An Investigation into the
Nature of the Modality Effect

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Abstract

The purpose of the research reported in this thesis is to investigate the nature of the modality effect, which is the better recall of final list items following auditory than visual list presentation. The dominant view that the modality effect arises from echoic memory is evaluated by examining several characteristics of the modality effect which appear to run counter to either some or all echoic memory theories.

The experiments can be divided into three main groups. First, the two principal experiments reported in Chapter 2 establish that the modality effect in serial recall of word lists is sensitive to the phonological characteristics of the list items. Second, evidence is presented in Chapter 3 which suggests that the modality effect in free recall persists in materially unchanged form for at least 15 seconds. And finally, the results of the experiments reported in the final two experimental chapters, 4 and 5, indicate that the modality effect is non-acoustic in nature. Whereas the first two sets of findings can be readily accommodated by either some or all echoic memory accounts, the results of the third group of experiments represent a major challenge to the notion that the modality effect arises from echoic memory. Chapter 6 summarises the principal experimental findings and their implications for theory and future research.

Chapter 1 - The Modality Effect

1.1 Introduction

Memory for the final few items of a temporally sequenced list - recency recall - is better for lists that are heard than for those that are silently read. The research reported in this thesis investigates the nature of this phenomenon, which is known as the modality effect. In this chapter some important characteristics of the modality effect are described (Section 1.2) and the major theoretical accounts of the effect are critically evaluated (Section 1.3). Finally the principal theoretical issues which are addressed in the four experimental chapters of the thesis are summarised (Section 1.4).

1.2 The Modality Effect

In this section the principal properties of the modality effect most important to the research reported in the thesis are described.

In recent years the modality effect has been extensively investigated in two paradigms, serial recall and free recall. Its characteristics differ slightly across the two procedures. In serial recall, where subjects are required to remember the input order of the list items, the modality effect typically shows a large advantage to auditory over visual items at the last two or three list positions (e.g., Conrad & Hull, 1968). In free recall, where subjects may recall list items in any order that they wish, the modality effect is not as great as in serial recall but extends back over four or five list positions (e.g., Craik, 1969).

In several respects however the modality effects obtained in serial and free recall are very similar. Of particular relevance to the research reported in the experimental chapters of the thesis are the influences of phonological similarity and post-list distraction on the modality effect in the two recall paradigms.

1.2.a Phonological Similarity

In both serial and free recall the modality effect is sensitive to the phonological characteristics of the list materials. In serial recall the modality effect is disrupted when phonologically similar list items are employed (Crowder, 1971; Darwin & Baddeley, 1974; Richardson, 1979; Watkins, Watkins & Crowder, 1974). Furthermore the modality effect disappears when the lists contain phonologically identical words such as "PEAR - PAIR - PARE" (Crowder, 1978). And in free recall the modality effect is eliminated when phonologically similar words are used (Watkins et al., 1974).

1.2.b Post-List Distraction

A sensitivity to the presentation mode of post-list distraction is also characteristic of the modality effect in both recall paradigms. In serial recall the distractor paradigm most commonly used is the suffix procedure, in which a single redundant item or suffix is presented at the end of the memory list typically in rhythm with the list items. The principal finding is that an auditory suffix impairs auditory recency (e.g., Crowder, 1969). No suffix effect occurs though either if a visual suffix follows an auditory list, or if an auditory suffix follows a visual list (Morton & Holloway, 1970). Thus the modality effect is diminished by an auditory suffix (Engle, 1974).

In free recall too the modality effect is disrupted by an auditory suffix (Engle, 1974; see also, Roediger & Crowder, 1976). The same pattern of modality-specific interference occurs in free recall when lengthier periods of post-list distraction are employed; Broadbent, Vines & Broadbent (1978) and Gardiner, Thompson & Maskarinec (1974) found that there is a large modality effect in free recall following 30 seconds silent distraction. In both cases the modality effect disappeared when the distractor information was spoken aloud.

1.3 Accounts of the Modality Effect

Several theoretical interpretations of the modality effect have been put forward. In this section the most influential accounts are outlined and evaluated. Two major classes of theoretical account are distinguished. The critical difference between these two approaches concerns whether or not the modality effect is attributed to a mechanism specific to the auditory sensory modality.

1.3.a Primary Memory Theories

Some early accounts ascribed the modality effect to a memory system accessible to both auditorily and visually presented material. These interpretations have now lost favour as a consequence of their failure to accommodate some critical findings. However, for the purposes of highlighting the features which distinguish this approach from the more widely accepted echoic memory accounts of the modality effect discussed next, two primary memory theories are considered in this section.

During the 1960s performance in short-term memory (STM) tasks was conventionally attributed to either one or both of two memory stores, which following Waugh & Norman (1965) shall be referred to here as primary and secondary memory. The evidence suggested that primary memory is a limited-capacity short-term store which employs an acoustic code even when the information is visually presented (e.g., Conrad, 1964). Several theorists put forward the view that primary memory is the origin of the modality effect. Laughery & Pinkus (1966; see also, Laughery & Fells, 1969) proposed that the modality effect arises because auditory information is more efficiently represented in primary memory than visual information. Brelsford & Atkinson (1968), on the other hand, suggested that different rules govern the displacement of auditory and visual items from primary memory and that, as a consequence of this, a larger number of recent auditory than visual items are likely to be retained in primary memory.

Several findings in the literature raise problems for these primary memory interpretations of the modality effect. Watkins et al. (1974) point out empirical evidence contrary to each of the two theories. But of greater importance to this review is the considerable amount of evidence which, counter to any primary memory account of the modality effect, dissociates the modality effect and visual recency. For example, the modality effect is impaired but visual recency uninfluenced when lists of high inter-item phonological similarity are employed (Watkins et al., 1974). Furthermore the modality effect is enhanced and visual recency diminished when subjects are instructed to commence recall from the beginning rather than from the end of the list (Craik, 1969), and when a period of silent distraction precedes recall (Watkins & Watkins, 1980). There is therefore good evidence to suggest that the modality effect and visual recency arise from different mechanisms, which is inconsistent with the primary memory theories of Laughery & Pinkus (1966) and Brelsford & Atkinson (1968). This evidence favours instead the interpretations of the modality effect which are reviewed in the next section. According to these the modality effect originates from a mechanism specific to the auditory sensory modality, echoic memory, and is therefore independent of visual recency.

1.3.b Echoic Memory Theories

In this section four echoic memory interpretations of the modality effect are critically evaluated, and consideration is given to some empirical problems for this class of account.

Murdock's Modality-Specific Storage Theory

Murdock (1967; Murdock & Walker, 1969) attributed both auditory and visual recency to the contribution of prelinguistic sensory stores. In contrast to the conventional two-store conceptualisation of STM (e.g., Waugh & Norman, 1965) according to which primary memory is independent of presentation mode, Murdock suggested that the most recent verbal items are represented in short-term stores specific to the sensory modality of input, output from which gives rise to the recency effects. It was proposed that the modality effect reflects the greater capacity of the auditory than the visual sensory store. This interpretation certainly fits well with the sensitivity of auditory recency to auditory but not visual post-list distraction (e.g., Morton & Holloway, 1970) which was noted in Section 1.2.b. However it fails to account for the equally well-established finding, also described in Section 1.2.b, that visual recency is not sensitive to the sensory modality of distractor information. Visual recency is indistinguishably influenced by visual and auditory suffixes in serial recall (e.g., Morton & Holloway, 1970) and by longer periods of silent and spoken distraction in free recall (e.g., Broadbent et al., 1978). Murdock's interpretation of the modality effect in terms of modality-specific short-term stores is clearly considerably weakened by its failure to accommodate these important asymmetrical influences of distractor modality on auditory and visual recency, and for this reason is rejected as an account of the modality effect.

In contrast to Murdock's interpretation, the remaining echoic memory theories considered in this section assume that the contribution of echoic memory is to provide a source of information which supplements the system of postcategorical storage believed to underpin visual recency. Thus the selective influence of distractor mode on auditory but not visual recency is readily accommodated by these accounts.

Crowder & Morton's PAS Theory

The most influential echoic memory theory was provided by Crowder & Morton (1969). According to their account the most recent auditory item is represented in precategorical acoustic storage (PAS); furthermore it is proposed that information in PAS, unlike material in the corresponding visual sensory store, persists for long enough to be useful at recall. The modality effect therefore arises from the additional contribution of PAS to the recall of the final auditory item.

Crowder & Morton (1969) proposed that information in PAS is processed to the level of feature extraction, and that the role of PAS is to provide additional stimulus information which may be used at recall. It has subsequently become clear that Morton's view is that PAS provides only order information (Morton, 1970; 1977). According to this approach PAS contributes to the modality effect only in tasks such as serial recall in which the subject is familiar with all of the list items but not with the order in which they were presented; the modality effect does not originate from PAS in free recall where memory for order is not tested. However, it is clear from Section 1.2 that there is considerable evidence to suggest that the modality effect has a common origin in serial and free recall. In particular, the effect shows the same sensitivity to the modality of post-list distraction and phonological similarity in the two paradigms (e.g., Engle, 1974; Watkins et al., 1974). This correspondence calls into question Morton's view that PAS provides order information only. The data are more consistent with the notion that the contribution of PAS is to provide item information - as indeed was implied in the original formulation of PAS theory (Crowder & Morton, 1969).

Although PAS theory readily accommodates the modality effect, it was developed primarily as an account of the auditory suffix effect. According to the theory, the auditory suffix replaces the final auditory item in PAS and so eliminates the contribution of PAS to the recall of that item. In fact many of the principles of PAS theory are based on results of suffix experiments. The major suffix findings and their implications for a PAS account of the modality effect are therefore discussed next.

Suffix Findings. In an influential series of experiments Morton, Crowder & Prussin (1971) established several important characteristics of the suffix effect. It was found to be highly sensitive to the acoustic relationship between suffix and list items - the effect was attenuated when, instead of a single speaker reading aloud the complete sequence, speakers of different sexes read the list items and the suffix. Taken in conjunction with the finding that the suffix effect is attenuated when phonologically similar list materials are employed (Crowder, 1971a), this result provides good evidence that the origin of the suffix effect is a source of acoustic information such as PAS. Furthermore it fits well with the finding described in Section 1.2.a that the modality effect is sensitive to the phonological characteristics of the list materials (e.g., Darwin & Baddeley, 1974). This susceptibility of both the modality and suffix effects to phonological similarity provides good support for the PAS theory view that both reflect a common mechanism, namely PAS. By the same token this pattern of results argues against accounts which accommodate only one of the two phenomena, such as Kahneman's (1973) attentional interpretation of the suffix effect.

Further data collected by Morton et al. (1971) which shows that no suffix effect occurs when non-speech auditory suffixes are employed suggests that speech sounds only are represented in PAS. Subsequent research by Morton and colleagues (Morton & Chambers, 1976; Morton, Marcus & Ottley, 1981) involving natural and artificial speech suffixes has reinforced this conclusion by identifying "speech-like" as the characteristic of a suffix required to yield a typical auditory suffix effect. And finally, Morton et al. (1971) found the suffix effect to be independent of the categorical relationship between suffix and list items - the effect remained intact when the suffix belonged to a different semantic category to the list items. Taken together, the results of these suffix experiments suggest that PAS, and therefore the modality effect, is speech-like and categorical in nature.

The suffix paradigm has also proved to be a useful device for evaluating the mechanism by which PAS contributes to the modality effect. Crowder (1971b; 1972) found no suffix effect when the suffix was delayed by more than two seconds after the final list item. A slightly greater estimate of the critical delay at which an auditory suffix ceases to impair auditory recency, of between 3.2 and 6.4 seconds, was provided by Routh & Mayes (1974a).

In order to reconcile these delayed suffix findings with the occurrence of the modality effect in procedures such as serial recall in which the final list item is typically recalled more than two seconds after list presentation, PAS theorists have suggested that this critical period reflects the time taken for PAS information to be recoded into modality-independent postcategorical storage. Hence after two seconds or so PAS still contributes to recall, but indirectly. Several mechanisms for this transfer of PAS information have been put forward. Crowder (1971b; 1972) has proposed that this information may be actively used in a "rehearsal check", in which a comparison is made between the contents of PAS and of the items currently being rehearsed in postcategorical memory. A similar account of the modality effect was put forward by Craik (1969; Note 1). On the basis of the occurrence of the modality effect in delayed free recall he attributed the effect to the contribution of echoic information which is transferred to short-term storage prior to recall. An alternative interpretation is favoured by Morton (1970). He has suggested that PAS information is passively integrated into the cognitive system, which for the purposes of the thesis corresponds to secondary memory. Some support for this account was provided by Routh & Mayes (1974b). These researchers found that preventing subjects from rehearsing, which according to Crowder's notion of a rehearsal check should prevent the recoding of PAS information, did not affect the influence of suffix delay on the suffix effect. Thus PAS information may indeed be passively transferred to secondary memory within a few seconds through which it indirectly contributes to the modality effect, as suggested by Morton.

Broadbent's Sensory Recency Theory

Broadbent and associates (Broadbent, Vines & Broadbent, 1978; Broadbent, Cooper, Frankish & Broadbent, 1980) have also put forward a sensory-echoic interpretation of the modality effect. According to their account the sensory features or attributes of recent auditory items are represented in auditory sensory memory. The critical point of departure between this account and PAS theory for the purposes of the thesis concerns the way in which this sensory information contributes to the modality effect. To briefly restate the PAS positon, echoic traces are assumed to be quickly recoded into postcategorical storage where they make a more stable contribution to recall (e.g., Crowder, 1971b). In contrast according to sensory recency theory the sensory traces persist and may be used directly at recall until overwritten by subsequent acoustic information containing the same physical attributes.

Some indirect support for the notion that echoic information is used directly at recall is provided by Broadbent et al.'s (1978) finding that the modality effect in free recall remains intact following a 30-second period of silent distraction (see also, Watkins & Watkins, 1980, Expt. 5). This result is not in principle incompatible with the PAS view that echoic information is quickly recoded and hence contributes only indirectly to the modality effect at recall delays of beyond two seconds. However, it argues against the specific accounts put forward by Craik (1969) and Crowder (1971b), according to which echoic traces are recoded into short-term storage prior to recall, as the contribution of this system should be abolished by a lengthy period of silent distraction.

More compelling evidence that echoic information contributes directly to the modality effect was provided by Watkins & Watkins (1980, Expt. 6). It was found that the modality effect in serial recall is sensitive to the presentation modality of a period of distraction delayed by 15 seconds after list presentation - the modality effect was impaired by delayed auditory but not visual distraction. So counter to the prediction of PAS theory, the modality effect at least in serial recall can be disrupted by auditory material after as long as a quarter of a minute. This finding clearly favours instead the sensory recency view that echoic information persists indefinitely in the absence of subsequent acoustic material and may aid recall directly.

Watkins & Watkins' Echoic Persistence Theory

The conceptualisation of echoic memory favoured by Watkins & Watkins (1980) themselves has some features in common with sensory recency theory. Echoic persistence theory also assumes that echoic information is not subject to decay and may be consulted at recall. There are however important conceptual differences between these two accounts. Watkins & Watkins do not attach sensory status to echoic memory. This approach was adopted primarily as a consequence of the finding that the modality effect is uninfluenced by word length (Watkins, 1972; Watkins & Watkins, 1973). The Watkins' view is that this result calls into question the assumption made by both sensory recency theory and PAS theory that the origin of the modality effect is a precategorical source of information. Echoic persistence theory accordingly adopts a more functional approach to echoic memory than either of the other two accounts. Echoic information is not conceptualised as independent from postcategorical storage, but instead as one of many aspects of a stimulus trace.

Some Problems for Echoic Memory Theories

Several recently reported findings appear to be incompatible with any account of the modality effect in terms of echoic memory. Three major problems are considered here. The first relates to results reported by Richardson (1979), which suggest that the modality effect is sensitive to phonological similarity in the manner described in Section 1.2.a only when meaningless materials such as letters are employed as list items. When the list materials were words the modality effect was found to be uninfluenced by phonological similarity. This pattern of findings clearly represents a problem for any of the echoic memory theories reviewed in this section, according to which the modality effect with words as well as with other list materials arises from echoic memory. Richardson favoured an alternative explanation, which is that although a system corresponding to echoic memory gives rise to the modality effect when letters and other nonlexical materials are employed, the modality effect with words originates from postcategorical lexical storage.

A second challenge to echoic accounts of the modality effect is provided by findings reported by Gardiner & Gregg (1979). In this study it was shown that, despite the well-established finding that the modality effect in free recall is eliminated by a period of auditory post-list distraction (e.g., Broadbent et al., 1978), the effect re-appears when a period of auditory distraction precedes and follows every item in the memory list. This paradoxical finding calls into question the assumption made by all echoic memory theories that the modality effect arises from a source of information which is overwritten by subsequent material presented in the auditory sensory mode.

Finally, the notion that the modality effect originates from echoic memory is challenged by recent findings involving lipreading. Spoehr & Corin (1978) reported that a lipread suffix impaired auditory recency to an equivalent extent to an auditory suffix. And Campbell & Dodd (1980) found that lipread recency, but not conventional visual recency, was disrupted by an auditory suffix. This seems to cast into doubt the most fundamental assumption of an echoic memory account of the modality effect, which is that the effect arises from a source of acoustic information.

1.4 Preview of Experimental Chapters

The research reported in the thesis evaluates current accounts of the modality effect. Evidence reviewed in this chapter favours the view that the modality effect arises from echoic memory. However, there is still debate between theorists concerning the characteristics of echoic memory. Furthermore some of the findings discussed in the previous section do not fit with any interpretation of the modality effect in terms of echoic memory. The approach pursued in the experimental chapters of the thesis is to investigate further several of the characteristics of the modality effect which run counter to either some or all echoic memory theories. It is hoped that this approach will facilitate the development of a better account of the modality effect than is currently available.

All of the echoic memory theories considered in this chapter attribute the modality effect to echoic memory irrespective of the categorical characteristics of the list materials. In contrast Richardson (1979) has recently proposed that although echoic memory gives rise to the modality effect when nonlexical materials are employed, when words are the list materials the modality effect originates from a non-echoic mechanism. The research reported in Chapter 2 evaluates some of the evidence presented by Richardson in support of this theoretical distinction.

Precisely how echoic memory contributes to the modality effect is an issue which divides the major echoic memory theories. According to PAS theory echoic information is quickly recoded into postcategorical memory, through which it makes an indirect contribution to recall. In contrast it is assumed by both echoic persistence theory and sensory recency theory that echoic information may be utilised directly at recall. The experimental work reported in Chapter 3 seeks to determine whether the modality effect in free recall arises from the direct or indirect usage of echoic information.

The central assumption of all echoic memory theories, that modality and suffix effects originate from a mechanism specific to material presented in the auditory sensory mode, is challenged by some recent findings involving lipreading. The final two experimental chapters of the thesis therefore investigate the influences of lipreading on the recency and suffix effects (Chapter 4) and on the modality effect (Chapter 5).

Chapter 2 - Phonological Similarity and the Modality Effect

2.1 Introduction

The two principal experiments reported in this chapter examine the influence of the phonological characteristics of lists of words on the modality effect in serial recall. The results call into question the proposal made recently by Richardson (1979) that the modality effect in this situation arises from a system of postcategorical lexical storage. Instead the findings are entirely consistent with the major echoic memory accounts of the modality effect considered in Chapter 1, according to which the modality effect with words as well as with other list materials originates from echoic memory.

2.2 Experiment 1

Evidence that the modality effect is sensitive to phonological characteristics of the list items is reviewed in Section 1.2.a. To summarise, the modality effect in serial recall is disrupted when lists of high inter-item phonological similarity are employed (e.g., Darwin & Baddeley, 1974) and when lists contain phonologically identical words (Crowder, 1978). Watkins et al. (1974) established that this sensitivity of the modality effect to similarity occurs in both serial and free recall.

It was noted in Section 1.3.b that some results recently reported by Richardson (1979) suggest that this sensitivity of the modality effect to phonological similarity only arises when letters or other meaningless materials are employed as list items. In this study although the modality effect was eliminated by phonological similarity when the serial recall of lists of letters was tested, with word lists similarity did not influence the modality effect. Primarily on the basis of these findings, Richardson proposed that a system corresponding to echoic memory contributes to the modality effect only when nonlexical materials such as letters are used. With word lists it was suggested that the modality effect originates from postcategorical lexical storage. This interpretation contrasts with all of the major echoic memory theories reviewed in Chapter 1, according to which the modality effect arises from echoic memory irrespective of the categorical characteristics of the list materials.

The findings of one previous study cast Richardson's (1979) theory into doubt, however. Watkins et al. (1974) also investigated the influence of phonological similarity on the modality effect with words in serial recall, and indeed in free recall also, and in contrast to Richardson found the modality effect to be reduced when similar word lists were employed. Richardson attributed the Watkins et al. result to the auditory presentation procedure used in their study. Whereas Richardson's subjects heard the experimenter read aloud the list items, subjects in the Watkins et al. experiment read aloud visually presented words. Richardson suggested that similar-sounding words become progressively more difficult to vocalise throughout the list, and that this leads to an impairment in the encoding of final list items. Thus according to Richardson the Watkins et al. finding that the modality effect with word lists is sensitive to phonological similarity is not due to interference in echoic memory, but merely reflects the disruptive influence of their vocalisation procedure on the encoding of recency items.

Experiment 1 seeks to establish whether the modality effect in serial recall of word lists is sensitive to phonological similarity. The serial recall of phonologically distinct and similar word lists is compared under conditions in which the subjects either silently reads the words, or hears them spoken aloud by the experimenter. According to Richardson's (1979) theory, the modality effect in this situation arises from postcategorical lexical storage and so should not be influenced by the phonological characteristics of list items. In contrast the major echoic interpretations of the modality effect reviewed in Chapter 1 all attribute the modality effect with words to echoic memory and so predict that it should be sensitive to phonological similarity.

On each trial in Experiment 1 subjects receive a novel set of words. The purpose of this design is to allow the data to be scored both by a strict serial criterion, according to which only items recalled in the serial position in which they were presented are scored correct, and by a free recall criterion, which accepts as correct any items recalled from the list irrespective of their output position. Comparisons of the serial and free data bear on two separate theoretical issues. Firstly, the generality of the modality effect across serial and free recall is a matter of considerable importance. It is noted in Section 1.3.b that Morton (e.g., 1977) has suggested that echoic memory provides only order information and so contributes to the modality effect only in tasks such as serial recall in which subjects need to recall the order in which the list items were presented. In contrast according to both sensory recency theory and echoic persistence theory, and indeed possibly to some interpretations of PAS theory, echoic memory retains item information and so would be expected to contribute to performance in both serial and free recall. A comparison of the serial data, which takes account of both item and order information, and the free data, which is a measure of item recall only, in Experiment 1 is clearly relevant to this issue.

The more general influence of phonological similarity on the serial and free data in Experiment 1 is also of interest. It is known that phonological similarity has dissociable influences on overall performance in serial and free recall tasks. Whereas serial recall is impaired when similar lists are employed (e.g., Watkins et al., 1974), similarity either has no influence on free recall (e.g., Watkins et al., 1974) or its effect is facilitatory (e.g., Craik & Levy, 1970). It therefore appears that similarity differentially influences the retention of item and order information in postcategorical memory. It is hoped that by scoring the data from Experiment 1 by both free and serial recall criteria, this hypothesis can be tested further.

Method

Subjects. The subjects were 16 London University students, all of whom spoke English as their first language. They were tested either individually or in pairs, and were paid for their assistance.

Materials. Listed in Appendix 1 are 32 lists each containing eight words with a high degree of inter-item phonological similarity which were constructed by the experimenter for use in Experiments 1 and 2. In each list the distinctive features between words are the consonant or consonants prior to the vowel; the vowels, and subsequent consonants where they occur, are the same for each word. As a consequence of the design employed in both Experiments 1 and 2 of presenting a novel set of words on each trial, a large number of word lists was required. It was therefore necessary in some instances to include words which are not represented in frequency norm texts. For this reason it was not possible to balance the lists for frequency.

Experiment 1 employed 21 lists selected arbitrarily from the pool listed in the Appendix. The same number of phonologically distinct lists was obtained by re-combining the words from the similar lists, in such a manner that no more than two words in each distinct list originated from a single list.

Thus each word occurred in one similar and one distinct list.

Design. Each subject was tested in all four conditions obtained by combining the two modes of list presentation, auditory and visual, and the two list types, phonologically distinct and similar. The lists were presented in four blocks each of ten trials. All of the lists in each block were presented in the same mode, either auditorily or visually, and presentation mode was alternated over successive blocks with half of the subjects receiving the first block presented visually, and the other half auditorily.

