LATERALITY DIFFERENCES IN MEMORY AND ATTENTION

THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

by

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Summary of Thesis submitted for the Degree of Doctor of Philosophy

A critical review of the auditory selective attention literature is presented, particular reference is made to methodological issues arising from the asymmetrical hemispheric representation of language in the context of the dominant research technique;dichotic shadowing. Subsequently the conceptof cerebral localization is introduced, and the experimental literature with reference to models of laterality effects in speech and audition discussed. The review indicated the importance of hemispheric asymmetries insofar as they might influence the results of dichotic shadowing tasks. It is suggested that there is a potential overlap between models of selective attention and hemispheric differences.

In Experiment I, a key experiment in auditory selective attention is replicated andby exercising control over possible laterality effects some of the conflicting results of earlier studies were reconciled. The three subsequent experiments, II, III and IV, are concerned with the recall of verbally shadowed inputs. A highly significant and consistent effect of ear of arrival upon the serial position of items recalled is reported.

Experiment V is directed towards an analysis of the effect that the processing of unattended inputs has upon the serial position of attended items that are recalled. A significant effect of the type of unattended material upon the recall of attended items was found to be influenced by the ear of arrival of inputs. In Experiment VI, differences between the two ears as attended and unattended input channels were clarified.

Two main conclusions were drawn from this work. First, that the dichotic shadowing technique cannot control attention. Instead the task of processing both channels of dichotic inputs is unevenly shared between the hemispheres as a function of the ear shadowed. Consequently, evidence for the processing of unattended information is considered in terms of constraints imposed by asymmetries in the functional organization of language, not in terms of a limited processing capacity model. The second conclusion to be drawn is that laterality differences can be effectively examined using the dichotic shadowing technique, a new model of laterality differences is proposed and discussed.

KEY WORDS: SELECTIVE ATTENTION, LATERALITY, DICHOTIC LISTENING.

KEVIN MICHAEL HOGAN, 1981.

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1.0. Introduction

This review is an attempt to cover the most pertinent of the abundance of literature concerned with the nature of selective attention. However the material presented here is representative and not exhaustive, even so, it is hoped that the research can be drawn together and some conclusions reached. In the present case one central question can be the starting point for the discussion: why is it that after the expenditure of so much time and effort, the value of our knowledge of selective attention is so little? For there can be no doubt that controversy, confusion, and equivocal experiments are frequently qualities of attention research.

There has been a vast addition to our knowledge of human behaviour with respect to attention during the last thirty years. Unfortunately the lack of theoretical cohesion seems to suggest that the information that has accumulated will remain unstructured and unused. Furthermore, the currents of research in attention betray the proliferation of topics that characterises the disharmony of cognitive psychology as a whole. It may well be that research will progress, and leave the problems raised in this discussion unresolved. However, such progress in attention theory would be at best transitory. More concerned with data collection, than theory testing if some of the contradictions already extent within the corpus of knowledge are not resolved.

The present work whilst it is not intended to achieve the aims set by an earlier student of attention, is carried out in full recognition of the fact that the conditions referred to over seventy years ago are still with us:

> In the present chaotic condition of attention theories an attempt, however modest, to harmonise the known facts with one another needs no apology.
>
> (Pillsbury, 1908, p.1)

1.1. Background to the Development of Selective Attention Research

After the Second World War, the psychological study of attentional phenomena increased considerably, in contrast to the sporadic interest of the previous thirty years. Of the several factors which led to this revival, one was the decline of the great 'schools' of psychology. Such schools as those led by Hull and Koffka were in rapid decline during the post-war years, when many psychologists were led towards a more eclectic approach in response to the variety of applied problems they faced. Attention research had waned because Behaviourists and those who had adopted Gestalt principles found no room for such a phenomenon. A further reason for the renewal of interest in attention arose from the great advances in neurophysiology during and after the Second World War. In particular, the discovery of the functional significance of the ascending reticular activating system, or A.R.A.S. (Magoun, 1954).

However, the most important factor in increasing interest in the concept of attention, at least in British Psychology, was the impact of the war time studies of man-machine interaction. Research which led to the realisation that the weak link in man-machine systems, the human operator, was capable of analysing only a limited amount of information at a time, (Hick, 1952). K.J.W. Craik was at the forefront of the experimental investigation of the manner in which the human operator allocates his resources among the multitude of information inputs, and developed a model of the human operator reacting as a single channel through which one signal from the environment had to be cleared, before another could be dealt with. A related factor in the development of this information processing view of man, was the theory of selective information produced by Shannon and Weaver (1949). It appeared at one time as though this would provide a universal metric for specifying the amount of information in stimulus displays. Although this use of the theory has largely been abandoned, the information theory approach was extremely influential in the 1940s and 1950s.

