DELAY	FIRST	8	5	6	0	1	2	1	6	4	2	4	2	3	0	3	47	21
	MIDDLE	8	9	7	5	1	8	0	8	7	4	4	4	7	3	4	79	35
	LAST	14	14	13	11	5	15	9	10	8	8	10	5	11	6	9	148	66
	TOTAL	30	28	26	16	7	25	10	24	19	14	18	11	21	9	16	274	41
	Ss.	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30		
A2 B1 IMMEDIATE RECALL	FIRST	2	3	2	7	4	2	0	2	1	2	0	1	3	3	2	34	15
	MIDDLE	1	2	0	3	4	1	0	1	0	0	1	1	2	1	3	20	9
	LAST	11	12	9	13	12	9	3	6	8	7	6	7	10	12	10	135	60
	TOTAL	14	17	11	23	20	12	3	9	9	9	7	9	15	16	15	189	28
	Ss.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST	2	2	2	0	0	2	0	4	1	0	2	0	1	0	1	17	23
	MIDDLE	3	1	1	1	0	0	0	3	1	0	2	1	0	1	0	14	19
	LAST	4	5	3	2	0	3	1	3	3	2	5	1	2	1	2	37	50
	TOTAL	9	8	6	3	0	5	1	10	5	2	9	2	3	2	3	68	31
	Ss.	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30		
A2 B2 FILLED DELAY	FIRST	2	3	2	4	2	2	0	3	0	1	0	2	3	3	3	30	40
	MIDDLE	0	1	0	2	1	1	0	1	0	0	0	1	3	1	1	12	16
	LAST	1	2	1	3	2	2	0	1	1	2	1	1	3	1	1	22	30
	TOTAL	3	6	3	9	5	5	0	5	1	3	1	4	9	5	5	64	29