Within each block of trials there were five similar and five distinct lists. These were unpredictably ordered with the constraint that no more than two consecutive lists were in the same condition. The order of the similar and the distinct lists within each block was balanced across two groups of subjects; additionally half of the subjects received the words within each list in reverse order.

Procedure. The experimenter read aloud each word in the list in the auditory presentation conditions, and showed the subject the word printed on a card in the visual presentation conditions. The lists were always presented at the rate of one word every second. Following presentation of the final word in each list a visual cue was given which signalled that subjects should commence written recall of the list on the response sheet provided. Subjects were given strict serial recall instructions, and were told to attempt to guess rather than leave blanks. One practice list was given before each of the first two block of trials.

Results

Each subject's response protocol was scored both by a serial, item-in-position, criterion, and by a free recall criterion which accepted items as correct regardless of their position at output. For statistical purposes the modality effect was defined as the advantage to auditory over visual presentation at the last serial position (see also, Crowder, 1971a; Richardson, 1979; Watkins et al., 1974). The data from preterminal (serial positions 1 to 7) and terminal positions (serial position 8) were therefore analysed separately.

The top panels of Figure 2.1 show the data scored serially. Comparing recall at the terminal serial position across the two panels, there is a large modality effect with distinct lists, $t(15)=7.66$, $p<.001$, which appears to be still present althogh reduced with similar lists, $t(15)=3.87$, $p<.001$. Comparisons of individual auditory-visual differences at the terminal position for distinct and similar

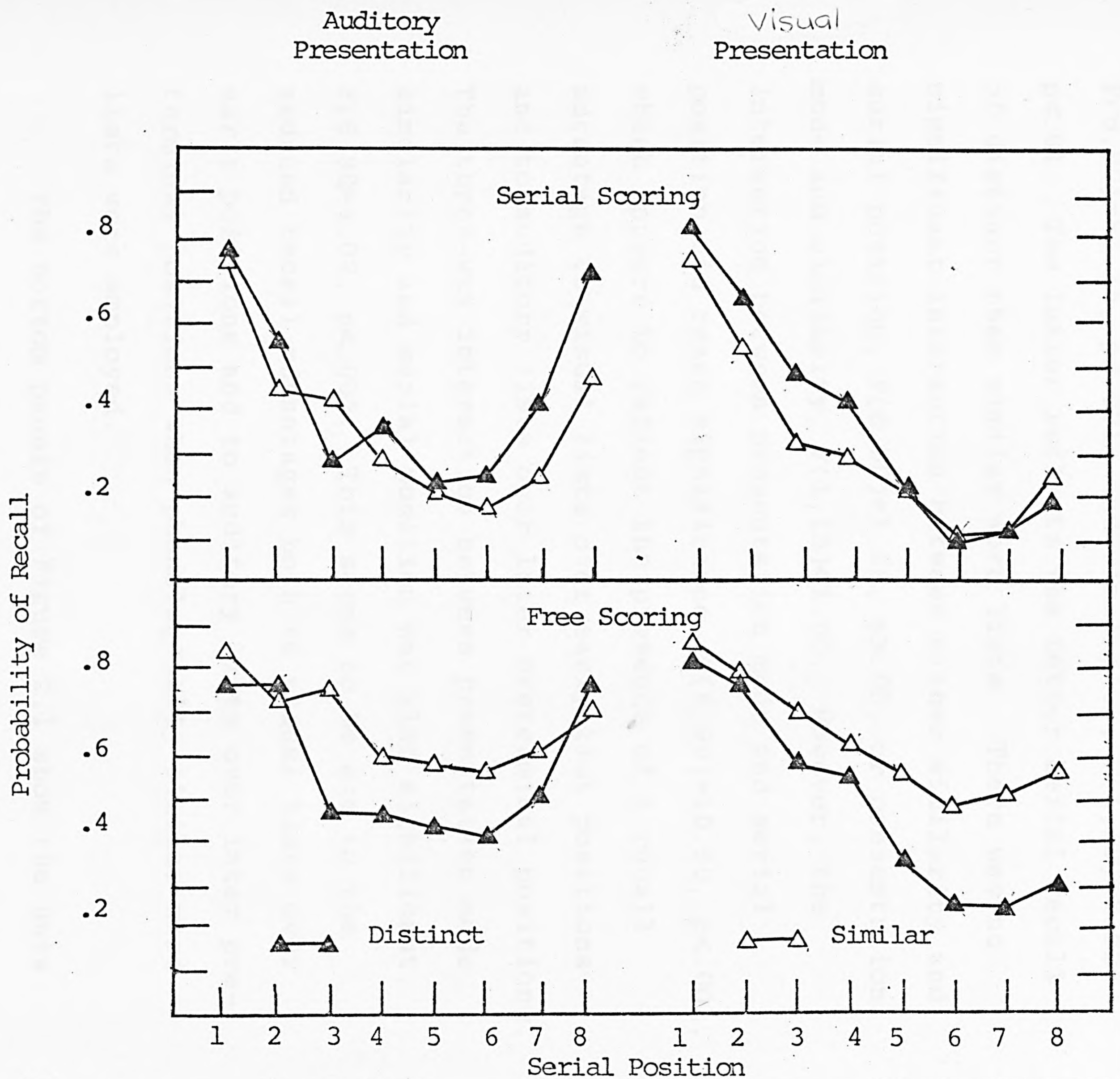

Figure 2.1 - Experiment I : Probability of serial scored and free scored recall as a function of method of presentation and list condition

lists show that this reduction in the modality effect with similar lists is significant, $t(15)=4.56$, $p<.001$.

An analysis of variance was performed on the data from the preterminal serial positions. There was no effect of presentation mode, $F(1,15)<1.00$, but significant main effects of both serial position, $F(6,90)=81.15$, $p<.001$, and similarity, $F(1,15)=8.92$, $p<.01$. The latter reflects the better serial recall of distinct than similar word lists. There was no significant interaction between either similarity and serial position, $F(6,90)=1.96$, $p>.05$, or presentation mode and similarity, $F(1,15)<1.00$. However, the interaction between presentation mode and serial position did reach significance, $F(6,90)=10.90$, $p<.001$, which appears to reflect the presence of a recall advantage to visual lists over early list positions and to auditory lists over later preterminal positions. The three-way interaction between presentation mode, similarity and serial position was also significant, $F(6,90)=4.02$, $p<.005$. This seems to be due to the reduced recall advantages both to visual lists over early positions and to auditory lists over later preterminal positions when phonologically similar word lists were employed.

The bottom panels of Figure 2.1 show the data scored according to the free recall criterion. Here too there is a large modality effect with distinct lists, $t(15)=1.31$, $p<.001$, which is still present although considerably reduced with similar lists, $t(15)=2.81$, $p<.01$. Comparisons of individual auditory-visual differences showed that this reduction in the modality effect with similar lists is highly significant, $t(15)=4.22$, $p<.001$. It should however be noted that in contrast to the serial data, where the reduction arises from a selective disruptive influence of similarity on the auditory lists, in the free data this attenuation occurs by virtue of the markedly higher level of recall of similar than distinct lists following visual but not auditory presentation.

The analysis of variance performed on the free data at preterminal positions revealed that recall performance was generally facilitated when phonologically similar lists were employed, $F(1,15)=42.36$, $p<.001$. There was also a main effect of serial position, $F(6,90)=33.88$, $p<.001$, but not of presentation mode, $F(1,15)<1.00$. The interaction between presentation mode and serial position was significant, $F(6,90)=6.07$, $p<.001$, possibly reflecting the auditory advantage over late preterminal positions. The interaction between similarity and serial position, $F(6,90)=4.16$, $p<.001$, appears to be attributable to the greater beneficial effect of similarity on recall at these positions. There was no interaction between presentation mode and similarity, $F(1,15)<1.00$. This indication that both modes were correspondingly influenced by similarity at preterminal positions was further supported by the absence of a significant three-way interaction, between presentation mode, similarity and serial position, $F(6,90)=1.61$, $p>.05$.

Discussion

The modality effect in serial recall was found to be materially reduced when lists of phonologically similar words were employed and the experimenter vocalised the lists in the auditory presentation conditions. Experiment 1 therefore fails to replicate Richardson's (1979) finding that the modality effect with word lists in serial recall is not sensitive to phonological similarity. Instead the results extend the generality of Watkins et al.'s results (1974) to the situation in which the experimenter rather than the subject vocalises the list items. The results of Experiment 1 thus lend no support to Richardson's proposal that the modality effect with lexical list materials originates from postcategorical lexical storage. They are, on the other hand, entirely consistent with the view held by all of the major echoic memory theories reviewed in Chapter 1 that the modality effect with words as well as with other types of list materials arises from echoic memory.

Several interesting findings emerge when the serial and free data from Experiment 1 are compared.

The first concerns the modality effect. In this experiment, as indeed in Watkins et al.'s (1974) serial recall experiment, the reduction in the modality effect when phonologically similar word lists are employed is independent of whether or not a measure of ordered recall is taken. This suggests that the modality effect originates not from a source of solely order information as suggested by Morton (e.g., 1977), but of item information too (see also, Watkins & Todres, 1979). This aspect of the data is consistent with both the sensory recency theory put forward by Broadbent (e.g., Broadbent et al., 1980) and Watkins & Watkins' (1980) echoic persistence theory.

Although the influence of phonological similarity on the modality effect was independent of scoring criterion in Experiment 1, similarity did differentially influence overall performance in the serial and free data. Similarity facilitated free scored recall but slightly impaired serial scored recall. This pattern of findings is discussed in Section 2.5 in conjunction with the results of Experiment 2.

2.3 Experiment 2

Experiment 2 was designed primarily to determine the reliability of the results of Experiment 1, and additionally to test Richardson's (1979) suggestion that vocalisation impairs encoding of final items from similar word lists. Although it is clear on the basis of the results of Experiment 1 that the reduction of the modality effect in serial recall of word lists of high inter-item phonological similarity reported by Watkins et al. (1974) is not critically dependent on their use of a vocalisation procedure, it may still be the case that vocalisation does have a disruptive effect in the manner suggested by Richardson. In other words, the residual modality effect found in Experiment 1 with similar word lists, whose origin incidentally is considered in Section 2.5, may be reduced if the subjects vocalise lists at presentation. In fact there is already some evidence in the literature that vocalisation does impair recall performance. Crowder (1970) compared serial recall of lists of digits which were presented visually, vocalised by the subject and spoken by the experimenter. Vocalisation was found to impair recall of early list items. Recency, however, was uninfluenced by auditory presentation procedure. So although this study did not employ similar lists, the results suggest that any interfering effect of vocalisation on recall as a consequence of impaired encoding is likely to be located not at recency positions as suggested by Richardson, but at earlier list positions.

In Experiment 2 a direct comparison was made of the influences of vocalisation by subject and by experimenter on the modality effect in serial recall of phonologically distinct and similar lists. The purpose of including these two auditory presentation conditions was to test a modified version of Richardson's (1979) hypothesis concerning vocalisation, namely that the modality effect is disrupted more by phonological similarity when the subject rather than the experimenter vocalises the lists.

Method

Subjects. The subjects were 24 London University students, all of whom were tested individually and paid for their assistance.

Design and Materials. Each subject was tested in all six conditions obtained by combining the three methods of list presentation - experimenter vocalisation (auditory), subject vocalisation (vocalised) and visual - with the two list types - phonologically distinct and similar. All 32 similar lists in Appendix 1 were used in this experiment, and 32 phonologically distinct lists were constructed by re-combining these in the same manner as in Experiment 1.

There were six blocks of ten trials, and within each list there were five similar and five distinct lists. These were ordered unpredictably with the constraint that no more than two consecutive lists were of the same type, and the order of the similar and distinct lists within each block was balanced across two groups of subjects. Within each list, word order was reversed for half of the subjects. All of the lists within each block of ten trials were presented in the same way. All six orderings of the three presentation methods were each received by four subjects over the first three blocks, and the order was repeated for each subject over the second three blocks.

Procedure. For the auditory and visual presentation conditions the same procedures followed in Experiment 1 were employed. In the vocalised presentation conditions the lists were presented as in the visual conditions and the subject was required to read each word aloud. One practice block was given before each of the first three blocks of trials.

Results

As in Experiment 1, recall was scored by both a strict serial criterion and by a free recall criterion. Once again separate analyses are reported for

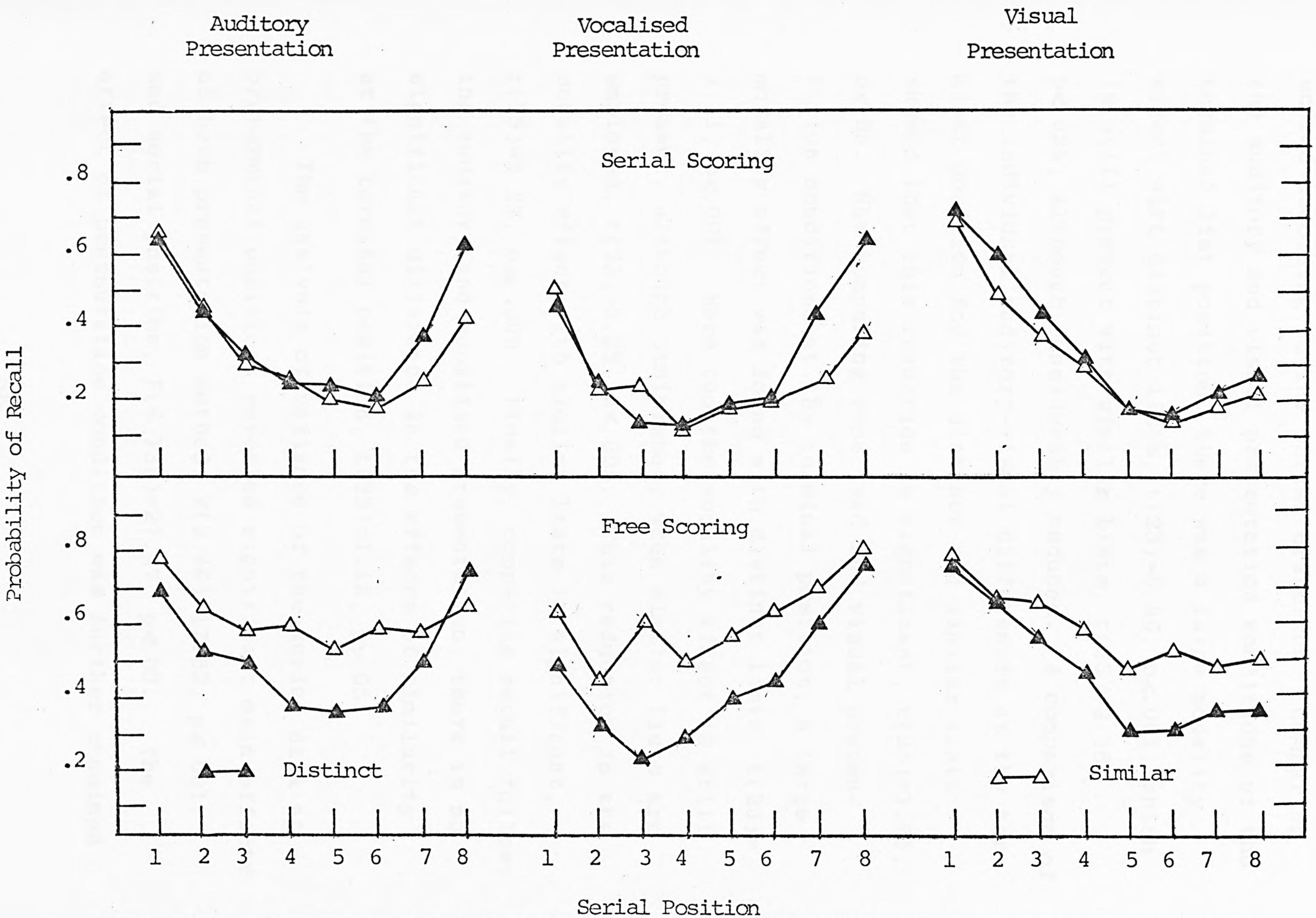

Figure 2.2 - Experiment 2 : Probability of serial scored and free scored recall as a function of method of presentation and list condition

the data from terminal (serial position 8) and preterminal (serial positions 1 to 7) positions.

The top panels of Figure 2.2 show the data scored according to the serial criterion. Comparing the auditory and visual presentation conditions at the terminal list position, there was a large modality effect with distinct lists, $t(23)=5.86$, $p<.001$, which is still present with similar lists, $t(23)=2.16$, $p<.025$, although considerably reduced. A comparison of the individual auditory-visual differences at the terminal position for the distinct and similar lists showed that this reduction is significant, $t(23)=1.95$, $p<.05$. Now comparing vocalised and visual presentation conditions at the terminal position, a large modality effect was found with distinct lists, $t(23)=7.11$, $p<.001$. Here too the modality effect is still present, although diminished, when similar lists are employed, $t(23)=3.23$, $p<.005$. This reduction in the modality effect with similar lists is significant, $t(23)=3.22$, $p<.005$. Finally, comparing recall following auditory and vocalised presentation, there is no significant difference in the effects of similarity at the terminal position, $t(23)=1.18$, $p>.05$.

The analysis of variance of the serial data at preterminal positions revealed significant main effects of both presentation method, $F(2,46)=17.63$, $p<.001$, and serial position, $F(6,138)=27.47$, $p<.001$. The effect of presentation condition was further examined in a Tukey's HSD test which established that both visual and auditory lists were better recalled than vocalised lists ($p<.01$ and $p<.05$, respectively). Both the effect of similarity, $F(1,23)=4.02$, $p>.05$, and the interaction between presentation method and similarity, $F(2,46)<1.00$, failed to reach significance. There was however a significant interaction between presentation method and serial position, $F(12,276)=10.29$, $p<.001$, which is probably due to the better recall of early list items following visual and auditory than vocalised presentation, and of later preterminal items following auditory and vocalised than visual presentation. There was also a significant interaction between similarity and serial position, $F(6,138)=3.03$, $p<.01$, which seems to reflect the detrimental effect of similarity over initial and late list positions. Finally, the three-way interaction between presentation method, similarity and serial position was significant, $F(12,276)=1.98$, $p<.05$. This is probably associated with the similarity decrement at late preterminal positions following auditory and vocalised presentation.

The lower panels of Figure 2.2 show the free scored data. As in the serial data, there is a large modality effect when distinct lists are employed with both the auditory, $t(23)=6.38$, $p<.001$, and the vocalised, $t(23)=7.64$, $p<.001$, presentation procedures. Although the modality effect still occurs when similar lists are employed with both auditory, $t(23)=2.96$, $p<.005$, and vocalised, $t(23)=4.40$, $p<.001$, presentation, it was in both cases significantly reduced, $t(23)=3.06$, $p<.005$, and $t(23)=3.76$, $p<.001$, respectively. There was no difference in the effects of similarity on recall at the terminal position following auditory and vocalised presentation, $t(23)<1.00$.

In the analysis of variance on the free data at preterminal positions, all three main effects were significant: presentation method, $F(2,46)=9.01$, $p<.001$; similarity, $F(1,23)=45.21$, $p<.001$; and serial position, $F(6,138)=8.00$, $p<.001$. A Tukey's HSD test established that the first term reflects the better recall of lists following both visual and auditory than vocalised presentation ($p<.05$ in both cases). All interactions were also significant. The interaction between presentation method and similarity, $F(2,46)=4.32$, $p<.05$, seems attributable to the greater similarity advantage following vocalised than auditory presentation, and following auditory than visual presentation. The interaction between presentation method and serial position, $F(12,276)=11.21$, $p<.001$, apparently reflects the lower level of recall at early list positions following vocalised presentation. The interaction between similarity and serial position, $F(6,138)=4.55$, $p<.001$, is probably due to the lesser effect of similarity on the recall of initial list items. Finally, the three-way interaction, $F(12,276)=3.17$, $p<.001$, may arise from the reduction in the similarity advantage for auditory and vocalised lists at the final preterminal position.

Discussion

The results of this experiment replicate and extend those of Experiment 1. The modality effect in serial recall of word lists was once again substantially reduced by phonological similarity. Moreover it was reduced by much the same extent whether the subject or the experimenter vocalised the list items in the auditory presentation conditions. Experiment 2 therefore provides no support for Richardson's (1979) suggestion that vocalisation of similar word lists disrupts encoding of final list items. There was evidence that vocalisation impairs recall, but as in Crowder (1970) it was found that the disruption was located at early rather than late list positions, and furthermore occurred with both distinct and similar lists.

Once again, the influence of phonological similarity on the modality effect in this experiment was unaffected by whether a serial or a free scoring criterion was employed. And also as in Experiment 1, overall performance with similar and distinct lists was dependent on scoring criterion - free scored recall was enhanced when similar lists were employed, whereas serial scored recall performance did not differ significantly in the similar and the distinct lists conditions.

2.4 Experiments 3 and 4

The results of Experiments 1 and 2 establish that the modality effect with word lists is sensitive to phonological similarity. Experiments 3 and 4 are designed to provide an account of why Richardson (1979), in contrast, found no influence of phonological similarity on the modality effect when words were employed as list materials. Richardson's subjects showed very good recall of the final item from the distinct auditory lists - about 98%. The hypothesis investigated in the two experiments reported in this section is that the presence of a ceiling effect in Richardson's data in the condition in which subjects received lists of distinct words presented auditorily diminished the modality effect with distinct lists, and so masked a reduction in the modality effect when similar word lists were employed.

Similar designs were employed in Experiments 3 and 4. In both cases two of the experimental conditions were identical to two of those used by Richardson (1979; Expt. 1) - the same set of six phonologically distinct words were presented either visually or auditorily in a randomised sequence on each trial. In each experiment two further conditions were included, one in each presentation mode, in which a single aspect of Richardson's design was changed in such a way as to increase the difficulty of the recall task. In Experiment 3 whereas half of the subjects received the single set of six words employed by Richardson on each trial, the other half received a different population of words in each case. And Experiment 4 employed a within-subject design in which list length was increased from six to ten words on half of the trials. It was reasoned that if the modality effect with distinct words in Richardson's experiment was restricted by a ceiling effect, increasing the difficulty of recall either by using an unlimited set of items or by increasing list length should, by depressing the overall level of recall, lead to an increase in size of the modality effect. This account of the disparity between Richardson's results and those of Experiments 1 and 2 will have to be rejected if, on the other hand, these changes in design do not influence the modality effect.

Experiment 3

Method

Subjects. The subjects were 24 students all of whom spoke English as their first language. They were tested either individually or in pairs, and were paid for their assistance.

Materials. Two sets of stimulus materials were used. The limited set contained the six one-syllable words - bar, bun, day, few, rig, sup - employed by Richardson (1979) and taken by him from Baddeley (1966). The unlimited set were 120 words taken from the phonologically similar sets of words listed in Appendix 1. Twenty sets of six words were constructed from this pool, with no more than one word in each set being selected from a single similar list.

Design. Twelve subjects were randomly allocated to each of the two experimental groups. One group received lists containing the six words from the limited set on each trial, and the other group received different lists from the unlimited set in each case. Each subject received 20 experimental lists, ten presented auditorily and ten presented visually. Presentation condition was blocked, with half of the subjects in each group receiving the first block of ten lists presented auditorily, and the other half receiving it presented visually. The order of the lists remained constant for each subject, so that each list was given equally often in each experimental condition.

Procedure. The same auditory and visual presentation procedures that were employed in Experiments 1 and 2 were followed. For the group of subjects receiving the limited word set, a card on which the six list items were printed was displayed throughout the recall period. This information was not provided for the unlimited group. All subjects received one practice list prior to each block of experimental trials.

Results and Discussion

Figure 2.3 shows the results of this experiment. The modality effect was once again defined as the recall advantage to auditory over visual lists at the final list position, in this case serial position 6. Separate statistical analyses were therefore performed on the data from preterminal (serial positions 1 to 5) and terminal (serial position 6) list positions.

Comparing first recall of terminal auditory and visual items, there is a modality effect with both the unlimited set of materials, $t(11)=7.23$, $p<.001$, and the limited set, $t(11)=2.82$, $p<.001$. A comparison of individual auditory-visual differences at the terminal position for the two groups revealed that the modality effect was significantly greater for the unlimited than the limited set, $t(22)=2.82$, $p<.005$.