Work derived from the concept of man as a single channel for information transmission reflected a broad division of interests. On the one hand lay experiments concerned with analysing the effects of simultaneous stimuli when the subject is called upon to respond to both. This type of methodology was used to measure the time involved in the central control of behaviour, using tasks such as tracking (Craik, 1948, 1949; Welford, 1952). The other line of research was directed to the study of the human operator's ability to extract one signal, usually speech, from noise or a competing message (Broadbent, 1952a, b. 1953).

1.2. Broadbent's Theory of Selective Attention

Initially, research was focussed upon those physical characteristics of an input channel that facilitated selection between competing inputs. Broadbent (1952c) had found that using two voices for the different channels facilitated selection between them, also the angle of separation between inputs, whether perceived or actual (Poulton, 1953) facilitated the selection of an input. Other physical characteristics shared by the stimuli forming the attended input, for example frequency spectra, have been shown to enhance selection (Egan, Carterette and Thuring, 1954; Spieth, Curtis and Webster, 1954). Spieth, Curtis and Webster (1954) had also shown that the selected channel was more likely to be perceived correctly if there was a slight difference in onset time between the two messages. Cherry (1953) showed that using the two ears as input channels made it very easy to repeat one ear and ignore the other.

There were two main techniques developed at about this time in order to further research upon selective attention. The first of these was the 'question and answer' method developed by Broadbent, and the second was based upon some form of shadowing, where the subject was required to repeat or write down stimuli as they occurred. The last method came to prominence as an experimental technique in the form used by Cherry and Taylor (1954), who required subjects to shadow by repeating aloud one channel of a dichotic list of inputs.

These techniques very quickly gave rise to results that could not be explained as peripheral masking effects, that is from the obscuration of one input by the presence and physical chracteristics of another. Consequently, the subjects' failure to selectively attend to one of a competing set of stimuli, was attributed to the excessive demands made upon a single channel system of limited capacity, and therefore viewed as the effect of central cognitive organisation. Examples of studies leading to the central limitations model of attention were those of Broadbent (1952b, c) and Poulton (1953a).

The studies conducted by Broadbent examined the source of a subject's difficulties in replying to simultaneously presented questions. Poulton (1953a) demonstrated that messages preceded or succeeded by irrelevant messages were likely to be missed. Both studies reflected the importance of factors other than the physical masking of one imput by another, which can determine a subject's success in selective attending.

Broadbent concluded from his studies that the failure to attend arose from the use of two separate inputs, i.e. left and right ears, rather than the use of interleaved or overlapping messages. In essence it was the restriction of processing capacity to a serial mode rather than any masking by competing inputs, that constrained performance.

Another study which reflected upon the importance of purely physical cues in selecting attending, was that of Cherry (1953). In his study the ear of arrival of the messages in a modified dichotic shadowing task was effectively removed as a cue by which a subject might separate inputs. Previously the importance of this characteristic in terms of attentional selectivity had been proved by Broadbent (1952c).

The cue of ear of arrival was negated by presenting both the to-be-shadowed and unshadowed messages to each ear.

The shadowed message consisted of continuous prose, but the control message was made up of discontinuous highly redundant sequences. By this method Cherry demonstrated that the subject could employ conditional probabilities within a message as a cue for selectively attending, as was demonstrated by the accurate shadowing of the continuous prose sequences. This experiment revealed the importance of the informational content of a message in influencing the attention paid to it.

Early work by experimenters such as Broadbent, 1954; Cherry, 1953; Poulton, 1953a, suggested that there was a limit to the amount of information which could be taken up at any one time, and that by exceeding this limit experimenters could bring about the breakdown of selective attention. An attempt to elaborate the model of limitation caused by restrictions upon the rate of transmission of information was made by Webster and Thompson (1953, 1954).

Employing the concept of 'bits' of information, they measured the rate of transmission of information and reported a ceiling effect when two messages of high information content were presented simultaneously (Webster and Thompson, 1953). However, when the messages were of low information content, the rate of transmission of information could be increased. A subsequent replication of this effect was reported by Poulton (1956) who employed secondary messages that were either relevant to the content of the primary message, i.e. contained further information, or irrelevant in that they had no bearing whatsoever upon the primary message. There was a decrease in the efficiency of shadowing during the presentation of simultaneous relevant messages which did not occur during the presentation of irrelevant secondary messages.