APPENDIX N

EXPERIMENT V1

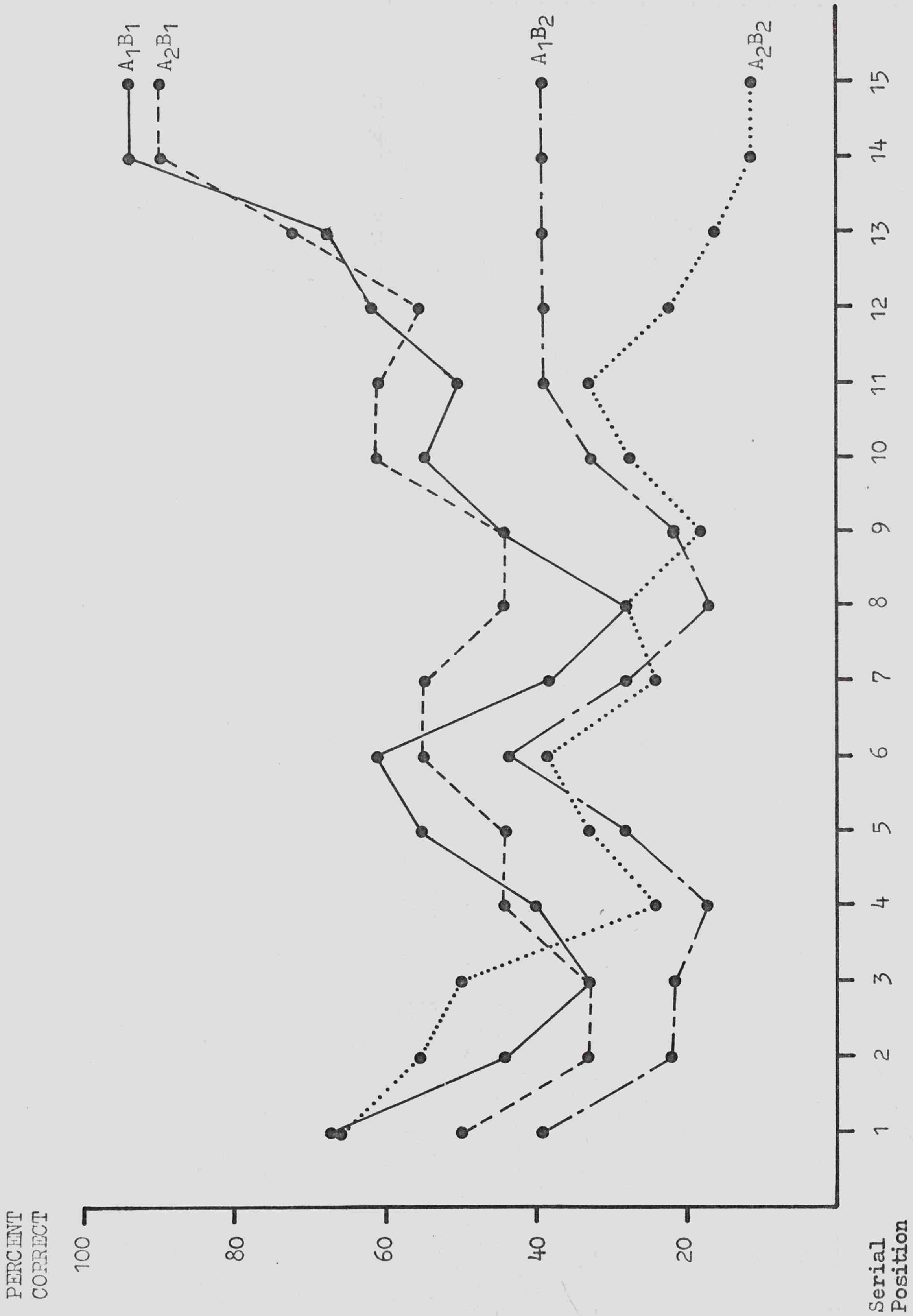
RAW SCORES

FREE RECALL CRITERION

EXPT. CONDITION	GROUPS	Ss.															TOTAL	%
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	29		
A1 B1 PURE DELAY	FIRST		10	9	8	6	6	7	5	9	6	4	5	3	4	3	5	90	40
	MIDDLE		11	11	12	9	8	14	11	12	12	10	9	9	11	9	9	157	70
	LAST		15	14	15	12	10	15	9	15	15	14	13	10	13	10	11	191	85
	TOTAL		36	34	35	27	24	36	25	36	33	28	27	22	28	22	25	438	65
		Ss.	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30		
A2 B1 IMMEDIATE RECALL	FIRST		6	8	7	9	9	7	2	8	5	6	5	6	8	8	7	101	45
	MIDDLE		7	10	6	8	9	7	4	8	4	6	4	7	9	7	5	101	45
	LAST		14	14	13	15	15	14.	10	13	12	13	11	13	15	15	15	202	90
	TOTAL		27	32	26	32	33	28	16	29	21	25	20	26	32	30	27	404	60
		Ss.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29		
A1 B2 PURE DELAY PLUS FILLED DELAY	FIRST		2	2	3	1	0	2	0	4	2	2	4	1	2	0	1	26	35
	MIDDLE		4	2	2	2	1	3	2	3	2	2	2	2	3	2	2	34	45
	LAST		4	5	4	3	0	4	3	5	4	3	5	3	2	1	3	49	65
	TOTAL		10	9	9	6	1	9	5	12	8	7	11	6	7	3	6	109	48
		Ss.	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30		
A2 B2 FILLED DELAY	FIRST		3	4	3	5	3	3	2	4	1	3	2	3	5	4	4	49	65
	MIDDLE		2	3	3	2	4	2	0	2	0	2	1	2	3	2	2	30	40
	LAST		2	3	2	4	3	4	0	3	2	2	1	2	4	3	2	37	49
	TOTAL		7	10	8	11	10	9	2	9	3	7	4	7	12	9	8	116	51