The analysis of variance performed on the data at preterminal positions revealed a significant main effect of materials, $F(1,22)=47.29$, $p<.001$, which is due to the better serial recall of words in the limited than the unlimited set. The main effects of present-

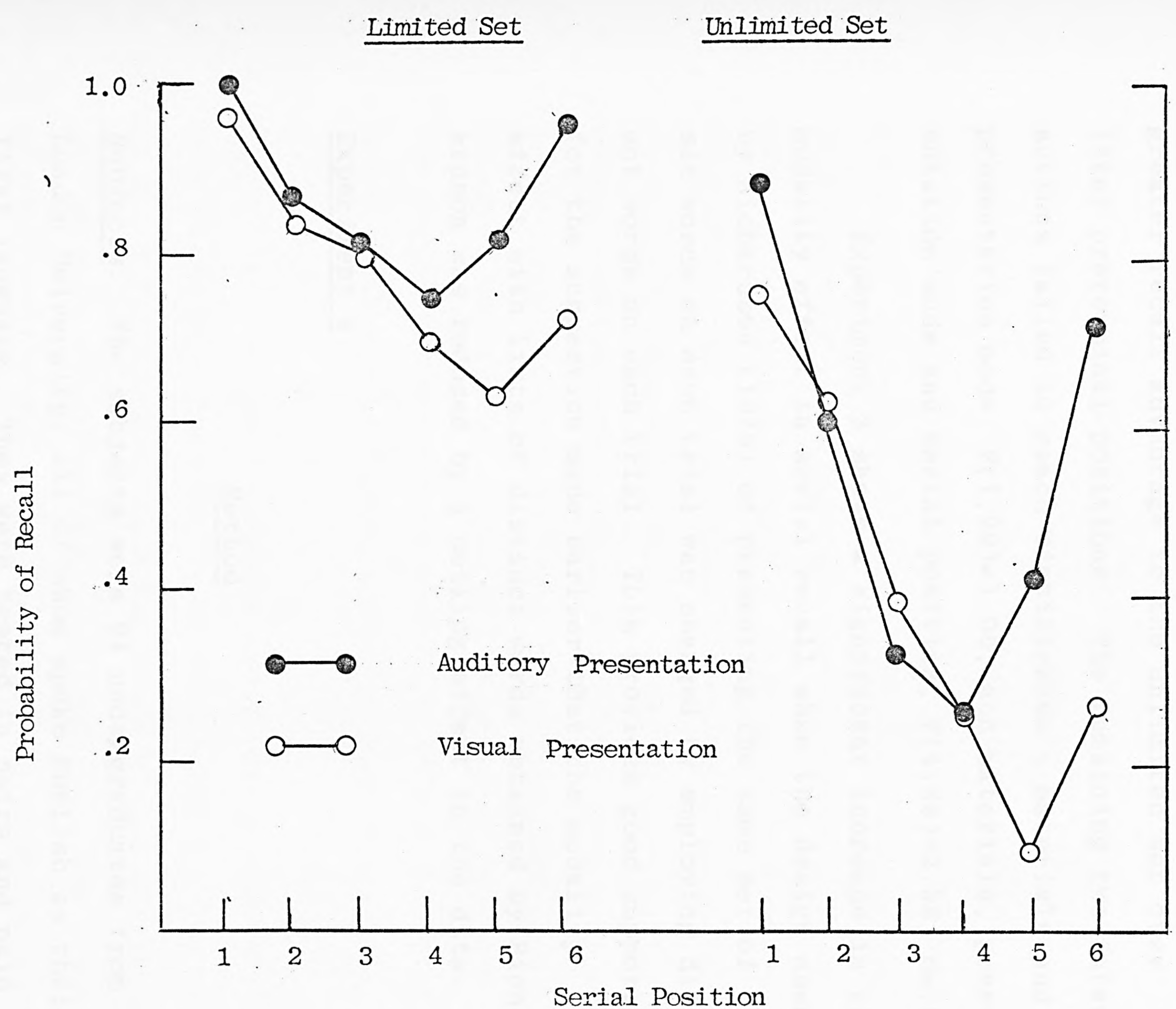

Figure 2.3 - Experiment 3 : Probability of serial recall as a function of materials and presentation mode

ation mode, $F(1,22)=10.84$, $p<.001$, and serial position, $F(4,88)=73.06$, $p<.001$, were also significant, the former reflecting the auditory advantage to recall at final preterminal positions. A significant interaction was found between materials and serial position, $F(4,88)=12.78$, $p<.001$, which seems to be due to the greater recall advantage to the unlimited set over later preterminal positions. The remaining two interactions failed to reach significance - materials and presentation mode, $F(1,22)<1.00$, and materials, presentation mode and serial position, $F(4,88)=2.36$, $p>.05$.

Experiment 3 shows a significant increase in the modality effect in serial recall when the design used by Richardson (1979) of presenting the same set of six words on each trial was changed by employing different words on each trial. This provides good support for the suggestion made earlier that the modality effect with lists of distinct words obtained by Richardson was reduced by a ceiling effect in the data.

Experiment 4

Method

Subjects. The subjects were 24 undergraduates from London University, all of whom spoke English as their first language. They were tested in pairs and paid for their assistance.

Materials. All of the materials employed in this experiment were taken from a pool constructed by Baddeley (1966). Two word lists were used, one containing the six words employed in Experiment 3. The other list contained these six words and four additional ones - cow, hot, pen and pit.

Design. Each subject was tested in all four conditions obtained by combining the two modes of presentation - auditory and visual - with the two list lengths - six and ten words. Forty experimental lists in all were presented, grouped into four blocks each containing five six-word lists and five ten-word lists. These were unpredictably ordered in each block with the constraint that no more than two consecutive lists were of the same list length. Order of list condition within each block was balanced over two groups of subjects. Presentation mode was constant within each block of ten trials. Half of the subjects received the blocks presented according to a AVVA arrangement, and the other half received them in VAAV order.

Procedure. The same auditory and visual presentation procedures were followed as in Experiment 3. The set of words presented on each trial was always displayed to subjects throughout the recall period. Two practice lists, one containing six words and one containing ten, preceded each of the first two experimental blocks of trials.

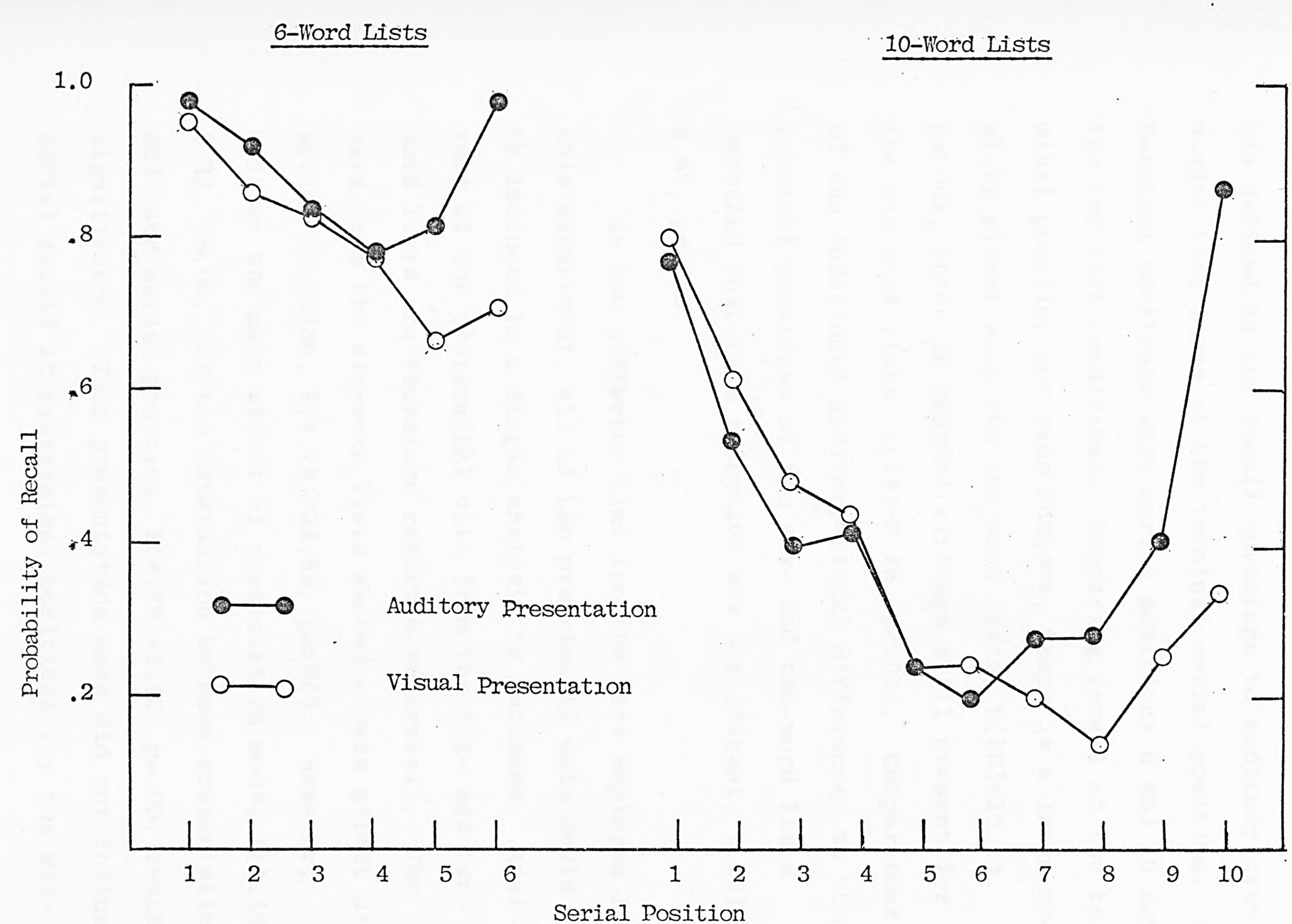

Figure 2.4 - Experiment 4 : Probability of serial recall as a function of list length and presentation mode

Results and Discussion

Figure 2.4 shows the results of this experiment. As in the previous experiments, the modality effect was defined as the recall advantage to auditory over visual list items at the terminal serial position. The terminal positions were serial positions 6 and 10 for the two list conditions. Comparing recall at the terminal position for each subject, there is a large modality effect with the ten-word lists, $t(19)=13.13$, $p<.001$, which is reduced although still present for the six word lists, $t(19)=5.48$, $p<.001$. Comparisons of the individual auditory-visual differences at the terminal positions of the six- and ten-word lists revealed that this reduction was significant, $t(19)=2.87$, $p<.025$.

As two different list lengths were employed in this experiment, all of the preterminal data could not be included in a single analysis of variance. Analyses of the preterminal data from the six- and ten-word lists are therefore reported separately. The data from the six-word lists showed a main effect of serial position, $F(4,76)=24.56$, $p<.001$. However, neither the main effect of presentation mode, $F(1,19)=3.32$, $p>.05$, nor the interaction between presentation mode and serial position, $F(4,76)=2.42$, $p>.05$, reached significance. Thus presentation mode did not influence serial recall at preterminal positions for the six-word lists.

The analysis of the preterminal data for the ten-word lists also showed a significant main effect of serial position, $F(8,152)=45.95$, $p<.001$, but not of presentation mode, $F(1,19)<1.00$. This time however the interaction between presentation mode and serial position did reach significance, $F(8,152)=4.11$, $p<.001$, which appears to be due to the auditory recall advantage at the last few preterminal positions.

The findings of this experiment are completely consistent with those of Experiment 3. In both cases the modality effect in serial recall of distinct word lists obtained using Richardson's (1979) design increased in size when the recall task was made more difficult. This suggests that his results were indeed due to the presence of a ceiling effect.

2.5 General Discussion

Experiments 1 and 2 establish that the modality effect in serial recall of word lists is sensitive to phonological similarity. This finding replicates the results of Watkins et al. (1974). This is entirely consistent with all of the major echoic memory accounts of the modality effect reviewed in Chapter 1, according to which the effect arises from echoic memory irrespective of the categorical characteristics of the list materials. These results therefore call into question Richardson's (1979) proposal that a system of postcategorical lexical storage gives rise to the modality effect with word lists. Furthermore the finding in Experiment 2 that the sensitivity of the modality effect to phonological similarity is independent of whether the subject or the experimenter reads aloud the list items in the auditory presentation conditions runs counter to Richardson's suggestion that vocalisation disrupts the encoding of final items from similar lists. Although the vocalisation procedure led to an impairment in recall, its influence was restricted to early list items from both similar and distinct lists.

Experiments 3 and 4 go some way towards accounting for the disparity between the results of the first two experiments reported in this chapter and Richardson's (1979) finding that the modality effect in serial recall of word lists is uninfluenced by similarity. Evidence was presented which is consistent with the possibility that the modality effect with distinct word lists obtained by Richardson was restricted in size by the presence of a ceiling effect; this may in turn have masked a reduction in the modality effect when similar word lists were employed in Richardson's experiment.

It is worth noting that in both Experiments 1 and 2, and indeed in the Watkins et al (1974) serial recall experiment, the modality effect, although diminished, remained when similar word lists were employed. In contrast the modality effect has been found to be eliminated when lists contain phonologically identical words (Crowder, 1978) and phonologically similar letters and syllables (Richardson, 1979; Crowder, 1971a). However, Darwin & Baddeley (1974) found the size of the modality effect with similar-sounding syllables to be dependent on the degree of inter-item similarity. So it may be the case that the failure to lose the modality effect completely when similar word lists are employed is simply due to their tendency to be more distinct than similar syllables or letters.

In both the serial and the free data from Experiments 1 and 2, as indeed in Watkins et al. (1974), the modality effect with word lists was found to be sensitive to phonological similarity. This suggests that the origin of the modality effect is not solely a source of order information as suggested by Morton (e.g., 1977). In this respect the findings of these experiments are consistent with the view held by at least two of the major echoic memory theories, echoic persistence theory and sensory recency theory, that the mechanism underpinning the modality effect is a source of item information.

In terms of overall performance, on the other hand, the influence of phonological similarity was dependent on scoring criterion. In both Experiments 1 and 2 free scored recall was in general facilitated by similarity, whereas serial scored recall was better for distinct lists in Experiment 1 and was equivalent for similar and distinct lists in Experiment 2. In the Watkins et al. serial recall experiment, too, the influence of similarity on overall performance was a function of scoring criterion. In that case though there was a large similarity decrement in the serial data, and no influence of similarity on the free data.

On the basis of the results of Experiments 1 and 2 and of Watkins et al. (1974), it seems that similarity differentially influenced the retention of order and item information. The beneficial effect of similarity on item recall may arise from what Crowder (1979a) has termed a "sophisticated guessing strategy", in which knowledge of intra-list structure (e.g., all words rhyme with "ALL") combines with partial stimulus information to enhance recall. If so, it would be predicted that the better defined the list structure, the more effective the sophisticated guessing strategy and therefore the influence of similarity will be. Applied in this way, this interpretation of the similarity advantage in free scored recall can provide an account of the disparity between the influences of similarity on the serial and free data in Experiments 1 and 2, and in the Watkins et al. experiment. The similar list materials employed by Watkins et al. shared only the middle vowel of each word, whereas in the experiments reported in this chapter the only difference between similar list items was the initial phoneme. Therefore subjects in these experiments should, by virtue of the materials having a more defined list structure, have been able to employ a more effective guessing strategy than those in the Watkins et al. experiment. So it would be expected that, as indeed was found, there would be a greater beneficial effect of similarity on free scored recall performance in Experiments 1 and 2 than in Watkins et al. The influences of similarity on the serial data from the two studies can be accommodated in the same manner. Serial scored recall requires the use of both item and order information, so any detrimental effect of similarity should be offset by the advantage to guessing strategy to an extent determined by the effectiveness of that strategy. This effectiveness can be operationally defined as the degree of facilitation to the similar lists in free scored recall. Hence the disruptive influence of phonological similarity on serial scored recall should be, and indeed is, greater in the Watkins et al. experiment than in the two experiments reported in this chapter.

Chapter 3 - Delayed Distraction and the Modality Effect

3.1 Introduction

The research reported in Chapter 2 yielded findings which are consistent with all of the major echoic memory accounts of the modality effect reviewed in Chapter 1. In this chapter two experiments are reported which distinguish between these echoic theories on the basis of the persistence they attribute to echoic information. The results favour the view put forward by both sensory recency theory and echoic persistence theory that the modality effect in free recall arises from a long-lasting source of echoic information which is used directly at recall.

3.2 Experiment 5

The way in which echoic information contributes to the modality effect is an issue which divides the major echoic theories reviewed in Chapter 1. According to the leading interpretation, PAS theory, information is recoded from echoic memory within a few seconds into either primary memory (e.g., Crowder, 1971b; see also, Craik, 1969) or secondary memory (e.g., Morton, 1970; Routh & Mayes, 1974b). Echoic information therefore contributes indirectly to recall beyond this delay. In contrast according to both sensory recency theory and echoic persistence theory echoic traces may persist indefinitely and be used directly at recall.

Some good evidence that the modality effect in serial recall does, as suggested by the sensory recency and echoic persistence theories, arise from the direct use of persistent echoic information was presented in Section 1.3.b. Watkins & Watkins (1980; Expt. 6) found a pattern of modality-specific interference when the distraction was delayed by 15 seconds after list presentation which corresponds to that known to characterise immediate distraction procedures (e.g., Engle, 1974). This suggests that, contrary to PAS theory and in line with the sensory recency and echoic persistence theories, the origin of the modality effect remains materially unchanged for at least a quarter of a minute.

Section 1.2 reviewed some convincing evidence that the modality effect has a common origin in serial and free recall. Both sensory recency theory and echoic persistence theory can accommodate the modality effect in these two recall paradigms. Indeed both Broadbent et al. (1978) and Watkins & Watkins (1980; Expt. 5) have provided support for the notion that the modality effect in free recall arises from persistent echoic memory by showing that the modality effect remains intact following a period of silent distraction. However it was noted in Section 1.3 that although this result runs counter to the idea that the modality effect in free recall originates from the use of echoic information recoded into primary memory as suggested by both Crowder (e.g., 1971b) and Craik (1969), it does not rule out the notion that echoic information is recoded into secondary memory (e.g., Morton, 1970).

Experiment 5 provides a more direct test of the view put forward by both sensory recency theory and echoic persistence theory that the contribution of long-lasting echoic traces directly gives rise to the modality effect in free recall. The sensitivity of the modality effect in free recall to the presentation mode of delayed distraction is investigated. The procedure used by Watkins & Watkins (1980; Expt. 6) of following a 15-second interval after auditory or visual list presentation with four distractor digits presented either auditorily or visually, or no distraction at all is adopted in order to allow direct comparisons of the modality effect to be made across serial and free recall. The only differences are that in Experiment 5 word lists rather than consonant lists are employed, and free rather than serial recall instructions are given.

Method

Subjects. The subjects were 24 members of the Birkbeck College subject panel. They were tested individually in a single experimental session lasting 90 minutes, and were paid for their assistance.

Design and Materials. Each subject received six practice lists and 48 experimental lists. Each list contained 11 words obtained by sampling randomly without replacement from the pool of items listed in Appendix 2. Eight experimental lists were presented in each of the six experimental conditions obtained by combining the two presentation modes - auditory and visual - with the three distractor conditions - no distractor, auditory distraction and visual distraction. Presentation mode was alternated across successive blocks of twelve lists, with half of the subjects receiving the first block presented auditorily, and the other half visually. Order of words within each list was also reversed for half of the subjects. Distractor condition was unpredictably ordered within each block with the constraints that each condition occurred four times within each block and that no more than two successive lists involved the same distractor condition. Order of distractor condition within each block was balanced over three groups of subjects. This design ensured that each list appeared equally often in each of the six experimental conditions.

Procedure. In the auditory presentation conditions the experimenter read the lists aloud at the rate of one word every two seconds, and in the visual presentation conditions the words were shown to the subjects printed on cards at the same rate. Immediately following the final word in each list there was a 15-second unfilled interval. In the no distractor conditions this delay was followed by a further three-second silent period, at the end of which the experimenter gave a non-verbal auditory signal which cued recall. Following the unfilled interval in the visual distractor conditions subjects had to copy down four digits which were printed on a single card placed in front of them. In the auditory distractor conditions the experimenter read aloud the four digits at a normal reading rate and the subjects wrote them down. In both the auditory and the visual distractor conditions subjects commenced recall as soon as they had written down the digits. Standard free recall instructions were given. Recall time was not limited, and was terminated by the subject turning to the next page in the response booklet. Before each of the first two blocks of experimental lists, one practice list in each of the three distractor conditions was given. There was a short break following the second block of lists.

Results

The results are shown in Figure 3.1. There is a modality effect in each of the three distractor conditions which seems to be slightly smaller following auditory distraction than either visual or no distraction. Neither distractor condition nor presentation mode seem to have influenced recall at list positions prior to recency.

Of principal interest in this experiment is the influence of distractor condition on the modality effect. For statistical purposes the modality effect was defined as the recall advantage to auditory over visual lists at recency positions. Separate statistical analyses are accordingly reported for the pre-recency (serial positions 1 to 6) and recency (serial positions 7 to 11) data. It should be noted that, unless stated otherwise, none of the conclusions to be drawn on the basis of statistical tests in this

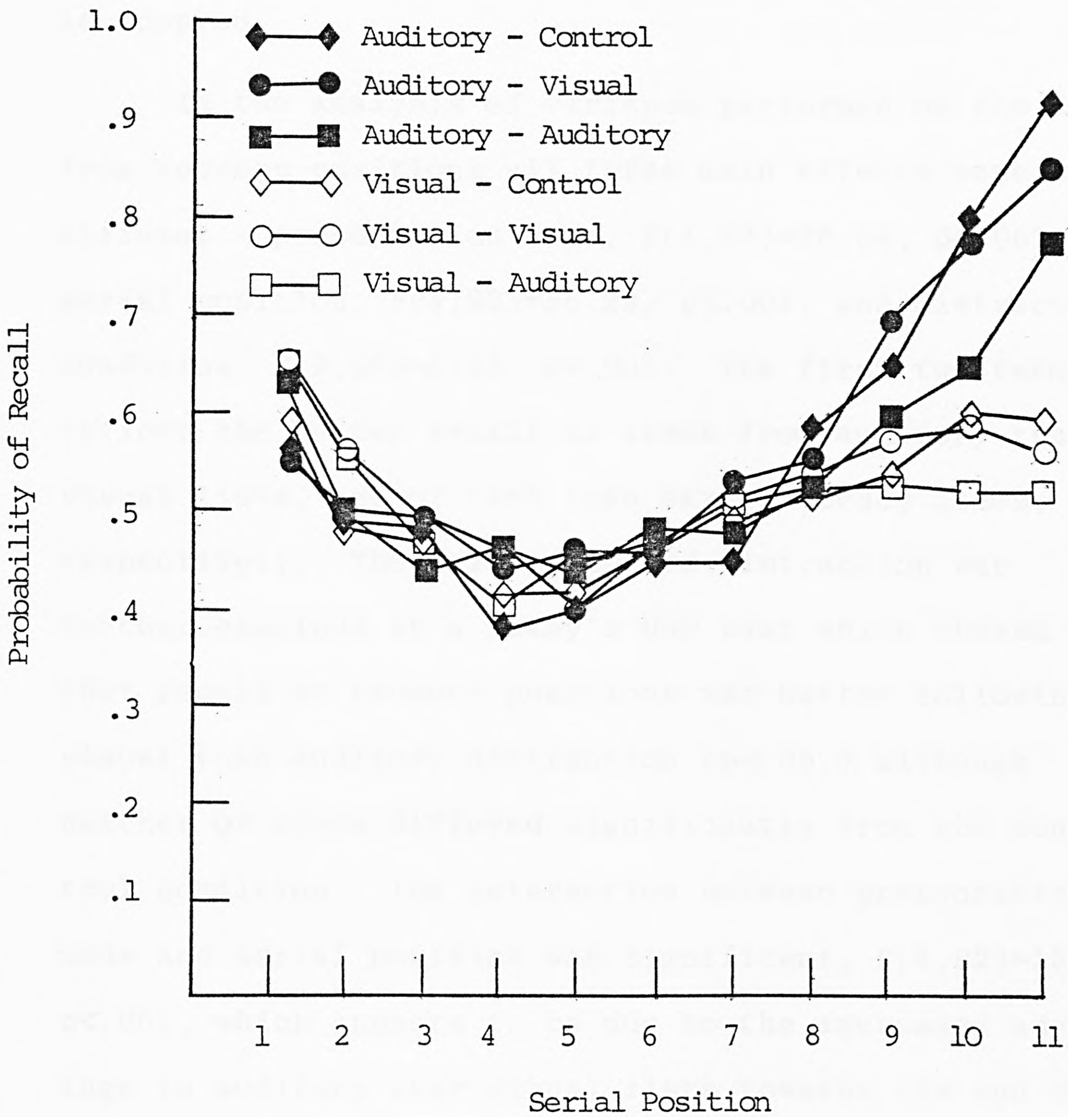

Figure 3.1 - Experiment 5 : Probability of free recall as a function of presentation mode and distractor condition

experiment are influenced by whether this definition of recency, or one including fewer serial positions, is adopted.