1.2.1. The Selective Filter

The experimental techniques which had established the value of a single channel model were next applied to a study of the mechanism whereby items were allowed into or denied entry into the channel. This mechanism was described as a 'filter' and the most significant work which explored this concept was that of Broadbent who made extensive use of the split span technique. Subsequently Broadbent was to draw upon the findings of Cherry's (1954) series of experiments, in his analysis of the time taken by the filter to operate in switching between inputs that are allowed access to the single channel.

Broadbent's first experiment using the split-span technique (Broadbent, 1954b) included three conditions, the experimental material was three dichotic pairs of words; condition one free recall, condition two demanded recall in alternating order, that is recall by simultaneous pairs and a control group consisting of eight pairs of words, in which subjects were required to remember the first half of the list from one ear and the second half from the other, order of ear of recall was randomised.

The results of the study are "amongst the most readily reproducible in the whole of psychology" (Moray, 1969a, p.129). When recall is by dichotic pair, i.e. 32-51-67 rather than by ear of arrival 356-216, then it is much reduced. Subjects recalled dichotic pairs accurately, on only 20% of trials. The ear by ear recall strategy gave rise to almost errorless trials. This pattern of results was obtained only for presentation rates in excess of one pair of digits every one and a half seconds.

Broadbent concluded from these results that a filter was operating to separate the two inputs, a filter that could not be 'switched' between inputs due to the rate of presentation of the digits. There are two separate lines of argument that have descended from this initial research: 1) the notion that this methodology is applicable to the problem of measuring switching time and 2) that it provides experimental support for the model of a single channel processor limiting human performance. Logically, the problem of timing the operation of a mechanism subsumes acknowledgement of its existence, therefore we shall first consider the support that 'split-span' studies add to the argument for single channel behaviour which includes the operation of a filter.

The primary piece of evidence in support of the filter postulate is that subjects failed to report dichotic lists by pairs, i.e. in the experimenter defined 'correct order', during the free recall task. Furthermore, when subjects were explicitly required to recall items in this fashion, recall was far less efficient than if they were not required to 'switch' each time so as to acquire each item of a dichotic pair, that is in reporting lists by ear of arrival of inputs rather than order of arrival by pairs.

However as Moray (1960b) has pointed out, there is no 'correct' order of report for simultaneously presented stimuli. Moreover when the opportunity is given for a subject to make two simultaneous responses to dichotic stimuli, efficiency is improved (Moray and Jordan, 1966). This would suggest that the serial behaviour noted in split-span studies is a function of the serial nature of the output device employed, namely speech.

It is also useful to note that the relatively undifferentiated stimuli employed in Broadbent's study, digit sequences, provide few cues for recall. Essentially there are but two cues available: ear of arrival and serial position. Recall by ear of arrival can utilise both these cues and thereby promotes effective recall. Stimulus 'tagging' in terms of such cues is known to be an effective subject strategy in recall tasks (Atkinson and Shiffrin, 1968).

Another factor for which this experiment does not control is the possibility that cerebral dominance may affect spontaneous recall strategies. Subsequent research has revealed that dichotic listening is a technique which exhibits the influence of the lateralisation of function (Kimura, 1961). More specifically, Bryden (1963) has shown that subjects spontaneously adopt a strategy of reporting ear by ear, reporting first the right ear and then the left. Although both conditions one and two of the original study would have yielded data that could have helped meet these criticisms, such data were not reported.

In addition to the arguments that must qualify any notions of a filter as derived from Broadbent's (1954) work, the initial study itself contains evidence which on analysis present considerable difficulties for a filter hypothesis. Firstly, 20% of all lists recalled using the alternating ear strategy were correct. This result must reflect more upon the speed of action of the filter rather more than the problem of whether or not it exists. However, if we are to presume that it does exist, then 20% correct represents a significant number of failures with respect to an all or nothing system, which is how the filter mechanism was postulated to act.

The second issue arises from the data of the control condition, which evidence would appear to be the most inconvenient for the notion of a filter. Subjects called upon to recall the first 4 digits from one ear and the second four from the other ear, reported only 5% of digits correctly. In exhibiting such a low level of performance this control condition would not appear to support the notion of a filter. In only operating once, the all or nothing switching of inputs reduced performance below the level achieved with many more switches in condition one.

This finding reflects upon the notion of an additive timing of switching requirements, that is the idea of discrete and cumulative sequences devoted to switching between inputs. Because more switching would reasonably indicate more time lost and therefore less efficient recall.