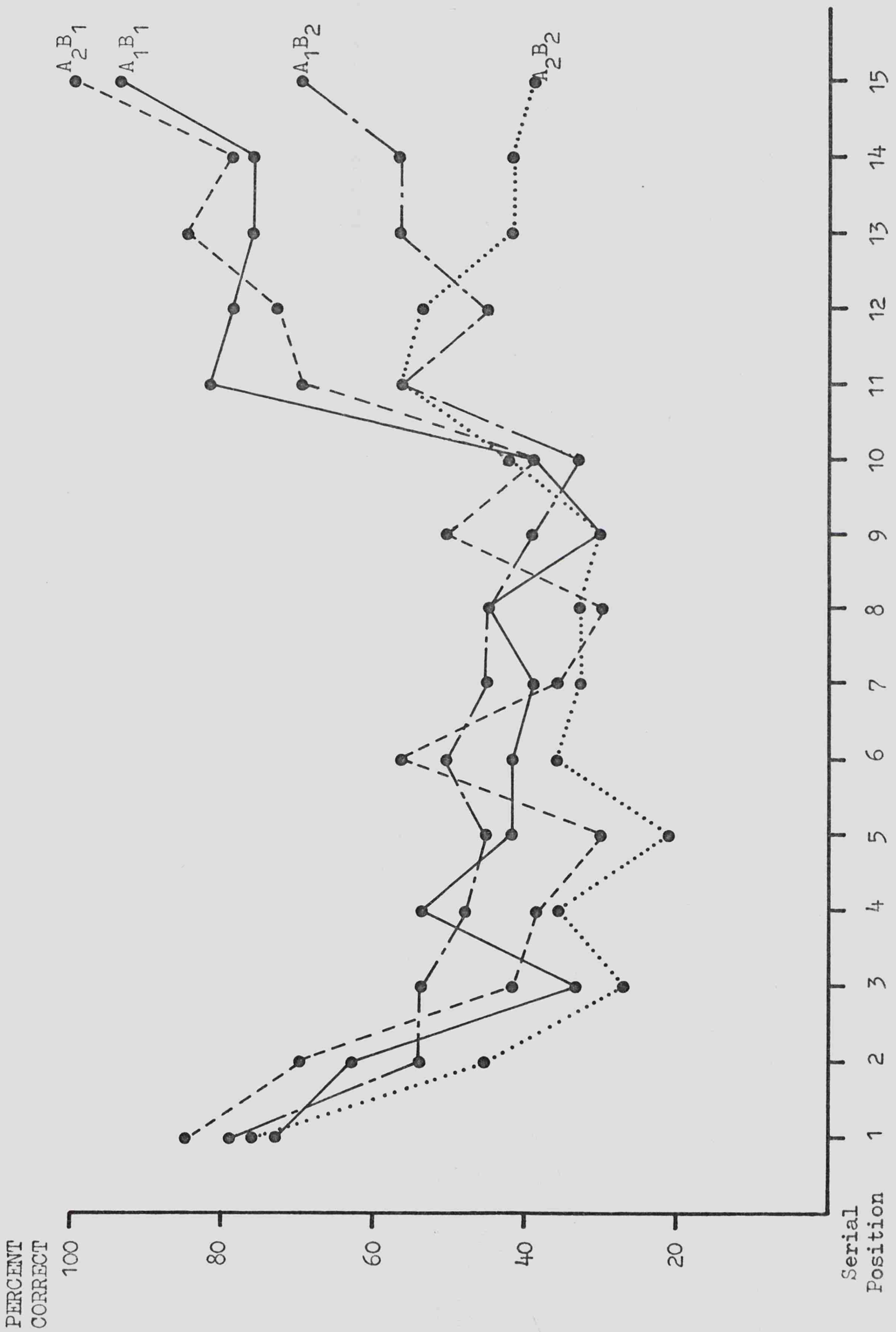
APPENDIX O

EXPERIMENT I



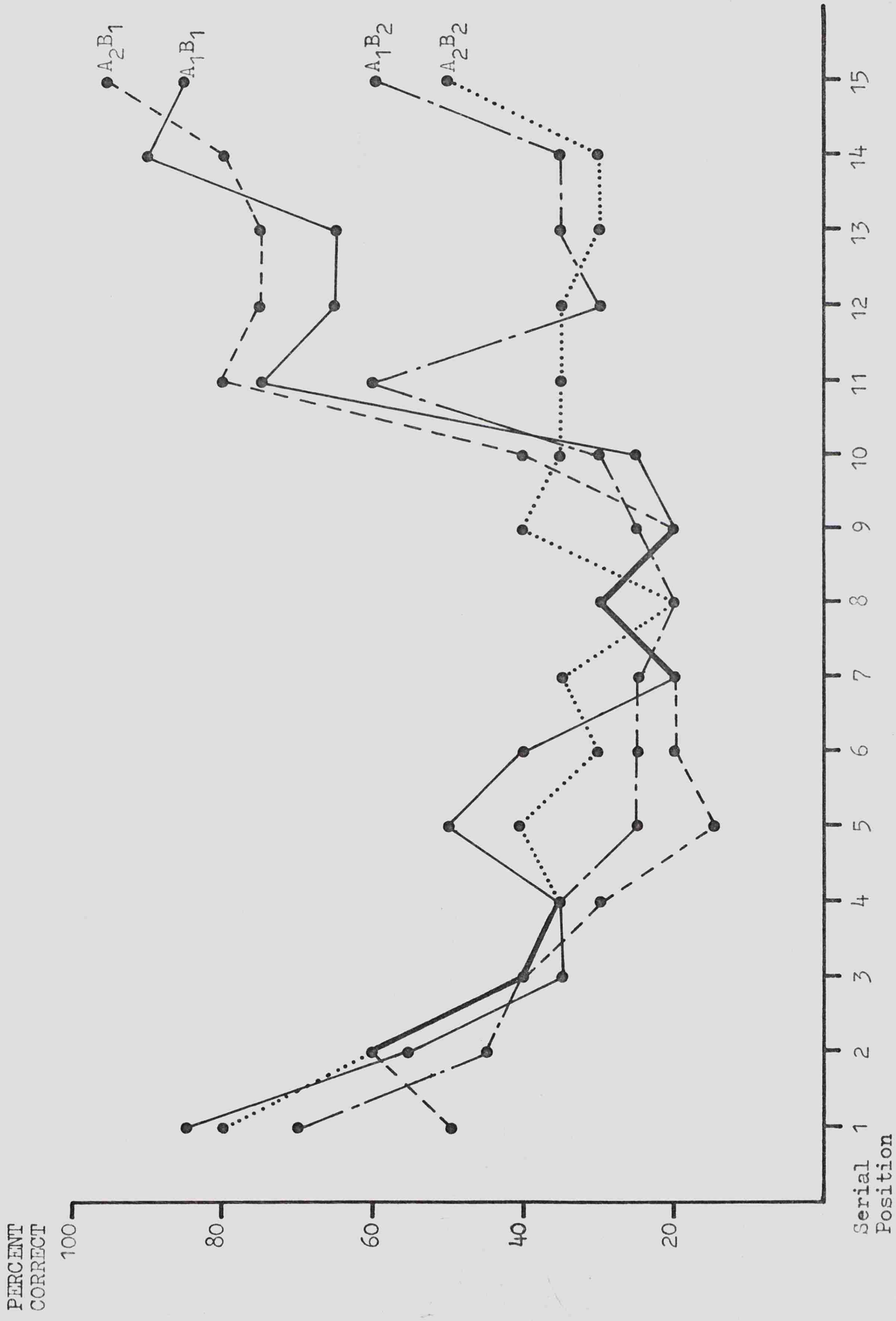