In the analysis of variance performed on the data from recency positions all three main effects were significant - presentation mode, $F(1,23)=38.04$, $p<.001$, serial position, $F(4,92)=26.22$, $p<.001$, and distractor condition, $F(2,46)=8.59$, $p<.001$. The first two terms reflect the better recall of items from auditory than visual lists, and of late than early recency items, respectively. The main effect of distraction was further examined by a Tukey's HSD test which showed that recall at recency positions was better following visual than auditory distraction ($p<.05$,) although neither of these differed significantly from the control condition. The interaction between presentation mode and serial position was significant, $F(4,92)=15.52$, $p<.001$, which appears to be due to the increased advantage to auditory over visual lists towards the end of the list. None of the remaining interactions reached significance - between presentation mode and distraction, $F(2,46)=1.10$, $p>.05$; between distraction and serial position, $F(8,184)=1.65$, $p>.05$; and between presentation mode, distraction and serial position, $F(8,184)<1.00$. Taken together these outcomes indicate that the modality effect was not influenced by distractor condition although, as the main effect of distraction revealed, there was a general depression in recency recall following auditory distraction in both presentation conditions.

A further analysis of variance was performed on the data from prerecency positions. There was a significant main effect of serial position, $F(5,115)=7.17$, $p<.001$. None of the remaining terms in this analysis, however, were significant - presentation mode, $F(1,23)<1.00$, distraction, $F(2,46)=1.72$, $p>.05$; interactions between presentation mode and distraction, $F(2,46)<1.00$, between presentation mode and serial position, $F(10,230)<1.00$, and between presentation mode, distraction and serial position, $F(10,230)<1.00$. These outcomes confirm the observation made earlier that neither presentation mode nor distractor condition affected recall over prerecency positions.

Discussion

The modality effect in free recall was not materially influenced when, following a silent unfilled interval, subjects wrote down four distractor digits read aloud by the experimenter. Delayed auditory distraction disrupted recall of both auditory and visual list items at recency positions. This result is in marked contrast with the selective influence of delayed auditory distraction on the modality effect in serial recall reported by Watkins & Watkins (1980).

The results of Experiment 5 provide little support for the view put forward by both sensory recency theory and echoic persistence theory that the modality effect in free recall arises from the direct use of persistent echoic traces. Instead the insensitivity of the modality effect in this paradigm to the presentation mode of delayed distraction is more in line with the PAS view that echoic information is quickly recoded into postcategorical memory through which it indirectly contributes to the modality effect.

However, when the recall of the final item only of each list is considered, performance is significantly lower following auditory than visual distraction for the auditory lists, $t(23)=2.73$, $p<.05$, but not for the visual lists, $t(23)<1.00$. It is therefore just possible that the brief period of delayed auditory distraction which diminished the modality effect in serial recall of consonant lists (Watkins & Watkins, 1980; Expt. 6) is not quite sufficient to significantly impair the modality effect in free recall of word lists. And there is already evidence in the literature, showing that the modality effect is less sensitive to auditory post-list distraction in free recall than in serial recall even when the same list materials are employed (Engle, 1974), which suggests that this might indeed be the case.

In order to facilitate direct comparisons of of the influence of delayed distraction on the modality effect across serial and free recall, the procedure employed by Watkins & Watkins (1980; Expt. 6) of requiring the subjects to copy down four distractor digits was adopted as the distractor task in Experiment 5. However, in at least two of the major free recall studies which have demonstrated modality-specific interference with immediate post-list distraction tasks were employed which lasted for 30 seconds (Broadbent et al., 1978; Gardiner et al., 1974). In the next experiment the period of distractor activity was therefore increased to 30 seconds in order to increase compatibility with these immediate distraction free recall studies, and so to determine whether the failure to obtain a selective influence of delayed auditory distraction on the modality effect in Experiment 5 did reflect its postcategorical nature, or alternatively was merely a consequence of employing insufficient distraction. Experiment 6 compares free recall of auditorily and visually presented word list following 30-second periods of delayed auditory and visual distraction.

3.3 Experiment 6

Method

Subjects. The subjects were 24 members of the Birkbeck College subject panel. They were tested either singly or in pairs in a single session lasting for about 90 minutes, and were paid for their assistance.

Design and Materials. Each subject received four practice lists and 32 experimental lists. Each list contained 11 words taken from the pool of items listed in Appendix 2. The design was essentially the same as in Experiment 5, the only differences arising from the absence of a no distractor condition in Experiment 6. Each subject was therefore tested in the four experimental conditions obtained by combining the two modes of list presentation - auditory and visual - with the two modes of distraction - auditory and visual. Eight experimental lists were presented in each condition, with list presentation blocked in sets of eight lists. In each block four lists were presented in each distractor condition, and these were ordered in the same manner as in the previous experiment. Presentation mode was alternated over successive blocks. Presentation condition and distractor type were balanced across subjects such that, over the 24 subjects, each list occurred equally often in each experimental condition.

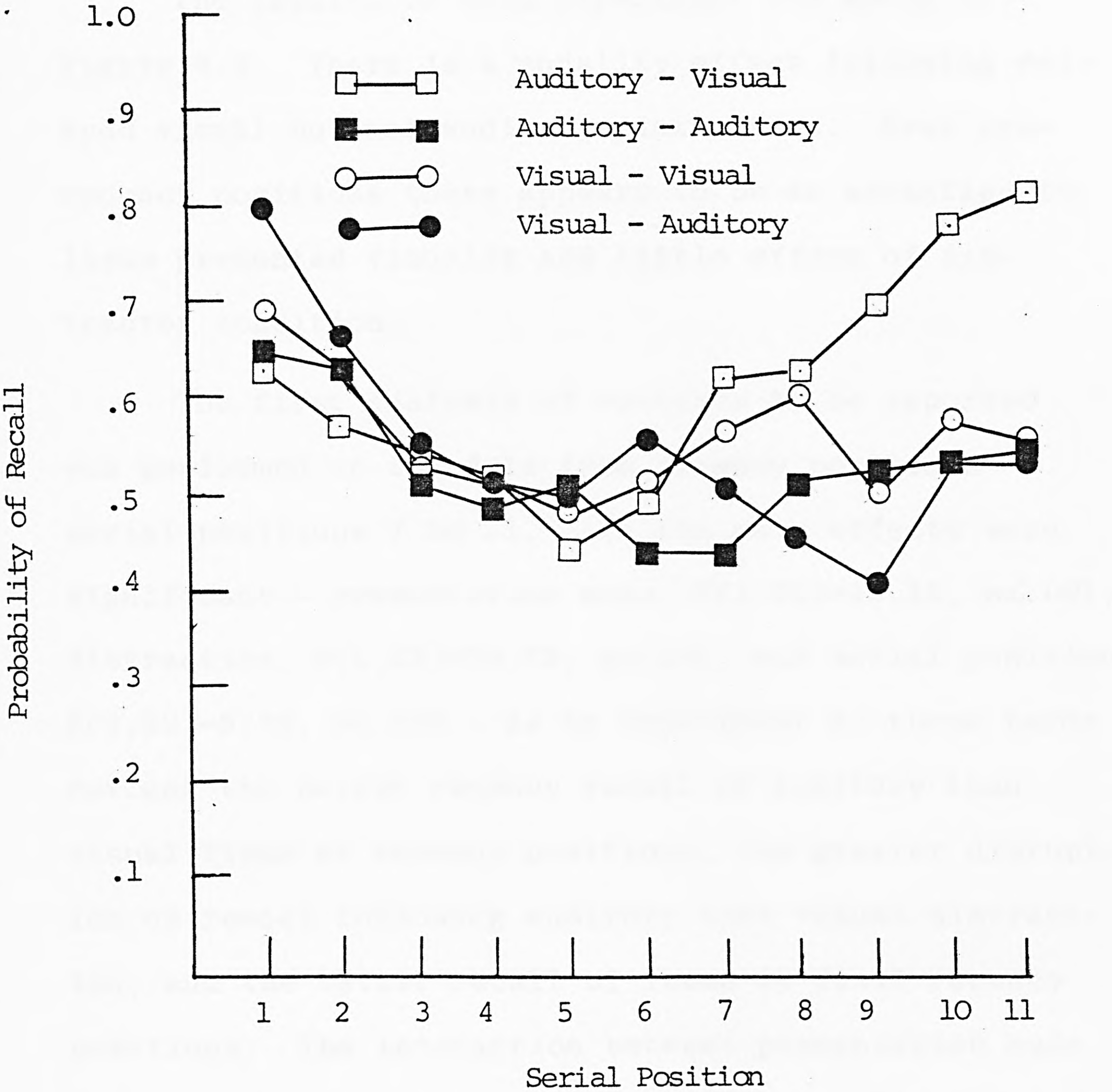

Figure 3.2 - Experiment 6 : Probability of free recall as a function of presentation mode and distractor condition

Results

The results of this experiment are shown in Figure 3.2. There is a modality effect following delayed visual but not auditory distraction. Over pre-recency positions there appears to be an advantage to lists presented visually and little effect of distractor condition.

The first analysis of variance to be reported was performed on the data from recency positions - serial positions 7 to 11. All the main effects were significant - presentation mode, $F(1,23)=15.15$, $p<.001$; distraction, $F(1,23)=59.72$, $p<.001$; and serial position, $F(4,92)=5.34$, $p<.005$. As in Experiment 5, these terms reflect the better recency recall of auditory than visual items at recency positions, the greater disruption of recall following auditory than visual distraction, and the better recall of items at final recency positions. The interaction between presentation mode and serial position was also significant, $F(4,92)=4.57$, $p<.005$, which seems to reflect the increasing auditory advantage towards the end of the list. The elimination of the modality effect with auditory distraction is reflected in the significant interactions between presentation mode and distraction, $F(1,23)=20.29$, $p<.001$, and between presentation mode, distraction and serial position, $F(4,92)=2.64$, $p<.05$. The interaction between distraction and serial position, $F(4,92)<1.00$, was the only term in this analysis which was not significant.

The prerecency data - serial positions 1 to 6 - were also analysed. There were significant main effects of both presentation mode, $F(1,23)=4.76$, $p<.05$, and serial position, $F(5,115)=18.21$, $p<.001$. Distractor condition did not significantly influence prerecency recall, $F(1,23)=2.61$, $p>.05$. None of the interactions in this analysis reached significance - between presentation mode and distraction, $F(1,23)<1.00$; between distraction and serial position, $F(5,115)=1.19$, $p>.05$; between presentation mode and serial position, $F(5,115)=1.43$, $p>.05$; and between presentation mode, distraction and serial position, $F(5,115)<1.00$. These results seem to confirm the observations made earlier that whereas visual presentation led to better recall of early list items than auditory presentation, prerecency recall was not influenced by distractor condition.

One further aspect of the data from this experiment was examined. Subjects were instructed to copy down the digits as fast as possible during the 30-second distractor period in each trial. So the number of distractor digits monitored by subjects was not experimentally controlled, in contrast to Experiment 5 and to Watkins & Watkins (1980; Expt. 6) where a constant number of distractor digits was presented on each trial. It is therefore possible that the selective influence of distractor condition on the modality effect in Experiment 6 was not due to the presentation mode of the distractor task per se, but instead to differences across the experimental conditions in the number of distractor digits monitored. In order to determine whether such an account of the results is plausible, the mean number of digits copied in each experimental condition was calculated. Table 3.1 shows the results of this analysis.

Table 3.1 - Experiment 6: Mean Number of Digits Copied in Distractor Task

Distractor Condition	Presentation Mode: Auditory	Presentation Mode: Visual
Auditory	60	61
Visual	60	60

Almost identical numbers of distractor digits were monitored in the four experimental conditions. This rules out the possibility that the elimination of the modality effect with delayed auditory distraction in Experiment 6 was due to subjects responding to more digits in the auditory than the visual distractor conditions.

3.4 General Discussion

Thirty seconds of delayed auditory but not visual distraction abolished the modality effect in free recall of word lists in Experiment 6. The modality-specific nature of this pattern of interference corresponds with that found in immediate post-list distraction studies (e.g., Broadbent et al., 1978; Gardiner et al., 1974). This set of findings calls into question the view of PAS theory that echoic traces are recoded in a few seconds into postcategorical storage, whether primary memory (e.g., Crowder, 1971b; see also Craik, 1969) or secondary memory (e.g., Morton, 1970). Instead these results are fully consistent with both sensory recency theory and echoic persistence theory, according to which the modality effect in free recall arises from the direct use of persistent echoic information.

The results of Experiment 6 contrast with those of Experiment 5 where a delayed auditory distractor task lasting for about three seconds did not significantly diminish the modality effect in free recall. Given the similarity of the two experiments in all but the duration of the distraction, it appears that the initial failure to obtain a reliable reduction in the modality effect with delayed auditory distraction may have been due to insufficient auditory distraction. This small amount of delayed auditory distraction was enough, however, to disrupt the modality effect in serial recall of consonant lists in Watkins & Watkins' (1980) Expt. 6. There are at least two possible reasons for this disparity. Firstly, it may have been due to the different list materials employed in the two studies. Perhaps words require more overwriting in echoic memory than consonants simply because being longer they are also more acoustically redundant. One way of testing this account would be to compare the influence of a constant amount of auditory distraction on the modality effect with lists of single- and multi-syllable words.

Alternatively, the disparate influence of a short period of delayed auditory distraction on the modality effect in Experiment 5 of this chapter and Watkins & Watkins (1980; Expt. 6) might be due at least in part to the different recall procedures used. Engle (1974) provides some support for this interpretation by showing that the modality effect in free recall is less sensitive to an auditory suffix than the effect in serial recall, even when the same word lists are employed in both cases. At present the theoretical implications of these paradigm differences in the sensitivity of the modality effect to auditory distraction are far from clear. Serial and free recall quite obviously make different demands on memory, with the serial procedure requiring a relatively greater contribution of order information. The occurrence of the modality effect in free recall, and the converging evidence that it has the same origin as the effect in serial recall (Section 1.2), argues against the notion put forward by Morton (e.g., 1977) that echoic memory only provides cues concerning order information. However it remains possible that auditory distraction more readily disrupts the retention of order than item information in echoic memory, and so has a greater influence on the modality effect in serial than in free recall.

There is another reason why a complete correspondence between findings yielded in serial and free recall experiments might not be expected, and this concerns output order. Whereas in serial recall the order of recall is controlled, in free recall any output order is acceptable. It is therefore possible that in free recall subjects pursue different output strategies across conditions as a means of maximising recall, and that this leads to a greater resistance of the modality effect to auditory distraction in free than in serial recall. A more radical hypothesis is that output order strategies do not merely increase the robustness of the modality effect in free recall, but actually give rise to the effect. In other words the modality effect may not originate from echoic memory, but from an output interference mechanism of the kind suggested by Dalezman (1976). If this is the case, the elimination of the modality effect in

Experiment 6 following delayed auditory distraction should be associated with the later output of final auditory items in the auditory than the visual distractor condition. Logical problems are admittedly raised when causality is attributed to an association in this way, but it will become apparent that this situation does not arise here.

In order to test the hypothesis that output strategies mediate the modality effect in free recall, or its disappearance following delayed auditory distraction, two post hoc analyses of output order were conducted on the data from Experiments 5 and 6. Firstly, following Broadbent et al. (1978) and Murdock & Walker (1969), the mean serial positions of items recalled at each output position in all experimental conditions for each subject were calculated. This procedure was followed at every output position at which each subject contributed at least one serial position value. Table 3.2 summarises the results of this analysis.

Table 3.2 - Experiments 5 and 6 : Mean Serial Position as a Function of Output Position

Experiment	Presentation Mode	Distractor Condition	Output Position 1	2	3	4	5
1	Auditory	Auditory	6.32	6.38	6.46	6.28	
		Visual	6.47	6.44	6.41	6.32	
		Control	6.31	6.38	6.21	5.92	
	Visual	Auditory	6.45	6.57	6.68	6.46	
		Visual	6.67	6.52	6.68	6.43	
		Control	6.66	6.21	6.16	6.36	
2	Auditory	Auditory	6.04	6.10	6.28	5.92	5.72
		Visual	6.02	6.33	6.47	5.88	6.20
	Visual	Auditory	6.08	6.23	6.31	6.17	6.18
		Visual	5.98	6.26	6.26	6.01	5.65

There does not appear to be any association between the modality effect and output order in Experiments 5 and 6. This observation was upheld by the results of the analysis of variance performed on the data from each experiment, in which no terms reached significance at the .05 level. Thus these output order data converge with those from other studies using this measure (Broadbent et al., 1978; Murdock & Walker, 1969) in providing no support for the notion that the modality effect in free recall arises from differences in the output priorities given to final auditory and visual list items.

Following Engle (1974) and Shand & Klima (1981), the second analysis of output order calculated the mean output positions of items recalled at each serial position in each of the experimental conditions for subjects tested in Experiments 5 and 6. Figures 3.3. and 3.4 show the results of this analysis.

From Figure 3.3 there appear to be two important aspects of the output order data from Experiment 5. Firstly, the mean output positions at each serial position are more or less constant, which suggests that none of the experimental conditions was characterised by the adoption of a consistent output strategy across subjects. A second related observation is that there is no association between the output position of items recalled and the modality effect - over the final

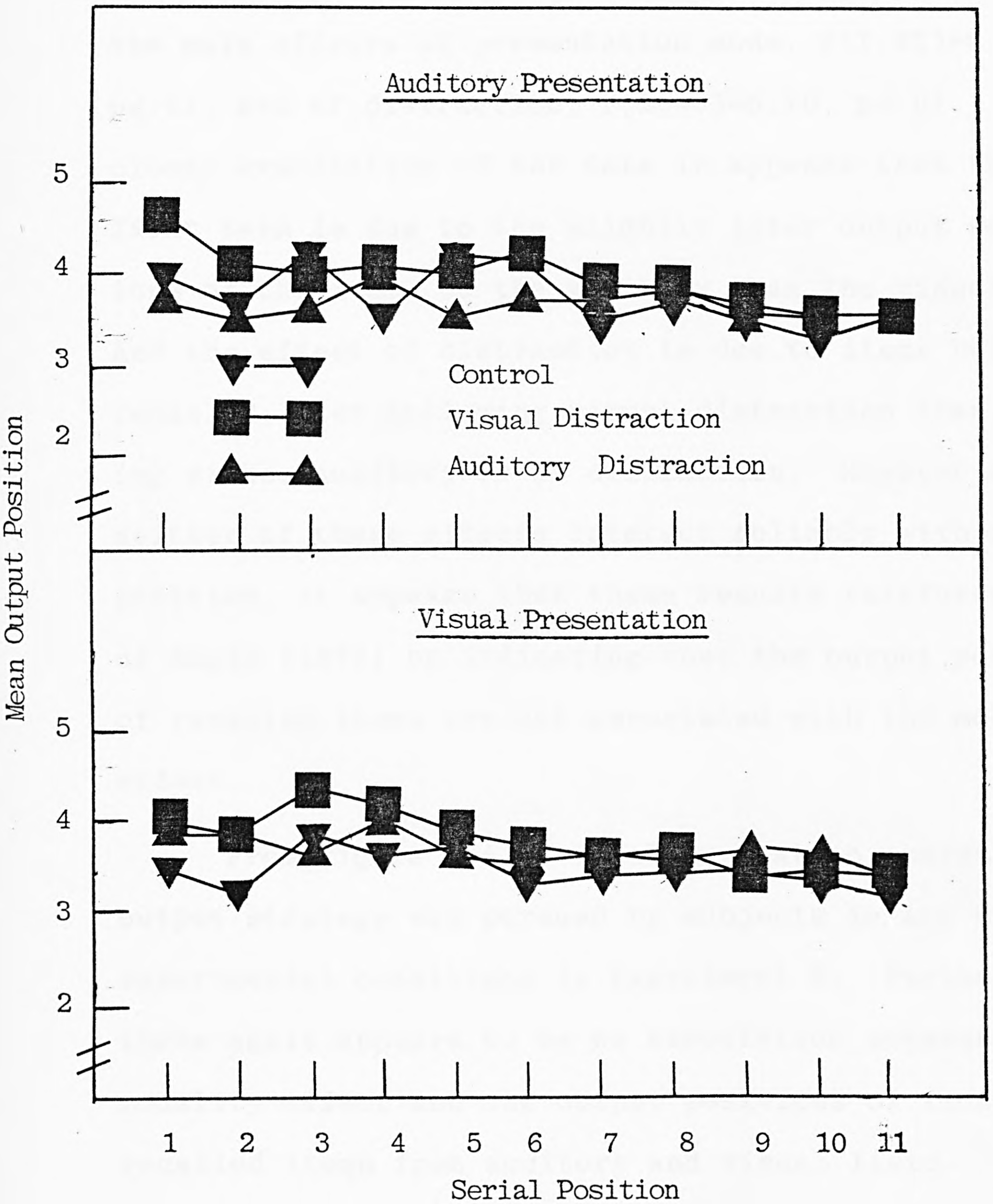

Figure 3.3 - Experiment 5 : Mean output position as a function of presentation mode and distractor condition

serial positions there is no consistent difference in the output positions of items from auditory and visual lists. However the analysis of variance performed on this data did yield two significant terms, which were the main effects of presentation mode, $F(1,23)=8.86$, $p<.01$, and of distraction, $F(2,46)=5.70$, $p<.01$. On closer examination of the data it appears that the first term is due to the slightly later output positions of the items in the auditory than the visual lists. And the effect of distraction is due to items being recalled later following visual distraction than following either auditory or no distraction. However as neither of these effects interact reliably with serial position, it appears that these results reinforce those of Engle (1974) by indicating that the output positions of recalled items are not associated with the modality effect.

From Figure 3.4 it is clear that no consistent output strategy was pursued by subjects in any of the experimental conditions in Experiment 6. Furthermore there again appears to be no association between the modality effect and the output positions of final recalled items from auditory and visual lists. Yet the analysis of variance performed on these data did yield one significant term, which is the three-way interaction between presentation mode, distraction and serial position, $F(10,230)=3.17$, $p<.001$. A closer look at the data suggests that this somewhat sur-

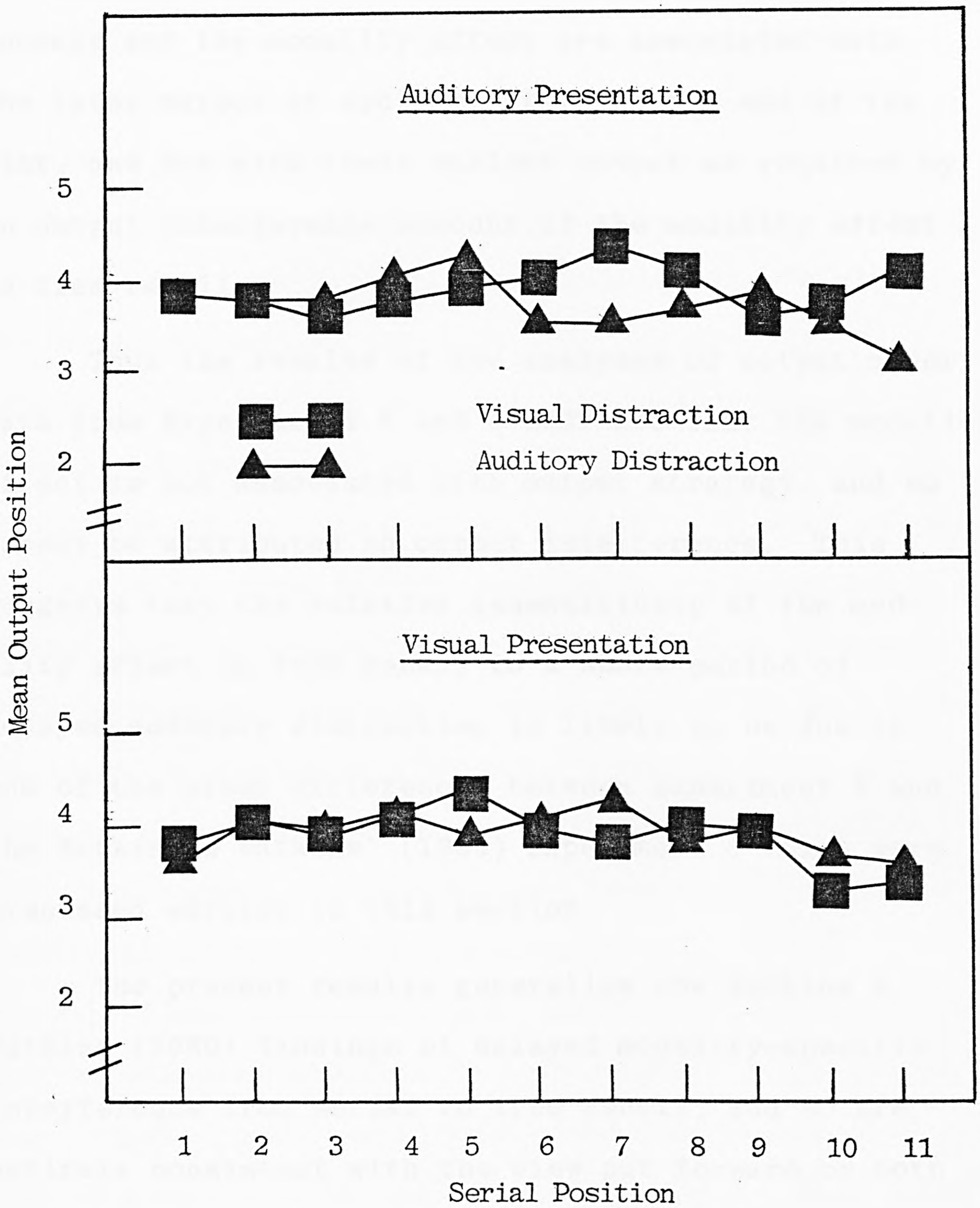

Figure 3.4 - Experiment 6 : Mean output position as a function of presentation mode and distractor condition.

prising interaction might reflect the tendency for subjects to recall auditory items at mid and late serial positions slightly earlier following auditory than visual distraction. So if anything, auditory recency and the modality effect are associated with the later output of auditory items at the end of the list, and not with their earlier output as required by an output interference account of the modality effect in free recall.

Thus the results of the analyses of output order data from Experiments 5 and 6 indicate that the modality effect is not associated with output strategy, and so cannot be attributed to output interference. This suggests that the relative insensitivity of the modality effect in free recall to a short period of delayed auditory distraction is likely to be due to one of the other differences between Experiment 5 and the Watkins & Watkins' (1980) Experiment 6 which were discussed earlier in this section.

The present results generalise the Watkins & Watkins (1980) findings of delayed modality-specific interference from serial to free recall, and so are entirely consistent with the view put forward by both sensory recency theory and echoic persistence theory that the modality effect in both paradigms arises from the direct use of persistent echoic information. It should however be acknowledged that these results do not correspond with conclusions drawn from findings in the delayed suffix literature. Several studies have shown that no suffix effect occurs when the suffix is delayed by more than a few seconds beyond the final item (e.g., Crowder, 1971b; Routh & Mayes, 1974b). Yet Experiment 6 of this chapter and of Watkins & Watkins (1980) show that a series of auditory suffixes delayed by a quarter of a minute greatly impairs the modality effect. One clear possibility is that different mechanisms are mediating the modality-specific interference at short and lengthy distractor delays. A conclusive demonstration of a directly echoic origin to the modality effect in delayed recall therefore requires further convergent evidence for the commonality of origin of the effect in immediate and delayed recall. One way in which this might be achieved would be to demonstrate that the acoustic properties of delayed distraction influence the modality effect in the same manner that has already been established for immediate suffixes (e.g., Morton et al., 1971). Despite these considerations, however, the results of the experiments reported in this chapter do go a long way towards establishing that persistent echoic information gives rise to the modality effect in free recall.

Chapter 4 - Lipreading : Recency and Suffix Effects

4.1 Introduction

The research reported in Chapters 2 and 3 is completely consistent with both sensory recency theory and echoic persistence theory, according to which the modality effect arises from the direct use of persistent echoic information. In contrast the experiment reported in this chapter, by showing a striking similarity between recency and suffix effects for heard and silently lipread stimuli, runs counter to any echoic memory theory.

4.2 Experiment 7

The results of some recent studies involving lipreading which were reviewed in Section 1.4 represent a major challenge to echoic memory theories. Silent lipreading has been found to influence the recency and suffix effects in serial recall in a manner more characteristic of auditorily than visually presented information (Campbell & Dodd, 1980; Spoehr & Corin, 1978). On the basis of this correspondence between auditory and lipread material, Campbell & Dodd suggested that the modality effect arises from a mechanism or code which, in contrast to echoic memory, is accessible to both auditory and lipread stimuli.

However several experimental comparisons critical to this notion that auditory and lipread recency have a common origin have still to be made. In Campbell & Dodd's (1980) study, the serial recall of lists of graphic and lipread digits was compared following either an auditory suffix or no suffix at all. It was found that an auditory suffix impaired lipread but not graphic recency. No graphic suffix condition was tested, though. This raises the possibility that lipread recency is impaired by both an auditory and a graphic suffix, in contrast to auditory recency which is known to be selectively diminished by an auditory suffix (e.g. Morton & Holloway, 1970). Furthermore Campbell & Dodd did not examine the influence of a lipread suffix on lipread recency. If auditory and lipread recency do have a common origin as argued by Campbell & Dodd, then as an auditory suffix is known to impair auditory recency (e.g., Crowder, 1969), a lipread suffix should impair lipread recency. Finally, Campbell & Dodd's proposal hinges on the complementary findings that an auditory suffix impairs lipread recency and that a lipread suffix disrupts auditory recency. However these two results arose from two independent studies across which there is at least one procedural difference. In Spoehr & Corin's (1978) study the experimenter mouthed the lipread suffix "live", whereas in Campbell & Dodd's lipread presentation conditions subjects saw a silent video tape-recording of the experimenter reading aloud the digit sequence. It is important to Campbell & Dodd's interpretation of this pattern of lipreading findings that they can be generalised, and are not specific to the particular presentation procedure originally employed.

Further work is clearly required to substantiate Campbell & Dodd's (1980) proposal that the modality effect arises from a mechanism common to both auditory and lipread information. Experiment 7 is accordingly designed to provide a stronger test of this hypothesis than the two related studies in the literature (Campbell & Dodd, 1980; Spoehr & Corin, 1978). The serial recall of digit lists which are either presented auditorily or silently lipread is compared in each of three suffix conditions - lipread suffix, auditory suffix and graphic suffix. In order to ensure complete compatibility across corresponding auditory and lipread conditions, in both cases the subjects saw the same video tape-recording of the experimenter reading aloud the items. The only difference between these conditions was that in the auditory cases the experimenter's voice was also heard. This experiment makes three important contributions to the lipreading literature to date. Firstly, it provides two previously untested comparisons which are critical to Campbell & Dodd's account of the modality effect. Secondly, the corresponding auditory and lipread conditions are standardised, such that the same visual information is provided in each case. A final related benefit of this design is that it provides a within-experiment comparison of the influences of auditory and lipread information on both the recency and suffix effects.

Method

Subjects. The subjects were 32 members of the Birkbeck College subject panel. They were tested either individually or in pairs and were paid for their assistance.

Design. Each subject received 60 experimental lists. Each list contained eight digits and was constructed by sampling randomly without replacement from the digits from 1 to 9 excluding 7. Ten experimental lists were presented in each of the six conditions obtained by combining the two modes of list presentation - lipread and auditory - with the three suffix conditions - lipread, auditory and graphic. Lists were grouped into six blocks each containing ten lists, and presentation mode was alternated over successive blocks. For half of the subjects the first block was presented auditorily, and for the remaining half it was lipread. All lists in the first two blocks were followed by a graphic suffix. In each of the remaining four blocks five lists were presented in each of the auditory and lipread suffix conditions, and these were ordered in an unpredictable manner with the constraint that no more than two consecutive lists were in the same condition. Technical considerations dictated this design of blocking the graphic suffix trials. However, it is worth noting that in the studies of both Campbell & Dodd (1980) and Spoehr & Corin (1978) all suffix conditions were blocked. In Experiment 7 the order of lipread and auditory suffix conditions in the last four blocks was balanced across two groups of subjects.

The suffix item was "ZERO" in the ten experimental trials in each block. However, following Spoehr & Corin (1978), in one additional "catch" trial located at progressively later positions in successive blocks, the suffix was "SEVEN". On these trials subjects were not required to recall the digit list but instead to write down the first eight letters of the alphabet. These catch trials were included to ensure that subjects always attended to the suffix.

Procedure. A practice session designed to familiarise subjects with the task of lipreading digits preceded the experimental trials. Subjects were shown a video tape-recording (VTR) of the experimenter reading aloud 15 digits at the rate of one every five seconds. The subject's task was to repeat each digit aloud. Five trials were then given in which the experimenter was shown reading aloud a set of three digits at the rate of one a second, which the subjects again had to repeat aloud. In both phases subjects were told by the experimenter whether or not their responses were correct. Only one subject, who was subsequently excluded from the experiment and replaced by another subject, was unable to lipread by the end of the practice session.

On each experimental trial the subject was shown a VTR of the experimenter reading aloud a list of eight digits at the rate of one item every second. In the auditory list conditions subjects also heard the experimenter's voice. A suffix item, which was either "ZERO" or "SEVEN", was always presented one second after the final list item as though it was the ninth item in the series. Subjects saw the experimenter reading aloud the suffix on the VTR in the lipread suffix conditions, and was both seen and heard saying the suffix in the auditory suffix conditions. In the graphic suffix conditions the printed word was displayed on the VTR. Subjects were told that the suffix item "ZERO" signalled recall of the memory list, and strict serial recall instructions were given and enforced. Subjects were instructed to write down the first eight letters of the alphabet, however, when the suffix was "SEVEN".

Results

Figure 4.1 shows the mean recall data from Experiment 7. Although there was generally better recall of auditory than lipread lists, the two list conditions showed a similar sensitivity to suffix condition. In both cases recall at most serial positions was impaired following the auditory and lipread suffixes in comparison with a graphic suffix, and this decrement appears to be greatest at the final list position. For the auditory lists though the auditory suffix appears to have disrupted recall at this position to an appreciably greater extent than the lipread suffix.

By convention the suffix effect refers to the selective influence of a suffix on recall of the final list item (e.g., Crowder & Morton, 1969).

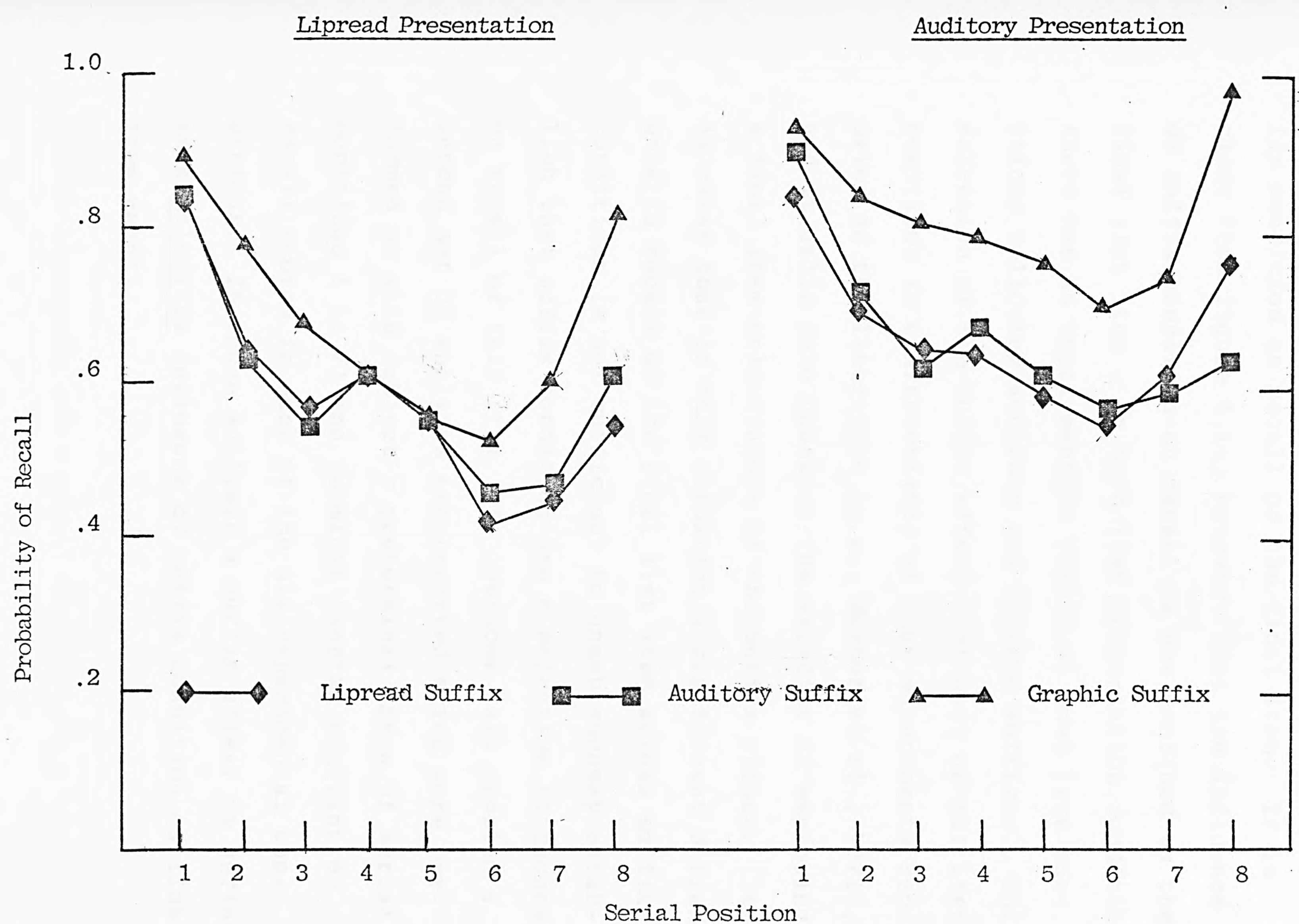

Figure 4.1 - Experiment 7 : Probability of serial recall as a function of presentation and suffix conditions

Accordingly the statistical definition of the suffix effect adopted in the first set of analyses reported here, and indeed in many other suffix experiments (e.g., Morton et al., 1971), is the influence of suffix condition on recall of the final item. It is clear from Figure 4.1., however, that the influence of suffix condition on recall is not confined to the final list item - in both list presentation conditions there was an impairment in recall at most list positions following auditory and lipread suffixes. This extension of the suffix effect over most or all list positions is characteristic of many experiments reported in the literature (e.g., Morton et al., 1971), and it calls into question the validity of employing a final item only measure of the suffix effect. It is clear that in this situation a significant difference in recall of the final list item across suffix conditions is not sufficient to unambiguously establish that suffix condition has a selective influence on recall of this item. To overcome this problem a second set of analyses are reported which were performed on each subject's preterminal (mean of serial positions 1 to 7) and terminal (serial position 8) recall scores in each of the six experimental conditions. In these analyses a suffix effect is defined as a selective influence of suffix condition on final item recall.

In the first set of analyses recall at the final list position only, serial position 8, was considered. Two Tukey's HSD tests established that in comparison with the graphic suffix condition, final item recall of both the lipread and auditory lists was impaired in the lipread and auditory suffix conditions ($p<.01$ in each case). There was no reliable difference in final item recall of lipread lists in the auditory and lipread suffix conditions ($p>.05$). However, final item recall of auditory lists was disrupted more by an auditory than a lipread suffix ($p<.01$). Hence by a final item only definition of the suffix effect, different suffix effects were found between lipread and graphic and between auditory and graphic suffix conditions with lipread lists, and between auditory and graphic, lipread and graphic, and auditory and lipread suffix conditions with auditory lists.

The second measure of the suffix effect considered was a selective influence of suffix condition on terminal as opposed to preterminal recall. Figure 4.2 shows the mean preterminal and terminal data. Firstly, an analysis of variance was performed on the preterminal and terminal recall scores for each subject in each condition. All main effects were significant - suffix condition, $F(2,62)=50.71$, $p<.001$; list position, $F(1,31)=15.52$, $p<.001$; and presentation mode, $F(1,31)=50.72$, $p<.001$. The main effect of suffix condition was further examined in a Tukey's

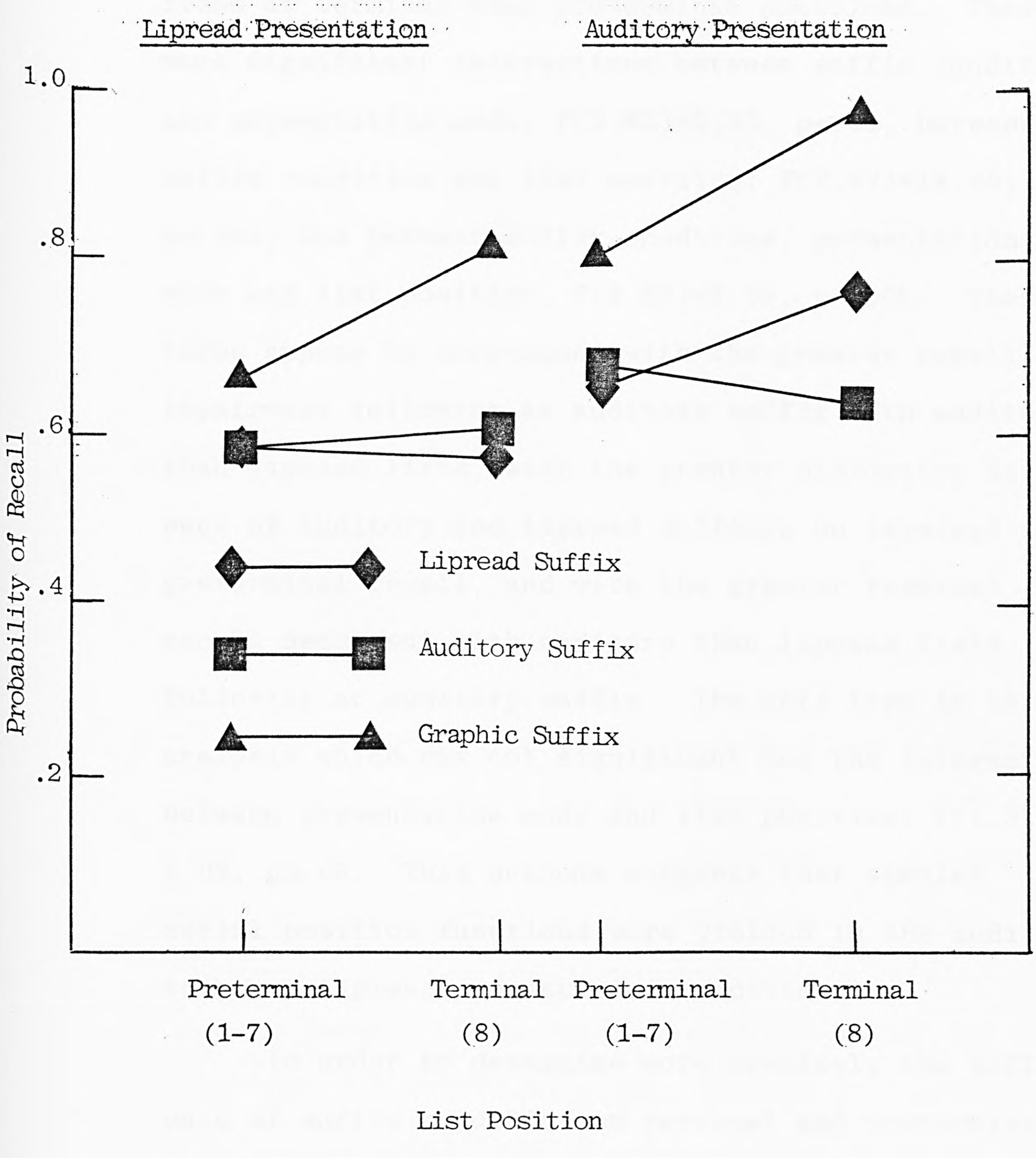

Figure 4.2 - Experiment 7 : Probability of serial recall at preterminal and terminal list positions as a function of presentation and suffix conditions

HSD test, which revealed that lists were better recalled following a graphic suffix than either a lip-read or an auditory suffix ($p<.01$ in both cases). The remaining two main effects reflect respectively the better recall of auditory than lipread lists, and of items at terminal than preterminal positions. There were significant interactions between suffix condition and presentation mode, $F(2,62)=5.23$, $p<.01$, between suffix condition and list position, $F(2,62)=14.85$, $p<.001$, and between suffix condition, presentation mode and list position, $F(2,62)=8.09$, $p<.005$. These terms appear to correspond with the greater recall impairment following an auditory suffix with auditory than lipread lists, with the greater disruptive influence of auditory and lipread suffixes on terminal than preterminal recall, and with the greater terminal recall decrement with auditory than lipread lists following an auditory suffix. The only term in this analysis which was not significant was the interaction between presentation mode and list position, $F(1,31)=1.02$, $p>.05$. This outcome suggests that similar serial position functions were yielded in the auditory and lipread presentation conditions.

In order to determine more precisely the influence of suffix condition on terminal and preterminal recall, the differences between each subject's terminal and preterminal recall scores in each condition was calculated. This provides a measure of the recency effect in each case. The mean scores are shown in Table 4.1.

Table 4.1 - Experiment 7: Mean Recency Scores in Each Condition

Suffix Condition	Presentation Mode: Lipread	Presentation Mode: Auditory
Lipread	-.15	1.09
Auditory	.21	-.34
Graphic	1.58	1.68

The effect of suffix condition on this measure for the lipread lists was significant, $F(2,62)=8.27$, $p<.001$. A Tukey's HSD test established that there was a greater recency effect following a graphic suffix than either an auditory or a lipread suffix ($p<.01$ in both cases). Thus with lipread lists, suffix effects were found following both lipread and auditory suffixes in comparison with the control graphic suffix condition.

The analysis of variance on the corresponding data from the auditory lists also revealed a significant effect of suffix condition, $F(2,62)=18.47$, $p<.001$. Once again a Tukey's HSD test revealed that there was a greater recency effect following a graphic than an auditory suffix ($p<.01$). This time, though, there was no difference between the lipread and graphic suffix conditions ($p>.05$), and greater recency was found following a lipread than an auditory suffix ($p<.01$). So with auditory lists, an auditory suffix effect was found in comparison with both lipread and graphic suffix conditions.

To summarise briefly, conclusions concerning the results of this experiment are dependent on which definition of the suffix effect is adopted. If the suffix effect is defined as an influence of suffix condition on final item recall, both lipread and auditory suffixes, in comparison with graphic suffixes, yielded suffix effects with both auditory and lipread lists. If, on the other hand, a definition of the suffix effect as a <u>selective</u> influence of suffix condition on final item recall is employed, no suffix effect occurred when a lipread suffix followed an auditory list. In all other critical respects, though, the results were not materially influenced by which definition was adopted.

4.3 Discussion

This experiment provides further evidence that the recency and suffix effects in serial recall are similarly influenced by auditory and lipread stimuli, and are affected in a readily distinguishable manner by graphic information. Lipread recency was diminished by an auditory suffix, in comparison with a graphic suffix. Moreover a lipread suffix also disrupted lipread recency, which complements the conventional auditory suffix effect also demonstrated in this experiment. Thus the results establish considerable generality to the correspondence between auditory and lipread recency in serial recall reported by Campbell & Dodd (1980), and go some way towards substantiating their proposal that they have a common origin.

The correspondence between auditory and lipread conditions is not, however, quite complete. Although a lipread suffix impaired final item recall of both auditory and lipread lists in comparison with the control graphic suffix conditions, it was only in the case of the lipread lists that the lipread suffix disrupted recall more at this than at previous list positions. In contrast in Spoehr & Corin's (1978) study the influence of a lipread suffix on recall of auditory lists was confined to the last list position. One possible reason for this disparity is that Spoehr & Corin's result is tied to their procedure of presenting the lipread suffix "live", and cannot be generalised to the video procedure used in Experiment 7. This seems unlikely. A more plausible account is that a lipread suffix effect with auditory lists in Experiment 7 was masked by a ceiling effect in the final item recall following a graphic suffix - performance reached 98% accuracy here. And it should be emphasised that when a definition of the suffix effect which takes account of the final item only was adopted (see also, e.g., Morton et al., 1971), a lipread suffix effect with auditory lists was found in Experiment 7.