APPENDIX P

EXPERIMENT II



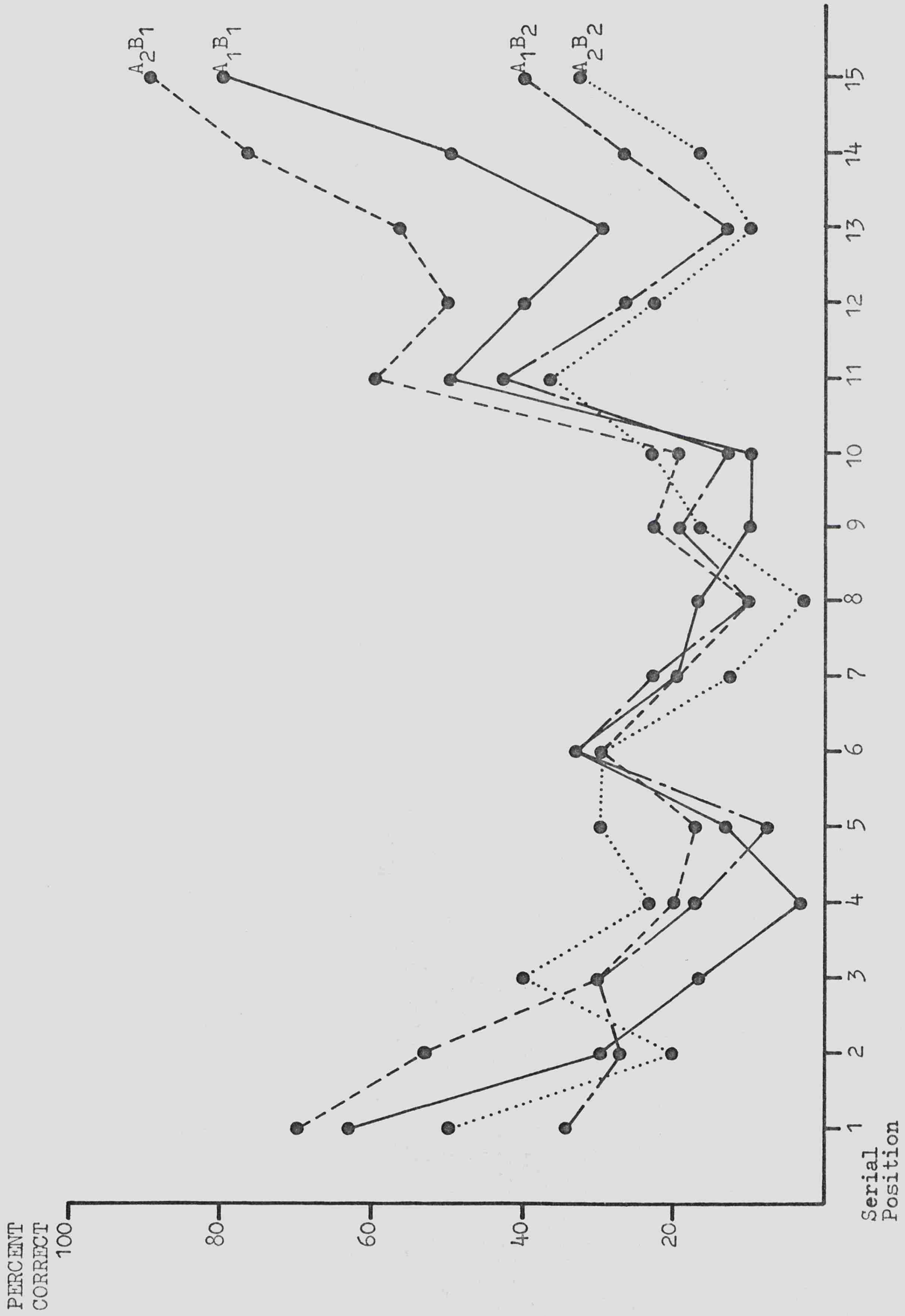
APPENDIX Q

EXPERIMENT III - Group