The problem of choosing a definition of the suffix effect in this experiment is a consequence of the presence of recall differences across suffix conditions which span many list positions. In the case of both the auditory and the lipread lists, recall at most list positions was better following a graphic suffix than either an auditory or a lipread suffix. Disruptions by the suffix on recall at early as well as late list positions are in fact a fairly frequent feature of auditory suffix experiments (e.g., Crowder & Raeburn, 1970; Morton et al., 1971). Data reported by Hitch (1975) show that the prerecency suffix effect, but not the effect at recency, disappears when a suffix follows every list item. On the basis of this pattern of results and corresponding data of their own dissociating the prerecency and recency suffix effects (see also, Baddeley & Hull, 1979), Balota & Engle (1981) have recently suggested that the auditory prerecency suffix effect is due to a disruption of attentional processes. It seems quite plausible that the pre-recency suffix effects found in Experiment 7 following lipread presentation of either suffix or list items, or both, also have an attentional origin. This could be tested quite simply by investigating the influence of Hitch's through-list suffix procedure on these pre-recency suffix effects. If they are due to attentional factors, they might be expected to disappear when suffixes are interspersed throughout the list.

In conclusion, the results of Experiment 7 provide considerable support for Campbell & Dodd's (1980) suggestion that auditory and lipread recency have a common origin. This is incompatible with the echoic memory interpretations of the suffix effect reviewed in Chapter 1, according to which only information presented in the auditory sensory mode may be represented in echoic memory. Instead the findings reported in this chapter suggest that the suffix effect and hence the modality effect derive from a mechanism accessible to both auditory and lipread information. This intepretation is tested directly in the two experiments reported in the next chapter. Some ideas concerning the nature of the proposed non-echoic mechanism are considered in the final chapter.

Chapter 5 - Lipreading and the Modality Effect

5.1 Introduction

A close correspondence between the influences of auditory and lipread information on the recency and suffix effects in serial recall was found in Chapter 4. Further evidence contrary to echoic memory interpretations of the modality effect is provided by the two experiments reported in this chapter, which establish that the modality effect in both free and backward recall is impaired by post-list lipread distraction.

5.2 Experiment 8

The striking similarities between auditory and lipread recency which were demonstrated in Chapter 4 represent a major challenge to echoic memory interpretations of the modality effect. The purpose of the experiments reported in this chapter is to test directly and provide convergent evidence for an alternative account put forward by Campbell & Dodd (1980), which is that the modality effect arises from a mechanism or code common to both auditory and lipread stimuli.

In both experiments the sensitivity of the modality effect to 30-second periods of lipread and graphic distraction is compared. In Experiment 8 a free recall paradigm is employed. It has already been established that a similar period of auditory but not graphic distraction eliminates the modality effect in this situation (Broadbent et al., 1978; Gardiner et al., 1974). If, as suggested by Campbell & Dodd (1980), the modality effect does arise from a mechanism accessible to both auditory and lipread stimuli, lipread distraction should also impair the modality effect in free recall. On the other hand, if the interference effects involving lipreading which were demonstrated in Chapter 4 reflect mechanisms other than those mediating the conventional suffix and modality effects, the modality effect in this experiment should not be sensitive to lipread distraction.

Method

<u>Subjects</u>. The subjects were 24 members of the Birkbeck College subject panel. They were tested either individually or in pairs and were paid for their assistance.

<u>Design and Materials</u>. Each subject received 32 experimental lists and two practice lists. East list contained 11 words and was constructed by sampling randomly without replacement from the word pool listed in Appendix 2. Eight experimental lists were presented in each of the four conditions obtained by combining the two modes of list presentation - auditory and graphic - with the two distractor conditions - lipread and graphic. Lists were grouped into four blocks each containing eight lists, and presentation mode was alternated over successive blocks. For half of the subjects the first block was auditorily presented, and for the other half it was presented graphically. Each distractor condition occurred four times within each block, and was ordered in an upredictable manner with the constraint that no more than two consecutive lists involved the same condition. Order of distractor conditions within each block was balanced over two groups of subjects. This design ensured that each list was presented equally often in each of the four experimental conditions. Order of words within lists was reversed for half of the subjects. The distractor task involved monitoring a series of random single digits with respect to whether each number was odd or even.

Procedure. The lists were presented by the experimenter at the rate of one word every two seconds either auditorily, by reading the words aloud, or graphically, by displaying the words one at a time printed on cards. Two video tape-recorders were used to present the distractor items on television screens, one for each distractor type, and the appropriate recorder was switched on by the experimenter immediately after the final word from the list had been presented. Each tape comprised a random sequence of single-digit numbers occuring at the rate of one number every three-quarters of a second, and lasting for a total of about ten minutes. In the graphic distractor condition, the numbers had been recorded directly from the VDU of a Commodore PET microcomputer which had been used to generate them. In the lipread distractor condition the recording was of the experimenter silently mouthing each digit.

During the experiment subjects worked through a response booklet with alternate pages allocated to the distractor task and recall test. In the distractor task subjects monitored each digit by writing down a "1" if the number was odd, and a "2" if it was even. They were instructed to respond to as many numbers as possible. The distractor activity lasted for 30 seconds and was terminated by the experimenter switching the recorder off. Recall time was not constrained, and subjects were instructed to turn to the next page in the response booklet when they had finished recalling. One practice trial was given before each of the first two blocks of lists, and the first of these always involved lipread distraction. Prior to this subjects were familiarised with the distractor task and its requirements. The experiment lasted about 65 minutes.

Results and Discussion

The results are shown in Figure 5.1. Two aspects of the data are worth noting. Firstly, distractor condition influenced the recall of late auditory but not graphic items. There was considerable auditory recency following graphic distraction but none following lipread distraction. Hence a modality effect occured following graphic but not lipread distraction. The second notable feature of the results concerns the recall of early list items. Recall at initial list positions was better following graphic than auditory presentation of the list, and this graphic advantage was unaffected by distractor condition. Hence recall of early and late list items in this experiment was independently influenced by presentation and distractor conditions.

The influence of experimental conditions on recency recall is of principal interest in this experiment. The serial position data for each subject were

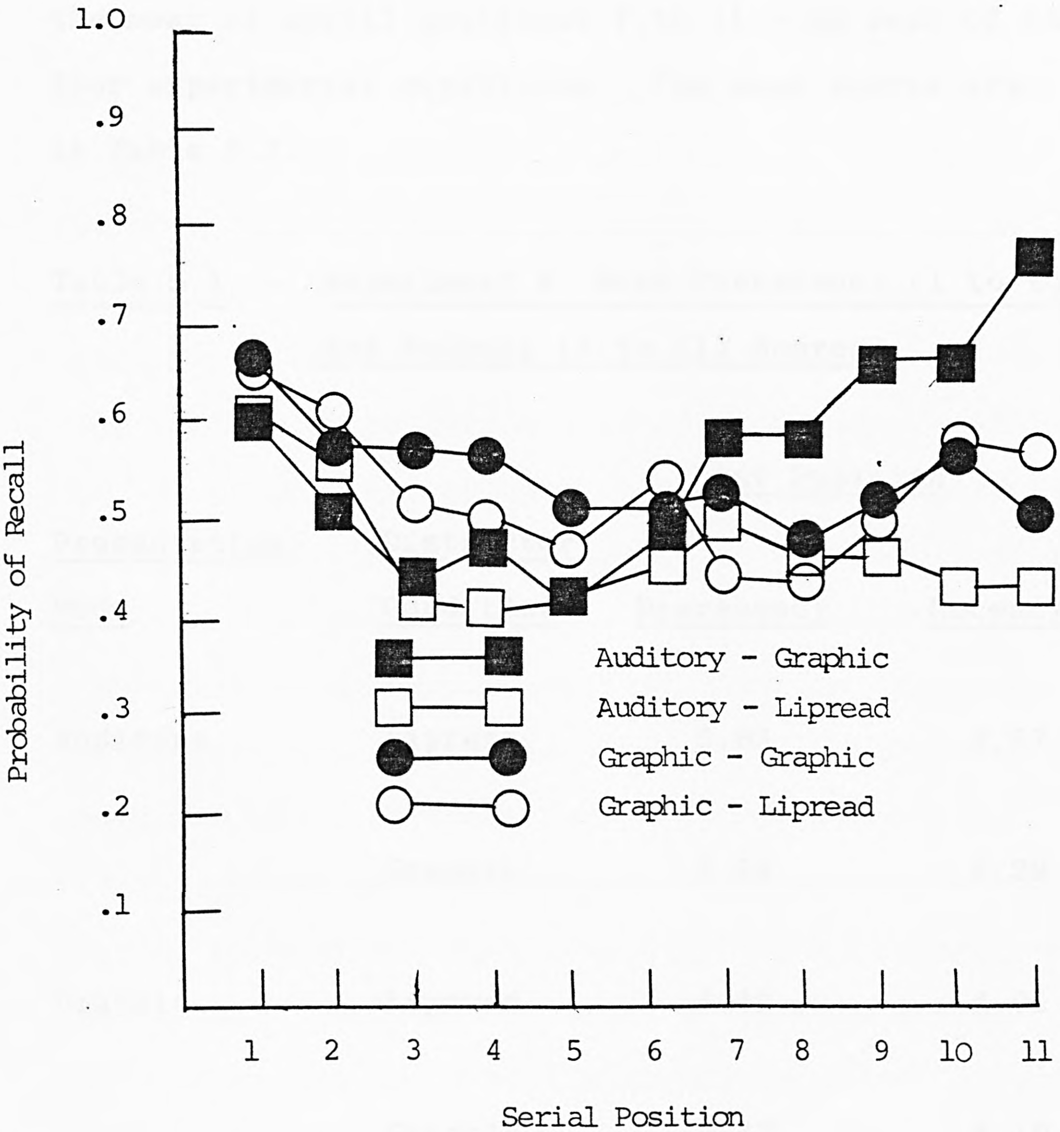

Figure 5.1 - Experiment 8 : Probability of free recall as a function of presentation mode and distractor condition

therefore collapsed to yield a prerecency score - the mean of serial positions 1 to 6 - and a recency score - the mean of serial positions 7 to 11 - in each of the four experimental conditions. The mean scores are in Table 5.1.

Table 5.1 - Experiment 8: Mean Prerecency (1 to 6) and Recency (7 to 11) Scores

		List Position	
Presentation Mode	Distractor Condition	Prerecency	Recency
Auditory	Lipread	3.83	3.67
	Graphic	3.89	5.29
Graphic	Lipread	4.42	4.01
	Graphic	4.47	4.10

(Maximum = 8)

These particular measures of prerecency and recency recall were chosen because they provide a conservative estimate of the modality effect. However, it should be noted that unless stated otherwise, none of the major conclusions reached in this chapter are critically dependent on the adoption of these rather arbitrary measures.

The better recall of lists following a graphic than a lipread distractor task was reflected in the significant main effect of distraction, $F(1,23)=20.21$, $p<.001$. The effects of presentation mode, $F(1,23)<1.00$, and list position, $F(1,23)<1.00$, were not significant. The interaction between presentation mode and distractor condition reached significance, $F(1,23)=22.49$, $p<.001$, and appears to be due to the disruptive influence of lipread distraction on the recall of auditory but not graphic lists. Significant interactions were also obtained between list position and presentation mode, $F(1,23)=12.75$, $p<.005$, and between list position and distractor condition, $F(1,23)=9.43$, $p<.01$. These seem to reflect respectively the better recall of auditory than graphic items at recency and of graphic than auditory items at prerecency, and the disruptive influence of lipreading on recall at recency positions. The three-way interaction between presentation mode, distractor condition and list position, $F(1,23)=11.72$, $p<.005$, was also significant. This interaction confirms the selective interfering effect of lipread distraction on auditory recency.

Thus no modality effect was found when subjects had to lipread irrelevant material immediately following list presentation. And lipreading had no influence on prerecency recall. This pattern of interference corresponds closely with that already established by previous free recall studies which employed auditory instead of lipread distraction (Broadbent et al., 1978; Gardiner et al., 1974). These results are clearly incompatible with the view of echoic memory theories that the modality effect arises from echoic memory, as if this was the case it should not be eliminated by silent lipread distraction. Instead, this experiment provides direct and compelling evidence that the modality effect originates from a mechanism or code accessible to both auditory and lipread stimuli (Campbell & Dodd, 1980).

One further aspect of the data from this experiment, however, needs to be considered. Output interference is not controlled in a free recall experiment, which raises the possibility that results are mediated by output strategy. Such an account of the pattern of delayed modality-specific interference found in Chapter 3 was dismissed on the basis of post hoc output order analyses (Section 3.4). However, it remains possible that the disappearance of the modality effect following lipread distraction in Experiment 8 was a consequence of recall strategy.

It is clearly critical to establish whether these results are associated with output order as, if this is the case, an interpretation of the modality effect in terms of a mechanism common to auditory and lipread stimuli on the basis of this experiment is cast into doubt. As in Chapter 3, two measures of output order were taken. Firstly, following Murdock & Walker (1969) and Broadbent et al. (1978), the mean serial positions of items at each output position were determined. For each subject the mean serial position of items recalled at each output position was calculated for each output position at which every subject recalled at least one item.

Figure 5.2 shows the results of this analysis. It is clear that the serial positions of items recalled first from auditory lists differs across the two distractor conditions. Later auditory items tended to be recalled earlier following graphic than lipread distraction. In contrast distractor condition did not appear to influence which graphic list items were recalled first.

An analysis of variance was performed on these data. Each subject contributed 20 scores which were the mean serial positions of the items recalled at the first five output positions in the four experimental conditions. There were significant main effects of presentation mode, $F(1,23)=9.18$, $p<.01$, and distractor condition, $F(1,23)=8.97$, $p<.01$. These correspond to the better recall of late list items following graphic than lipread distraction, and of late items from auditory than graphic lists, respectively. No effect of output position was found, $F(4,92)=1.29$, $p>.05$. The interaction between presentation mode and output

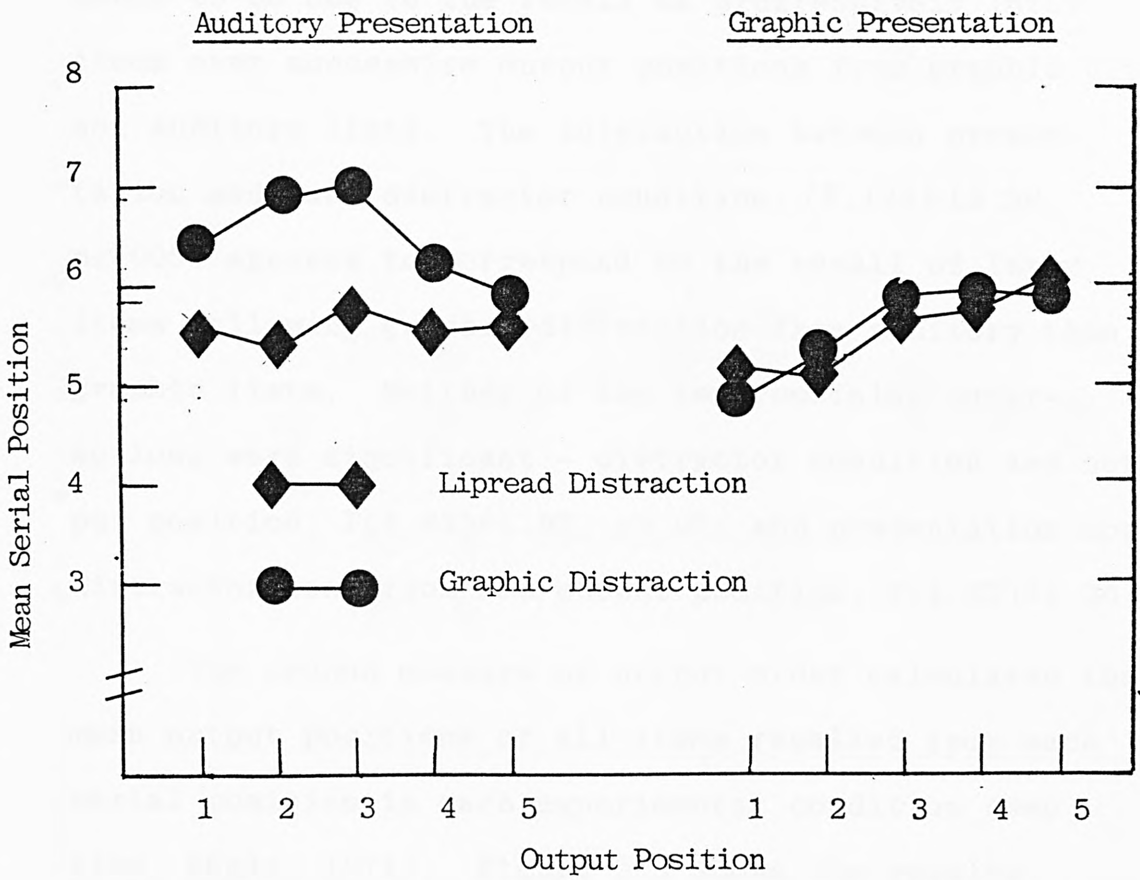

Figure 5.2 - Experiment 8 : Mean serial position as a function of output position, presentation mode and distractor condition.

position was significant, $F(4,92)=4.03$, $p<.005$. This seems to be due to the recall of progressively later items over successive output positions from graphic but not auditory lists. The interaction between presentation mode and distractor condition, $(F,123)=13.36$, $p<.005$, appears to correspond to the recall of later items following graphic distraction from auditory than graphic lists. Neither of the two remaining interactions were significant - distractor condition and output position, $F(4,92)=1.93$, $p>.05$; and presentation mode, distractor condition and output position, $F(4,92)<1.00$.

The second measure of output order calculated the mean output positions of all items recalled from each serial position in each experimental condition (see also, Engle, 1974). Figure 5.3 shows the results. Early auditory list items appear to have been recalled later following graphic than lipread distraction. Distractor condition does not, however, appear to have influenced the output position of either late auditory items or items from graphic lists. These observations were upheld by the results of the analysis of variance performed on this data, which showed a significant interaction between presentation mode and distractor condition, $F(1,23)=7.74$, $p<.05$. The only other terms in this analysis that reached significance were those of distractor condition, $F(1,23)=6.01$, $p<.05$, and serial position, $F(10,230)=3.44$, $p<.001$.

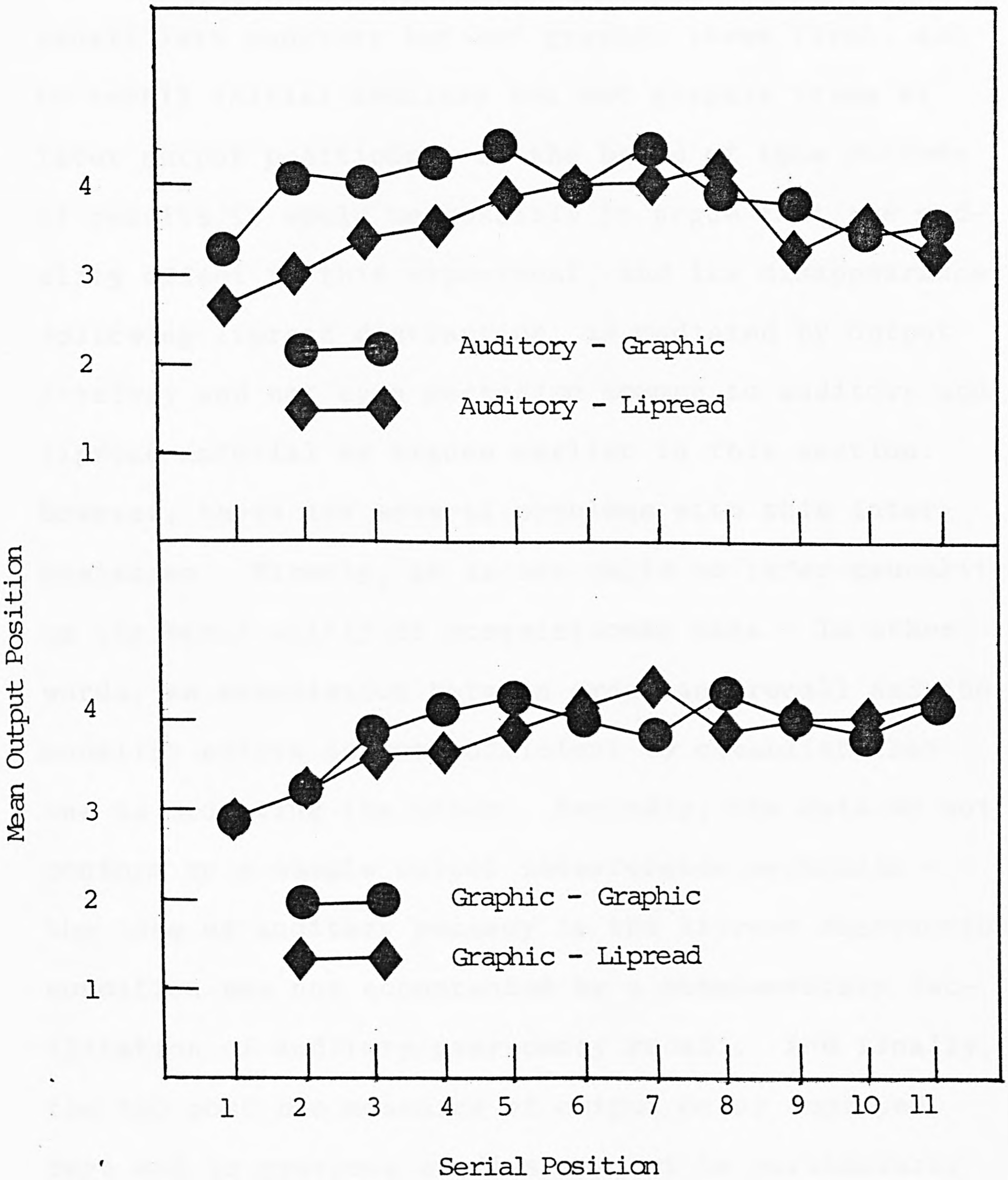

Figure 5.3 - Experiment 8 : Mean output position as a function of serial position, presentation mode and distractor condition

Both measures of output order considered here reveal consistent changes in the order of recall across experimental conditions. They show that the modality effect was associated with a tendency to recall late auditory but not graphic items first, and to recall initial auditory but not graphic items at later output positions. On the basis of this pattern of results it would be possible to argue that the modality effect in this experiment, and its disappearance following lipread distraction, is mediated by output strategy and not by a mechanism common to auditory and lipread material as argues earlier in this section. However, there are several problems with this interpretation. Firstly, it is not valid to infer causality on the basis solely of correlational data. In other words, an association between order and recall and the modality effect is not sufficient to establish that one is mediating the other. Secondly, the data do not conform to a simple output interference mechanism - the loss of auditory recency in the lipread distraction condition was not accompanied by a complementary facilitation of auditory prerecency recall. And finally, the two post hoc measures of output order employed here and in previous studies may not be particularly informative. Consider the situation in which output order strategy varies randomly from trial to trial. In terms of the mean serial position per output position analysis, it would be expected that the conditions which led to the best recall of final list items would produce the greatest mean serial position at each output position. Hence the association which was found between the modality effect and this output measure is predictable from a purely random variation in recall strategy. A similar situation arises when the measure of mean output position per input position is taken. The condition in which most late list items are recalled should be associated with a higher average output position of each item. This again yields an association between the modality effect and index of output order.

There are clearly many problems with an interpretation of the results of Experiment 8 in terms of output strategy, most of which cannot be resolved merely by further examination of the data. In order to provide a better assessment of the role played by output strategy in the disappearance of the modality effect following lipread distraction in Experiment 8, a further experiment was designed in which the same experimental conditions were tested but where order of recall was experimentally controlled. In Experiment 9 a procedure of backward recall was employed, in which subjects had to write down the last list item first and successively recall the items in reverse serial order. If output strategy was critical in Experiment 8, standardising output order across experimental conditions should produce a materially different pattern of results. If, on the other hand, the output order differences found in Experiment 8 were either artifactual or not playing a causal role, the modality effect in Experiment 9 should also be disrupted by lipread distraction.

5.3 Experiment 9

Method

Subjects. Twenty-four members of the Birkbeck College subject panel participated in this experiment. They were tested either individually or in pairs, and were paid for their assistance.

Design and Materials. The design and materials used in this experiment were identical to those employed in Experiment 8. Briefly, subjects were tested in all four conditions obtained by combining the two modes of list presentation - auditory and graphic - with the two distractor types - lipread and graphic. Each subject received eight experimental trials in each condition. The same blocking and balancing procedures were followed as in Experiment 8, so that each list was presented equally often in each experimental condition. The distractor task once again involved monitoring a sequence of random digits.

Procedure. A backward serial recall procedure was employed. Subjects were instructed to complete the grid of 11 boxes on their response sheet by writing the words down in reverse order in the boxes in strictly top-to-bottom order. Successive boxes in the grid were completed until the first word from the list, if recalled, was written in the bottom box. Blanks were allowed, but subjects were not permitted to complete an unfilled box if a lower box in the grid had been filled. A maximum period of one minute was allowed for recall.

In all other respects the procedure was identical to that employed in Experiment 8.

Results

The data were scored by a strict backward recall criterion, according to which only items recalled in their reverse serial position on the response sheet were scored correct. The results are shown in Figure 5.4. In some respects the results look very different from those of Experiment 8. In Experiment 9 recall of early and middle list items was generally at a much lower level, and there was a large recency effect in every condition. However, presentation and distractor conditions do appear to have influenced recall at recency positions in a corresponding manner in the two experiments. A larger modality effect was found following graphic than lipread distraction in Experiment 9, although in contrast with Experiment 8 a residual effect did remain in the lipread distraction condition. The other principal contrast between the results of the two experiments concerns recall of early list items - in Experiment 9 there was no recall

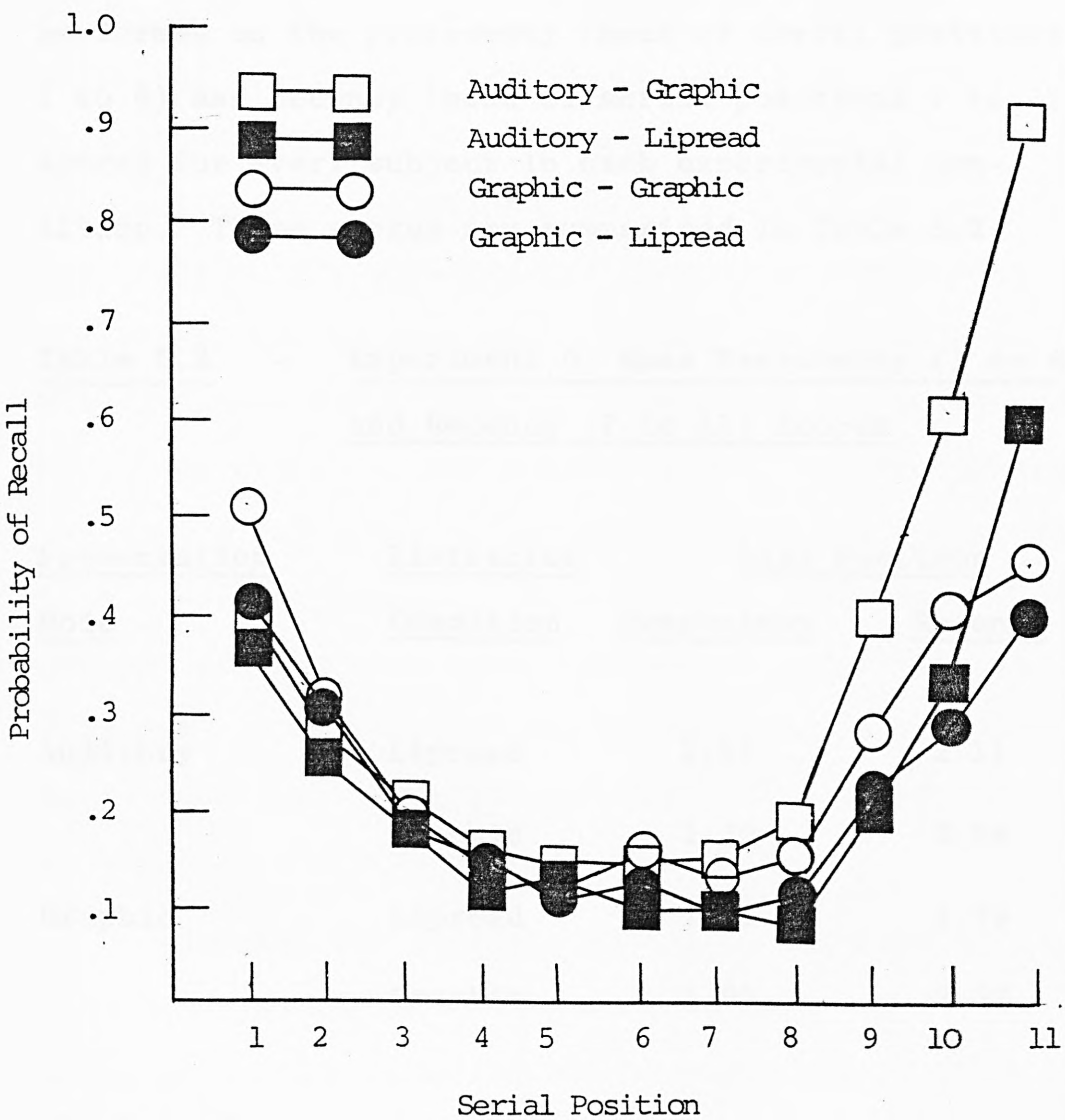

Figure 5.4 - Experiment 9 : Probability of backward recall as a function of presentation mode and distractor condition

advantage to graphic lists over prerecency positions.

As in Experiment 8, an analysis of variance was performed on the prerecency (mean of serial positions 1 to 6) and recency (mean of serial positions 7 to 11) scores for every subject in each experimental condition. These scores are summarised in Table 5.2.

Table 5.2 - Experiment 9: Mean Prerecency (1 to 6) and Recency (7 to 11) Scores

Presentation Mode	Distractor Condition	List Position Prerecency	Recency
Auditory	Lipread	1.51	2.11
	Graphic	1.79	3.58
Graphic	Lipread	1.71	1.79
	Graphic	1.93	2.27

(Maximum=8)

All main effects in this analysis were significant : presentation mode, $F(1,23)=6.57$, $p<.01$, distractor condition, $F(1,23)=58.85$, $p<.001$; and list position, $F(1,23)=9.14$, $p<.01$. These correspond respectively to the better recall of auditory than graphic lists, of lists following graphic than lipread distraction, and of items at recency than prerecency positions. The interaction between presentation mode and distractor condition, $F(1,23)=5.94$, $p<.05$, appears to be due to the greater detrimental effect of lipread distraction on recall of auditory than graphic lists. The interactions between list position and presentation mode, $F(1,23)=48.96$, $p<.001$, and between list position and distractor condition, $F(1,23)=18.24$, $p<.001$, also reached significance. Respectively, these seem to reflect the better recency recall of auditory than graphic lists, and the greater disruptive influence of lipread distraction on recency than prerecency recall. Finally, the interaction between presentation mode, distractor condition and list position, $F(1,23)=7.46$, $p<.01$, appears to correspond with the disruptive influence of lipread distraction on the modality effect.

Although the modality effect is impaired by lipread distraction, it does seem from Figure 5.4 that there is a small modality effect remaining in this condition. Yet a comparison of the recency scores (means of serial positions 7 to 11) of each subject for the graphic and the lipread lists in the lipread distractor condition yielded no significant difference, $t(23)<1.00$. This measure may not however have been sufficiently sensitive to detect a small modality effect, as the difference in the means for the auditory and graphic lists in this condition is confined to the last list position. Accordingly, when recall in these two conditions was compared at serial position 11 only, a significant modality effect was found in the lipread distractor condition, $t(23)=3.16$, $p<.01$.

Before discussing the theoretical implications of the results of both this experiment and Experiment 8, one final aspect of performance in both of these experiments should be considered. In both the lipread and the graphic distractor conditions, the distractor digits were presented at a constant rate of one number every three-quarters of a second for the full 30-second distractor period. Hence on each trial 40 distractor digits in all were presented. However subjects did not always monitor all of these. It is therefore possible that recall performance was related in a systematic fashion to distractor performance. This was investigated by making a post hoc check of the number of digits monitored in each of the experimental conditions.

Table 5.3 - Experiments 8 and 9 : Mean Number of Distractor Digits Monitored

Presentation Mode	Distractor Condition	Mean Number of Digits Experiment 8	Experiment 9
Auditory	Lipread	31	31
	Graphic	37	37
Graphic	Lipread	33	31
	Graphic	38	36

It is clear that in both experiments more digits were monitored in the graphic than the lipread distractor conditions. Distractor performance was not influenced by list presentation mode. This rules out the possibility that the results at recency were mediated by distractor task performance.

5.4 General Discussion

It is established that a period of post-list lip-read distraction impairs the modality effect in both backward and free recall. This set of findings makes several important contributions to the modality effect literature. Firstly, it provides direct evidence in support of the suggestion made by Campbell & Dodd (1980) that the modality effect arises from a mechanism or code accessible to both auditory and lipread stimuli, and by the same token runs counter to echoic memory interpretations of the modality effect. Secondly, the demonstration that the modality effect is sensitive to lipread distraction in backward ordered recall rules out an output order account of the free recall findings. Furthermore in conjunction with the serial recall findings described in Chapter 4 and reported by Campbell & Dodd and Spoehr & Corin (1978), these results establish considerable paradigm generality to the correspondence between the influences of auditory and lipread information on recency.

Chapter 6 - Summary and Conclusions

6.1 Introduction

A major objective of the thesis is to provide an evaluation of echoic memory accounts of the modality effect. In this chapter consideration is given to the implications of the findings of the thesis for echoic memory theories (Section 6.2) and for broader theoretical and empirical issues (Section 6.3). Finally, the major theoretical conclusions reached on the basis of the research reported in the thesis are summarised (Section 6.4).

6.2 Principal Findings and Implications for Echoic Memory Theories

The research reported in the thesis has important implications for the major echoic memory interpretations of the modality effect reviewed in Chapter 1 - PAS theory (Crowder & Morton, 1969), sensory recency theory (e.g., Broadbent et al., 1980) and echoic persistence theory (Watkins & Watkins, 1980). These echoic memory theories are characterised by the notion that the modality effect arises from the contribution of a source of modality-specific information to recall following auditory but not visual list presentation. They can be differentiated with respect to the sensory and categorical status they attribute to echoic memory, and in terms of the way in which echoic information is assumed to aid recall. Theorists also differ over whether echoic memory retains item or order information. The principal findings of the thesis and their implications for each of these echoic theories are summarised below. Each of the characteristics of the modality effect established by this research is discussed separately.

The Modality Effect : Prelexical

In Chapter 2 the influence of the phonological characteristics of the list materials on the modality effect in serial recall was investigated. The modality effect was found to be impaired when lists contained words of high inter-item phonological similarity. Furthermore this sensitivity of the modality effect to similarity was independent of whether the subject or the experimenter vocalised the list items in the auditory presentation conditions. These results run counter to the recent proposal made by Richardson (1979) that the modality effect with word lists originates from a system of postcategorical lexical storage, as according to this the effect should not be influenced by the phonological characteristics of the list materials. Instead the prelexical nature of the modality effect suggested by these findings is fully consistent with the suggestion made by all three principal echoic memory theories considered in the thesis - PAS theory, sensory recency theory and echoic persistence theory - that auditory stimuli are represented in echoic memory irrespective of their lexical status.

<u>The Modality Effect : Persistent</u>

The influence of the presentation mode of delayed distraction on the modality effect in free recall was examined in Chapter 3. The modality effect was found to be eliminated by a period of delayed auditory but not visual distraction. This pattern of modality-specific interference corresponds closely with that already known to characterise the immediate post-list distraction situation (e.g., Broadbent et al., 1978). The results suggest that the origin of the modality effect in free recall remains materially unchanged for at least 15 seconds, and therefore run counter to the view of PAS theory that echoic information is recoded into postcategorical storage within about two seconds (e.g., Crowder, 1971b; Morton, 1970). The findings of Chapter 3 instead favour the more recent sensory recency and echoic persistence theories, both of which propose that echoic information may persist and be used directly at recall for an indefinite period.

This conclusion should however be qualified. A demonstration of delayed modality-specific interference does not unambiguously establish that the modality effect in free recall has a directly echoic origin. And there is some evidence in the literature that this pattern of interference might reflect different mechanisms in the immediate and delayed distractor situations - it is known that no suffix effect occurs when the suffix effect arrives more than a few seconds after the final list item (e.g., Crowder, 1971b). For these reasons it is believed that further evidence is required to establish that the sensitivity of the modality effect to auditory distraction at short and lengthy distractor delays has a common origin. A demonstration that the modality effect is sensitive to the acoustic characteristics of delayed distractor information, for example, would go a long way towards providing such convergent evidence.

The Modality Effect : Non-Acoustic

The research reported in the final two experimental chapters, in contrast to the earlier experiments, calls into question all echoic memory interpretations of the modality effect - PAS theory, sensory recency theory and echoic persistence theory. The experiment described in Chapter 4 demonstrated that in serial recall lipread recency displays very similar characteristics to auditory recency. Furthermore it was found in Chapter 5 that in both free and backward recall the modality effect is impaired when a period of silent lipread distraction follows list presentation. These findings are clearly inconsistent with the notion that the modality effect arises from a mechanism such as echoic memory which is specific to information presented in the auditory sensory mode. For this reason it is believed that the prelexical and persistent characteristics of the modality effect discussed above should not be accommodated in the context of an echoic memory theory, but should instead be incorporated into the framework of a non-echoic account of the modality effect. Two such interpretations are discussed later in the chapter.

The Modality Effect : Generalisable across Recall Paradigms

Auditory and lipread information were shown to influence recency recall in a similar manner in three paradigms - serial recall (Chapter 4) and free and backward recall (Chapter 5). Furthermore the sensitivity of the modality effect in free recall to the presentation mode of delayed distraction (Chapter 3) is similar to that found by Watkins & Watkins (1980) in serial recall. And the influence of phonological similarity on the modality effect with words in Chapter 2 was independent of whether a serial or free scoring criterion was adopted. These findings converge with those reviewed in Section 1.2 in suggesting that the modality effect has a common origin in free and ordered recall, and so run counter to the view put forward by Morton (e.g., 1977) that the modality effect arises from the availability of additional order cues concerning the final auditory item. Instead the paradigm generality of the modality effect indicates that its origin is a source of item as well as order information. This is entirely consistent with both echoic persistence theory and sensory recency theory, and possibly to some readings of PAS theory. However, on the basis of the lipreading findings reviewed above it is believed that the paradigm generality of the modality effect should be incorporated by a non-echoic account.

6.3 Broader Theoretical and Empirical Issues

The prelexical, persistent and general characteristics of the modality effect established by the research reported in this thesis are consistent with two of the major echoic memory theories reviewed in Chapter 1 - sensory recency theory and echoic persistence theory. The non-acoustic nature of the modality effect suggested by the findings of the two final experimental chapters, however, runs counter to the assumption made by both of these theories that the effect arises from modality-specific storage. In this section two non-echoic accounts of the modality effect are therefore considered - the changing state hypothesis put forward originally by Campbell & Dodd (1980) and elaborated by Gardiner, Gathercole & Gregg (Note 2), and the primary linguistic coding hypothesis of Shand & Klima (1981). Finally, some ideas for research which would discriminate between these two accounts are discussed.

Changing State Hypothesis

Campbell & Dodd (1980) consider two possible non-echoic accounts of the modality effect. One is that it arises from a phonological processing stage shared by both heard and seen speech. However, as pointed out by Crowder (1978b), the influence of phonological factors on short-term memory appears to be located at prerecency, rather than recency, recall. The other non-echoic interpretation of the modality effect considered by Campbell & Dodd is, in the opinion of the author, more compelling. The proposal is that enhanced recency is a consequence of the temporal ordering of features in auditory and lipread stimuli. Specifically, they suggest that the recency and suffix effects associated with auditory presentation procedures "may reflect a general tendency for changing state information to be processed differently than information which can be resolved instantaneously" (p. 97).

This suggestion was developed more formally by Gardiner, Gathercole & Gregg (Note 2). They proposed that non-instantaneous complex stimuli such as spoken words require temporal integration prior to categorical decision, and that the integration process automatically generates an additional source of stimulus information. Since conventionally presented graphic stimuli are instantaneous, they do not require integration and so no integrational information is produced. Thus the modality effect is attributed to the contribution of integrational information to recall following auditory but not graphic list presentation.

Gardiner et al. suggest that this integrational information could be conceptualised in an attribute framework. Consistent with this approach would be the assumption that the utility or salience of the integrational attributes diminishes as a function of the amount of subsequent integrational attributes. This could provide an explanation both for the restriction of the modality effect to the last few list positions, and for its diminution following auditory but not graphic distraction demonstrated in Chapter 3.

This hypothesis can successfully accommodate those findings of the thesis which are incompatible with echoic memory accounts of the modality effect. Since lipread as well as auditory stimuli are temporally fragmented, they too would be expected to require temporal integration and consequently to give rise to integrational information. Hence the corresponding characteristics of lipread and auditory recency shown in Chapter 4 and the interfering influence of lipread distraction on the modality effect found in Chapter 5 are in complete accordance with such a changing state hypothesis.

Primary Linguistic Coding Hypothesis

Shand & Klima (1981) have also provided an account of the modality effect which does not rely on the concept of echoic memory. They proposed that any information presented in a form which serves as an individual's primary linguistic code will be associated with the recency and suffix effects known to characterise short-term memory for auditory material. According to this hypothesis the modality effect arises because for the normal speaking population the heard speech signal represents a primary linguistic input, whereas written language has to be converted into a derived form of the primary linguistic code.

Shand & Klima proposed that lipread as well as auditory stimuli represent a primary linguistic input for the hearing population. On the basis of this assumption, their theoretical framework can accommodate all of the principal findings of the thesis. It predicts both the correspondence between auditory and lipread recency observed in Chapter 4 and the interference between the modality effect and auditory and lipread but not graphic distraction demonstrated in Chapters 3 and 5. And the sensitivity of the modality effect to phonological similarity reported in Chapter 2 is entirely consistent with the notion that the origin of this effect is a code based on spoken language.

Support for the primary linguistic coding hypothesis was provided by Shand & Klima's (1981) finding of recency and suffix effects in free recall when a group of congenitally deaf subjects received lists of words presented in the form of American Sign Language (ASL). They argued that this result is in complete accordance with their conceptual framework, as ASL would be expected to be a primary linguistic input for this American signing deaf population. This accommodation of recency and suffix effects with sign language, lipread and heard speech is a particularly elegant feature of the primary linguistic coding hypothesis. It should however be noted that the sign language findings are equally consistent with a changing state hypothesis as moving hand signals, like heard speech signals, involve a temporal ordering of features.

Further Research

Both the correspondence between the influences of auditory and lipread information on recency demonstrated in the thesis and the occurrence of recency and suffix effects when deaf subjects recall lists of words presented via ASL reported by Shand & Klima (1981) are readily accommodated by both of the non-echoic accounts of the modality effect considered above. Further work, although unfortunately beyond the resources of the thesis, is clearly required to discriminate between the primary linguistic coding hypothesis and a changing state hypothesis. Some suggestions are made here about what directions this research might usefully follow.

In fact Shand & Klima (1981) have already presented some evidence which they suggest rules out a changing state hypothesis. They found recency and suffix effects when a group of signing deaf subjects received series of pictorial representations of ASL stimuli. As these pictures were not temporally fragmented at presentation, this finding suggests that the changing state nature of auditory, lipread and ASL stimuli is not critical to these phenomena. However, recency and suffix effects are also found with graphic stimuli (e.g., Kahneman, 1973). Both the auditory and lipread recency and suffix effects have been shown to have dissociable characteristics from the graphic phenomena - Hitch (1975) found that the graphic but not the auditory suffix effect disappeared when a procedure of presenting suffixes throughout the list was employed, and an auditory suffix impairs lipread but not graphic recency (e.g., Chapter 4; Morton & Holloway, 1970). These dissociations provide strong justification for the assumption made by both changing state and primary linguistic coding hypotheses that the auditory and lipread suffix effects derive from a different mechanism from the graphic suffix effect. There is in contrast no evidence as yet that the graphic and pictorial ASL suffix effects have different origins. Such evidence is critical to the primary linguistic coding hypothesis, and to Shand & Klima's rejection of a changing state hypothesis on the basis of findings with Pictorial ASL stimuli. One way to test whether the pictorial ASL and auditory suffix effects have a common origin would be to compare the two suffix effects in a standard presentation condition and a through-list suffix presentation condition. The graphic suffix effect, although not the auditory suffix effect, is known to disappear when suffixes are presented throughout the list (Hitch, 1975). If, as Shand & Klima suggest, their pictorial ASL suffix effect has the same origin as the auditory suffix effect with a hearing population, it too should not be influenced by a through-list suffix procedure.

The two hypotheses are further distinguished when the predictions of each concerning the characteristics of short-term memory for auditory nonverbal stimuli are considered. The primary linguistic coding hypothesis can only accommodate the occurrence of enhanced recency and suffix effects with verbal stimuli - nonverbal information cannot represent a primary linguistic input to either hearing or a signing deaf population. In contrast according to a changing state hypothesis, any stimuli whose features are temporally sequenced at presentation will give rise to these phenomena, irrespective of their linguistic category. Indeed there is already some evidence to suggest that recency and suffix effects are not confined to verbal auditory stimuli. Suffix effects are not confined to verbal auditory stimuli. Suffix effects have been found with tones (Foreit, 1976; Leshowitz & Hanzi, 1974) and environmental sounds (Rowe & Rowe, 1976; Spoehr & Corin, 1978). However, further evidence is required to dissociate these suffix effects from the graphic suffix effect before they can be attributed to the same mechanism as the auditory and lipread suffix effects. An experiment designed to provide such evidence is clearly important, as the finding that the graphic and nonverbal auditory suffix effects are dissociable would provide a major challenge to the primary linguistic coding hypothesis.

A changing state hypothesis can also be tested more directly. It predicts that a procedure of temporally fragmenting graphic stimuli at presentation - by, for example, presenting one phoneme or syllable from a word at a time - will enhance recency in comparison with conventional graphic presentation. Furthermore this recency effect should be impaired by either an auditory, lipread or temporally fragmented graphic suffix, but not a conventional graphic suffix. Such an outcome would presumably run counter to the primary linguistic coding hypothesis, as it seems implausible to assume that a temporally fragmented graphic stimulus represents a primary linguistic input.

Finally, it should be acknowledged that it remains possible that neither of the hypotheses considered in this section are sufficiently complex to provide a complete account of the modality and suffix effects. It may for example be the case that the modality effect reflects not one but several mechanisms, one of which may even correspond to echoic memory. This must remain a possibility, particularly when the existence of a residual, although dramatically reduced, modality effect following lipread distraction in the backward recall experiment reported in Chapter 5 is considered. And the data presented in Chapter 4 are not sufficiently unambiguous to rule out the possibility that auditory and lipread recency have different origins. On the basis of the consistency of the correspondence between the influences of auditory and lipread material on short-term memory which has been established in the thesis, however, it is believed that single-mechanism interpretations of these phenomena are at least worthy of consideration.

6.4 Concluding Remarks

The experimental work reported in the thesis investigated several characteristics of the modality effect which are of current theoretical interest. The results suggest that the origin of the modality effect is a prelexical, persistent source of item information, which is entirely consistent with at least two echoic memory accounts of the effect, sensory recency theory and echoic persistence theory. However, the research also indicates that the modality effect is non-acoustic in nature, which runs counter to the central principle of any echoic memory theory. In conclusion, it appears that the wide-ranging experimental approach pursued in the thesis has, by establishing the need for non-echoic conceptualisations of the modality effect, provided further insight into the nature and characteristics of the phenomenon.

Footnote

Several of the experiments described in the thesis have been reported in different form in manuscripts co-authored by Dr John M. Gardiner, Dr Vernon H. Gregg and myself.

Experiments 1 and 2 are reported in a paper entitled "The modality effect and phonological similarity in serial recall - Does one's own voice play a role?" published in Memory & Cognition, (1982), 10 176-180 (Gathercole, S.E., Gardiner, J.M. & Gregg, V.H.).

A paper currently in press in the British Journal of Psychology, "The effects of delayed distraction on the modality effect in free recall" (Gathercole, S.E., Gregg, V.H. & Gardiner, J.M.), reports Experiments 5 and 6 of the thesis.

Finally, the two experiments described in Chapter 5 are reported in a manuscript entitled "On the selective influence of lipreading on auditory recency" which is in press in the Journal of Experimental Psychology : Human Learning and Memory (Gardiner, J.M., Gathercole, S.E. & Gregg, V.H.).