Recall Criterion



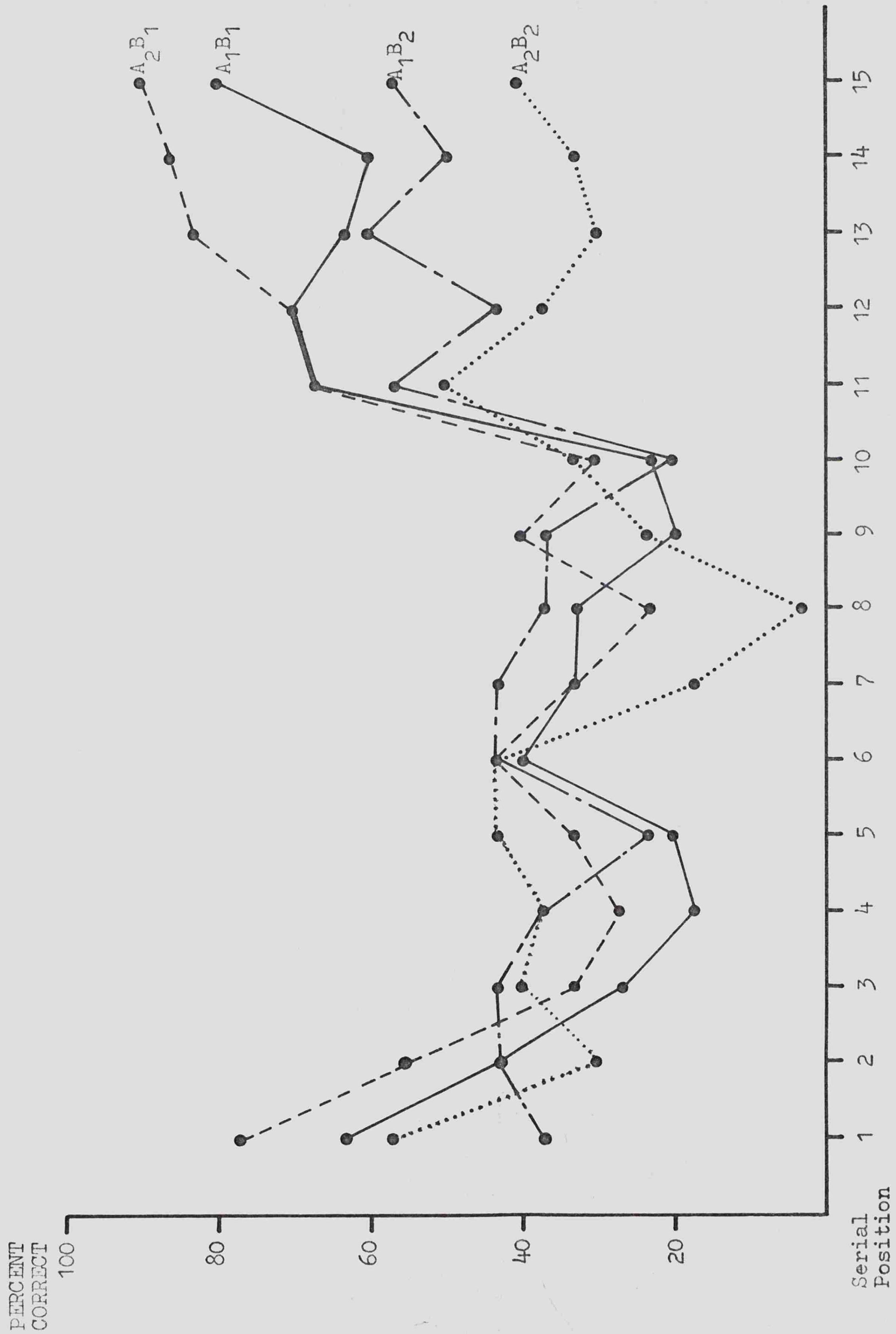
APPENDIX R

EXPERIMENT IV - Ordered Recall Criterion