Reference Notes

1. Craik, F.I.M. Modality differences in short-term free recall. Paper presented to the annual meeting of the American Association for the Advancement of Science, Boston, December 1969.

2. Gardiner, J.M., Gathercole, S.E. & Gregg, V.H. Lipreading and auditory memory. Unpublished manuscript.

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Appendix 1

Materials used in Experiments 1 and 2

Plot	Hat	Pit	Wart
Shot	Chat	Wit	Sort
Hot	Rat	Kit	Port
Lot	Cat	Bit	Nought
Pot	Mat	Lit	Thought
Cot	Bat	Grit	Short
Rot	Fat	Sit	Taught
Dot	Pat	Nit	Fought
Boar	Foe	Bow	Sea
Roar	Glow	Cow	Fee
Moor	Mow	Vow	Bee
Core	Low	Sow	Pea
Door	Toe	Now	Tree
Poor	Woe	How	Key
Tore	Doe	Plough	Tea
Sore	Roe	Brow	Plea
May	Thick	Fear	Heat
Day	Wick	Deer	Feet
Grey	Sick	Beer	Meat
Pay	Pick	Tier	Beat
Ray	Brick	Rear	Pleat
Lay	Kick	Near	Seat
Say	Lick	Leer	Neat
Way	Flick	Hear	Peat
White	Rate	Jail	Flop
Kite	Bait	Tail	Mop
Fight	Weight	Dale	Pop
Height	Gate	Bale	Lop
Bite	Fate	Sail	Top
Light	Late	Rail	Cop
Site	Date	Male	Hop
Night	Mate	Pail	Bop

Bode	Cry	Map	Luck
Code	Sly	Tap	Buck
Goad	Tie	Rap	Duck
Load	High	Gap	Suck
Node	Sigh	Sap	Tuck
Road	Buy	Bap	Muck
Woad	Guy	Lap	Chuck
Toad	Try	Cap	Pluck
Hair	Save	Moan	Ball
Rare	Wave	Tone	Hall
Mare	Rave	Cone	Call
Fare	Cave	Stone	Tall
Pear	Grave	Loan	Wall
Care	Brave	Bone	Drawl
Dare	Pave	Throne	Maul
Bare	Slave	Phone	Fall
Dole	Kind	Bold	Rote
Bowl	Bind	Hold	Vote
Sole	Hind	Mould	Dote
Mole	Rind	Told	Moat
Role	Grind	Gold	Note
Pole	Find	Sold	Goat
Goal	Mind	Cold	Boat
Hole	Blind	Fold	Coat
Kill	Hog	But	Bored
Hill	Dog	Hut	Cord
Mill	Bog	Cut	Horde
Sill	Log	Nut	Ford
Till	Smog	Put	Lord
Fill	Cog	Rut	Roared
Pill	Fog	Tut	Poured
Bill	Slog	Shut	Goured

Appendix 2

Materials used in Experiments 5, 6, 8 and 9

Absence	Barrel	Cable	Climate	Cottage	Demand
Abuse	Basin	Cabin	Closet	Cotton	Design
Account	Battle	Campaign	Clothing	Council	Desire
Acid	Beauty	Canal	Cluster	Country	Detail
Acre	Beaver	Candle	Coffee	Couple	Device
Action	Bedroom	Cannon	Collar	Courage	Devil
Affair	Beggar	Canvas	College	Cousin	Diamond
Anchor	Belief	Captain	Colour	Cover	Diet
Angel	Berry	Captive	Column	Coward	Digest
Ankle	Bible	Carbon	Combine	Cradle	Dinner
Answer	Billet	Career	Comment	Creature	Disease
Appear	Bishop	Carpet	Commerce	Credit	Disgrace
Apple	Blanket	Castle	Compass	Critic	Disguise
Armour	Blessing	Cattle	Compound	Crystal	Disgust
Array	Body	Centre	Comrade	Custom	Dislike
Arrow	Bottom	Cellar	Conflict	Danger	Dismay
Aspect	Branch	Circle	Congress	Darkness	Distance
Assault	Bridge	Circuit	Consent	Darling	District
Attack	Brother	City	Content	Daughter	Doctor
Attempt	Bubble	Chairman	Contest	Dealer	Doctrine
Autumn	Bullet	Chamber	Contract	Debate	Dollar
Balance	Bureau	Channel	Control	Decay	Doorway
Banker	Bushel	Chapel	Convert	Decrease	Double
Bargain	Butcher	Chapter	Copy	Degree	Dragon
Basis	Butter	Cherry	Corner	Delight	Drama
Basket	Button	Chimney	Costume	Delay	Duty

Eagle	Feeling	Ground	Industry	Lawyer	Matter
Earth	Fellow	Habit	Infant	Layer	Mayor
Echo	Fever	Hammer	Insect	Leader	Meadow
Effort	Figure	Handle	Instinct	Leather	Meeting
Elbow	Final	Harbour	Insult	Legend	Member
Empire	Finger	Harness	Intent	Lemon	Menace
Enemy	Finish	Harvest	Interest	Letter	Merchant
Engine	Flavour	Hatred	Island	Level	Mercy
Error	Flower	Heaven	Issue	Licence	Merit
Escape	Football	Helmet	Item	Lily	Message
Estate	Folly	Herald	Jacket	Limit	Metal
Event	Forehead	Hero	Jersey	Linen	Method
Excess	Forest	Highway	Jewel	Lion	Middle
Exhaust	Formal	Hillside	Journal	Liquid	Million
Export	Fortune	Hollow	Journey	Liquor	Minute
Express	Fountain	Honey	Judgement	Lover	Mirror
Extent	Friend	Honour	Junior	Lumber	Mischief
Extra	Frontier	Horror	Justice	Luncheon	Mission
Fabric	Function	Hotel	Keeper	Lustre	Mistake
Factor	Funeral	Human	Kettle	Machine	Mistress
Failure	Fury	Hunter	Kindness	Maiden	Mixture
Family	Future	Husband	Kingdom	Maintain	Model
Farewell	Gallop	Ideal	Kitchen	Maker	Moisture
Farmer	Garden	Import	Kitten	Manner	Moment
Father	Garment	Impulse	Lady	Marble	Monarchy
Favour	Genius	Incline	Language	Market	Money
Feather	Gesture	Income	Latin	Marvel	Monkey
Feature	Goddess	Increase	Laughter	Master	Monster

Moral	Officer	People	Princess	Report	Season
Morning	Olive	Pepper	Prison	Reply	Section
Mortal	Onion	Perfume	Problem	Request	Senate
Mother	Opinion	Period	Product	Research	Sentence
Motion	Opera	Permit	Profit	Reserve	Series
Motive	Orange	Person	Programme	Resource	Servant
Motor	Orchard	Picture	Project	Result	Service
Movement	Order	Pigeon	Prospect	Retreat	Shelter
Murder	Organ	Pillow	Province	Return	Shepherd
Muscle	Outline	Pilot	Public	Revenge	Sheriff
Music	Owner	Pistol	Pupil	Reverse	Shipping
Nation	Oven	Planet	Purchase	Review	Shiver
Native	Oyster	Platform	Purpose	Reward	Shoulder
Nature	Package	Player	Puzzle	Ribbon	Shower
Navy	Palace	Pleasure	Quarrel	Riches	Sickness
Needle	Paper	Pocket	Quarter	Rider	Signal
Neglect	Parcel	Poem	Rabbit	Rifle	Silence
Negro	Parent	Poison	Railway	Robber	Silver
Neighbour	Parlour	Police	Reason	Robin	Singer
Nephew	Partner	Pony	Rebel	Rubber	Sister
Notion	Party	Potion	Receipt	Saddle	Slipper
Novel	Passage	Powder	Record	Safety	Slumber
Object	Passion	Power	Refuge	Sailor	Soldier
Ocean	Pasture	Prairie	Regard	Salad	Sorrow
Odour	Patent	Prayer	Relief	Sandwich	Spaniard
Offence	Pattern	Presence	Remark	Science	Sparrow
Offer	Payment	Present	Repair	Scholar	Speaker
Office	Penny	Pressure	Repeat	School	Spider

Spirit	System	Union	Woman
Squirrel	Table	Unit	Worker
Stable	Talent	Valley	Worship
Standard	Teacher	Value	Wrinkle
Standing	Temper	Vapour	
Stanza	Temple	Velvet	
Station	Theory	Vessel	
Status	Thousand	Victim	
Steamer	Thunder	Village	
Stocking	Ticket	Virtue	
Stomach	Tiger	Visit	
Storey	Timber	Voyage	
Struggle	Title	Wagon	
Student	Total	Water	
Success	Traffic	Weakness	
Sugar	Traitor	Weapon	
Sulphur	Transfer	Weather	
Summer	Treasure	Wedding	
Sunlight	Treaty	Welcome	
Sunset	Tribute	Welfare	
Sunshine	Trifle	Whisper	
Supper	Triumph	Whistle	
Supply	Trouble	Widow	
Support	Trousers	Willow	
Surface	Tumble	Window	
Surprise	Tunnel	Winter	
Survey	Turkey	Wisdom	
Suspect	Uncle	Witness	

Appendix 3 - Analyses of Variance

Table A1 : Experiment 1

Summary of Analysis of Variance on Preterminal (Positions 1 - 7) Serial Scored Data

Source	DF	SS	MS	F	P
Presentation Method (P)	1	3.06	3.06	.41	.529
Error	15	110.55	7.37		
Similarity (S)	1	38.31	38.31	8.92	.009
Error	15	64.44	4.30		
Serial Position (SP)	6	1747.56	81.26	81.15	.000
Error	90	323.01	3.59		
P X S	1	.38	.38	.11	.740
Error	15	49.37	3.29		
P x SP	6	111.99	18.67	10.90	.000
Error	90	154.15	1.71		
S x SP	6	17.80	2.97	1.96	.080
Error	90	136.20	1.51		
P x S x SP	6	45.48	7.58	4.02	.001
Error	90	169.52	1.88		

Table A2 : Experiment 1

Summary of Analysis of Variance on Preterminal (Positions 1 - 7) Free Scored Data

Source	DF	SS	MS	F	P
Presentation Method (P)	1	2.15	2.15	.38	.546
Error	15	84.18	5.61		
Similarity (S)	1	207.65	207.65	42.36	.000
Error	15	73.53	4.90		
Serial Position (SP)	6	814.00	135.67	33.88	.000
Error	9	360.36	4.00		
P x S	1	.06	.06	.02	.981
Error	15	42.84	2.86		
P x SP	6	86.37	14.40	6.07	.000
Error	90	213.56	2.37		
S x SP	6	45.53	7.57	4.16	.001
Error	90	163.64	1.82		
P x S x SP	6	22.15	3.69	1.61	.153
Error	90	206.21	2.29		

Table A3: Experiment 2

Summary of Analysis of Variance on Preterminal (Positions 1 - 7) Serial Scored Data

Source	DF	SS	MS	F	P
Presentation Method (P)	2	232.51	116.26	17.63	.000
Error	46	303.34	6.59		
Similarity (S)	1	21.44	21.44	4.02	.057
Error	23	122.59	5.33		
Serial Position (SP)	6	2046.02	341.00	27.47	.000
Error	138	1713.22	12.41		
P x S	2	3.22	1.61	.41	.667
Error	46	181.11	3.94		
P x SP	12	447.78	37.31	10.29	.000
Error	276	1000.70	3.63		
S x SP	6	38.69	6.45	3.03	.008
Error	138	293.78	2.13		
P x S x SP	12	40.12	3.34	1.98	.026
Error	276	466.54	1.69		

Table A4 : Experiment 2

Summary of Analysis of Variance on Preterminal (Positions 1 - 7) Serial Scored Data

Source	DF	SS	MS	F	P
Presentation Method (P)	2	70.93	35.47	9.01	.000
Error	46	180.97	3.93		
Similarity (S)	1	458.73	458.73	45.21	.000
Error	23	233.37	10.15		
Serial Position (SP)	6	587.17	97.86	8.00	.000
Error	138	1687.93	12.23		
P x S	2	14.30	7.15	4.32	.019
Error	46	76.18	1.66		
P x SP	12	550.12	45.84	11.21	.000
Error	276	1128.64	4.09		
S x SP	6	78.02	13.00	4.55	.000
Error	138	394.22	2.86		
P x S x SP	12	86.20	7.18	3.17	.000
Error	276	625.99	2.27		

Table A5 : Experiment 3

Summary of Analysis of Variance on Preterminal (Positions 1 - 5) Data

Source	DF	SS	MS	F	P
Materials (M)	1	731.50	731.50	47.29	.000
Error	22	340.29	15.47		
Presentation Mode (P)	1	30.10	30.10	10.84	.003
Error	22	61.09	2.78		
Serial Position (SP)	4	607.14	151.79	73.06	.000
Error	88	182.83	2.08		
M x P	1	.10	.10	.04	.848
Error	22	61.09	2.78		
M x SP	4	106.22	26.56	12.78	.000
Error	88	182.83	2.08		
P x SP	4	59.54	14.89	11.45	.000
Error	88	114.37	1.30		
M x P x SP	4	12.29	3.07	2.36	.059
Error	88	114.37	1.30		

Table A6' : Experiment 4

Summary of Analysis of Variance on Preterminal (Positions 1 - 5) Data for 6-Word Lists

Source	DF	SS	MS	F	p
Presentation Mode (P)	1	17.41	17.41	3.32	.084
Error	19	99.49	5.24		
Serial Position (SP)	4	134.19	33.75	24.56	.000
Error	76	104.42	1.37		
P x SP	4	10.72	2.68	2.42	.055
Error	76	83.88	1.10		

Table A7 : Experiment 4

Summary of Analysis of Variance on Preterminal (Positions 1 - 9) Date for 10-Word Lists

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	1.22	1.22	.27	.609
Error	19	86.27	4.54		
Serial Position (SP)	8	1226.79	153.35	45.95	.000
Error	152	507.32	3.34		
P x SP	8	69.20	8.65	4.11	.000
Error	152	319.80	2.10		

Table A8 : Experiment 5

Summary of Analysis of Variance on Recency (Positions 7 - 11) Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	173.07	173.07	38.04	.000
Error	23	104.63	4.55		
Distractor Condition (D)	2	34.61	17.30	8.59	.001
Error	46	92.66	2.01		
Serial Position (SP)	4	265.41	66.35	26.22	.000
Error	92	232.79	2.53		
P x D	2	5.52	2.76	1.10	.342
Error	46	115.48	2.51		
P x SP	4	150.58	37.64	15.52	.000
Error	92	232.22	2.43		
D x SP	8	25.78	3.22	1.65	.114
Error	184	359.62	1.95		
P x D x SP	8	3.15	.39	.26	.978
Error	184	277.85	1.51		

Table A9 : Experiment 5

Summary of Analysis of Variance on Prerecency (Positions 1 - 6) Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	1.76	1.76	.60	.446
Error	23	67.49	2.93		
Distractor Condition	2	9.93	4.97	1.72	.190
Error	46	132.68	2.88		
Serial Position (SP)	5	193.35	38.67	7.17	.000
Error	115	620.34	5.39		
P x D	2	.34	.17	.06	.945
Error	46	138.49	3.01		
P x SP	5	6.84	1.37	.86	.512
Error	115	183.41	1.59		
D x SP	10	9.61	.96	.59	.823
Error	230	376.11	1.64		
P x D x SP	10	13.03	1.30	.75	.679
Error	230	401.13	1.74		

Table A10′ : Experiment 6

Summary of Analysis of Variance on Recency (Positions 7 - 11) Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	52.67	52.67	15.15	.000
Error	23	79.98	3.48		
Distractor Mode (D)	1	127.10	127.10	59.72	.000
Error	23	48.95	2.13		
Serial Position (SP)	4	34.42	8.61	5.34	.001
Error	92	148.17	1.61		
P x D	1	32.55	32.55	20.29	.000
Error	23	36.90	1.60		
P x SP	4	33.59	8.40	4.57	.002
Error	92	169.00	1.84		
D x SP	4	2.57	.64	.42	.797
Error	92	142.62	1.55		
P x D x SP	4	19.04	4.76	2.64	.039
Error	92	165.76	1.80		

Table All : Experiment 6

Summary of Analysis of Variance on Prerecency (Positions 1 - 6) Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	17.02	17.02	4.76	.040
Error	23	82.28	3.58		
Distractor Mode (D)	1	4.52	4.52	2.61	.120
Error	23	39.78	1.73		
Serial Position (SP)	5	212.01	42.40	18.21	.000
Error	115	267.78	2.33		
P x D	1	2.13	2.13	.83	.371
Error	23	58.83	2.56		
P x SP	5	9.74	1.95	1.43	.219
Error	115	156.71	1.36		
D x SP	5	8.99	1.80	1.19	.320
Error	115	174.46	1.52		
P x D x SP	5	7.38	1.48	.81	.544
Error	115	209.41	1.82		

Table A12 : Experiment 5

Summary of Analysis of Variance on Mean Serial Position as a Function of Output Position Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	3.75	3.75	.37	.551
Error	23	234.92	10.21		
Distractor Condition (D)	2	5.06	2.53	1.40	.257
Error	46	83.06	1.81		
Output Position (OP)	3	2.67	.89	.15	.927
Error	69	399.66	5.79		
P x D	2	.03	.01	.00	.994
Error	46	107.23	2.33		
P x OP	3	1.02	.34	.16	.926
Error	69	151,14	2.19		
D x OP	6	3.14	.52	.56	.758
Error	138	128.08	.93		
P x D x OP	6	2.50	.42	.39	.886
Error	138	148.54	1.08		

Table A13 : Experiment 6

Summary of Analysis of Variance on Mean Serial Position as a Function of Output Position Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	.02	.02	.00	.950
Error	23	87.32	3.80		
Distractor Mode (D)	1	.00	.00	.00	.980
Error	23	74.37	3.23		
Output Position (OP)	4	10.35	2.59	.31	.872
Error	92	773.42	8.41		
P x D	1	3.53	3.53	2.28	.145
Error	23	35.62	1.55		
P x OP	4	1.08	.27	.26	.900
Error	92	93.69	1.02		
D x OP	4	.70	.18	.10	.984
Error	92	168.63	1.83		
P x D x OP	4	3.57	.89	.84	.503
Error	92	97.65	1.06		

Table A14 : Experiment 5

Summary of Analysis of Variance on Mean Output Position as a Function of Serial Position Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	17.63	17.63	8.86	.007
Error	23	45.79	1.99		
Distractor Condition (D)	2	16.18	8.09	5.70	.006
Error	46	65.33	1.42		
Serial Position (SP)	10	57.60	5.76	1.27	.250
Error	230	1045.18	4.54		
P x D	2	3.59	1.80	1.02	.370
Error	46	81.36	1.77		
P x SP	10	8.88	.89	.44	.923
Error	230	459.95	2.00		
D x SP	20	26.48	1.32	1.16	.283
Error	460	523.82	1.14		
P x D x SP	20	11.45	.57	.45	.982
Error	460	583.40	1.27		

Table A15 : Experiment 6

Summary of Analysis of Variance on Mean Output Position as a Function of Serial Position Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	1.15	1.15	.69	.414
Error	23	38.25	1.66		
Distractor Mode (D)	1	1.79	1.79	1.19	.287
Error	23	34.59	1.50		
Serial Position (SP)	10	35.50	3.55	.47	.909
Error	230	1739.57	7.56		
P x D	1	2.91	2.91	2.28	.145
Error	23	29.36	1.28		
P x SP	10	8.47	.85	.80	.624
Error	230	242.05	1.05		
D x SP	10	9.04	.90	.72	.705
Error	230	288.85	1.26		
P x D x SP	10	26.01	2.60	3.17	.001
Error	230	188.77	.82		

Table A16 : Experiment 7

Summary of Analysis of Variance on Terminal (Position 8) Data from Lipread Lists

Source	DF	SS	MS	F	P
Suffix Condition	2	116.06	58.08	21.17	.000
Error	62	169.94	2.74		

Table A17 : Experiment 7

Summary of Analysis of Variance on Terminal (Position 8) Data from Auditory Lists

Source	DF	SS	MS	F	P
Suffix Condition	2	179.08	89.54	46.95	.000
Error	62	118.25	1.90		

Table A18 : Experiment 7

Summary of Analysis of Variance on Preterminal (Positions 1 - 7) and Terminal (Position 8) Data

Source	DF	SS	MS	F	P
Presentation Method (P)	1	117.35	117.35	50.72	.000
Error	31	71.73	2.31		
Suffix Condition (S)	2	272.36	136.18	50.71	.000
Error	62	166.49	2.69		
List Position (LP)	1	48.66	48.66	15.52	.000
Error	31	97.20	3.14		
P x S	2	13.31	6.65	5.23	.008
Error	62	78.87	1.27		
P x LP	1	1.23	1.23	1.02	.320
Error	31	37.21	1.20		
S x LP	2	50.41	25.20	14.85	.000
Error	62	105.24	1.70		
P x S x LP	2	15.17	7.59	8.09	.001
Error	62	58.14	.94		

Table A19 : Experiment 7

Summary of Analysis of Variance on Recency Data (Terminal - Preterminal Scores) from Lipread Lists

Source	DF	SS	MS	F	P
Suffix Condition	2	53.11	26.55	8.27	.000
Error	62	199.00	3.21		

Table A20 : Experiment 7

Summary of Analysis of Variance on Recency Data (Terminal - Preterminal Scores) from Auditory Lists

Source	DF	SS	MS	F	P
Suffix Condition	2	67.57	34.78	18.47	.000
Error	62	116.79	1.88		

Table A21 : Experiment 8

Summary of Analysis of Variance on Prerecency (Positions 1 - 6) and Recency (Positions 7 - 11) Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	.39	.39	.30	.590
Error	23	29.68	1.29		
Distractor Condition (D)	1	9.57	9.57	20.21	.000
Error	23	10.89	.47		
List Position (LP)	1	.51	.51	.41	.527
Error	23	28.52	1.24		
P x D	1	6.67	6.67	22.49	.000
Error	23	6.82	.30		
P x LP	1	11.71	11.71	12.75	.002
Error	23	21.13	.92		
D x LP	1	7.34	7.34	9.43	.005
Error	23	17.90	.78		
P x D x LP	1	6.68	6.68	11.72	.002
Error	23	13.12	.57		

Table A22 : Experiment 8

Summary of Analysis of Variance on Mean Serial Position as a Function of Output Position Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	22.41	22.41	9.18	.006
Error	23	56.17	2.44		
Distractor Condition (D)	1	23.19	23.19	8.97	.006
Error	23	59.46	2.59		
Output Position (OP)	4	19.40	4.85	1.29	.279
Error	92	345.48	3.76		
P x D	1	21.88	21.88	13.36	.001
Error	23	37.67	1.64		
P x OP	4	32.38	8.10	4.03	.005
Error	92	184.77	2.01		
D x OP	4	12.41	3.10	1.93	.112
Error	92	147.98	1.61		
P x D x OP	4	3.37	.84	.48	.749
Error	92	160.95	1.75		

Table A23 : Experiment 8

Summary of Analysis of Variance on Mean Output Position as a Function of Serial Position Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	2.82	2.82	.50	.487
Error	23	130.28	5.67		
Distractor Condition (D)	1	10.40	10.39	6.01	.022
Error	23	39.76	1.73		
Serial Position (SP)	10	111.52	11.15	3.44	.000
Error	230	745.14	3.24		
P x D	1	6.74	8.74	7.74	.011
Error	23	25.96	1.13		
P x SP	10	24.61	2.46	1.56	.119
Error	230	362.28	1.58		
D x SP	10	18.32	1.83	1.25	.262
Error	230	337.75	1.47		
P x D x SP	10	17.48	1.75	1.23	.273
Error	230	327.25	1.42		

Table A24 : Experiment 9

Summary of Analysis of Variance on Prerency (Positions 1 - 6) and Recency (Positions 7 - 11) Data

Source	DF	SS	MS	F	P
Presentation Mode (P)	1	4.89	4.89	6.57	.017
Error	23	17.14	.75		
Distractor Condition (D)	1	18.12	18.12	58.85	.000
Error	23	7.08	.31		
List Position (LP)	1	23.75	23.75	9.14	.006
Error	23	59.77	2.60		
P x D	1	3.32	3.32	5.94	.023
Error	23	12.85	.56		
P x LP	1	11.78	11.78	48.96	.000
Error	23	5.53	.24		
D x LP	1	6.46	6.46	18.24	.000
Error	23	8.14	.35		
P x D x LP	1	2.56	2.56	7.46	.012
Error	23	7.87	.34		