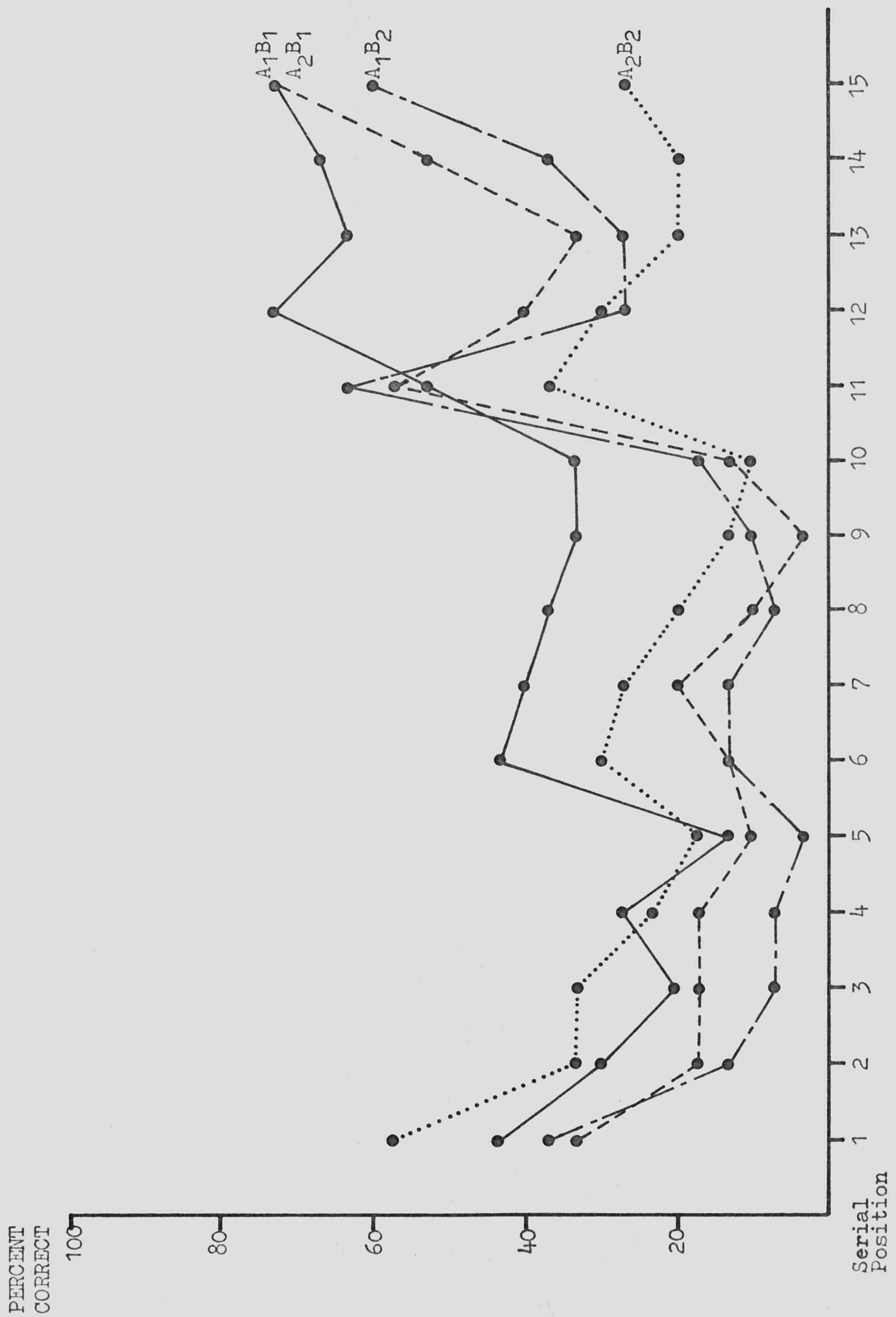
APPENDIX S

EXPERIMENT IV - Free Recall Criterion



APPENDIX T

EXPERIMENT V - Ordered Recall Criterion



APPENDIX U

EXPERIMENT V - Free Recall Criterion