It must be argued that what the control condition does show, in common with a wealth of subsequent research, is that performance in a dichotic listening task is dependent upon practice (Moray and Jordan, 1966; Underwood and Moray, 1974). In effect, Broadbent's relatively unpractised subjects were incapable of filtering out the secondary channel. When faced with the task of selecting one channel from another, they failed outright. It is in fact a very difficult task, and one by which unpractised subjects are entirely defeated.

This control condition reveals that subjects could not afford to actively select between inputs, instead they were forced to develop a mnemonic in order to store all the inputs. The six digits were entirely within their span and so a high rate of success was achieved in the first two conditions. The control group, however, required the storage of sixteen digits in all, two sequences of eight, and their separation. Notwithstanding the near impossibility of such selection, the score expressed as per cent correct, fails to control for the size of the memory load imposed in the control relative to the other two conditions. Therefore they exhibited a very low overall level of performance, which directly reflects their failure to select between inputs.

1.2.2. Switching between Inputs

Although the foregoing analysis would seem to remove the necessity for timing the action of the filter, more detailed consideration of this problem is required, largely because of the undeniable effect that Broadbent's (1958) analysis of this whole topic had upon subsequent work in the field of selective attention. Broadbent (1954c) showed that when the rate of presentation was decreased from one pair per second to one pair every two seconds, then efficiency rose from 20% to 50% of sequences correctly reported. Broadbent concluded from these data:

> that when attention is shifted away from one channel to another and then back to the first a time interval of between one and two seconds is required.
>
> (Broadbent, 1958, p.195)

The assumption of switching behaviour has been questioned and the timing of such a mechanism cannot be divorced from this primary supposition.

Initial doubt over the validity of this timing of the mechanism must derive from considering the fact that for at least 20% of all lists, switching can be seen to occur at a rate faster than that proposed by this analysis. There is however a second source of evidence that does afford some support for this conclusion. Cherry and Taylor (1954) showed that when a spoken message was switched between ears at increasing rates, shadowing declined and finally disappeared at a rate of three cps. Broadbent (1958, p.214) concluded from this that two shifts would take one third of a second. However, a control experiment undertaken by Cherry and Taylor (1954) revealed that this effect of switching between channels was affected by the rate of presentation of the material to be shadowed. Thus they did not measure the time taken to switch from one channel to another. Instead, they outlined the interaction that occurs between the rate of switching and the rate of presentation of material in determining the efficiency of shadowing.

It must be pointed out that Broadbent himself expressed some doubt about the validity of Cherry and Taylor's (1954) results being used to corroborate his own findings. However, he invited favourable comparison between the two times for the whole cycle of switching, his own figure of 1.5 to 2.0 seconds and that of Cherry and Taylor (1954), 1.0 to 1.3 seconds. Excusing his own slightly longer figure in the following manner:

> Remembering that naval ratings are probably slower than most laboratory subjects.
>
> (Broadbent, 1958, p.214)

The validity of this chain of reasoning is based upon further supposition, that subsequently proved to be entirely false. Broadbent went on to argue:

> Two shifts would then take 0.33 of a second, and if perception of a digit takes half a second this would give 1.0/1.33 seconds for the whole cycle of shifting between ears.
>
> (Broadbent, 1958, p.214)

Moray (1960a) has shown that digits can be recognised on the presentation of rather less than 50 m secs of their waveform. Yntema, Wozencraft and Elem (1964) report successful recognition at rates in excess of 10 digits per second. These findings are sufficient, without considering the vagueness of this usage of the term 'perception', to call for a total rejection of the analysis proposed by Broadbent (1958).

The evidence points to a clear inability to filter secondary material when it is drawn from the same class of stimuli, i.e. digits. However, both notions, that of the single channel and the filter, remained an ubiquitous feature of theorising with respect to selective attention for the next two decades.

1.2.3. The Concept of the Single Channel

It is important to place the concept of the single channel model of attentional performance in perspective. Broadbent (1958) had reviewed almost all of the research that had occurred subsequent to the introduction of the concepts of 'Information' and Cybernetics. The notion of the single channel had sprung from this theoretical source, the research undertaken by Broadbent and others had largely confirmed it as a description of psychological reality. The single channel model represented the empirical validity of a conceptual framework that was to dominate psychology in the two decades after the Second World War.

It is clear now that the early research on single channel models was most strikingly constrained to produce such behaviour. The conclusion that a model could represent psychological reality in the form of mechanism alone must be considered inappropriate. It should become obvious however that this was the long term consequence of the studies already reviewed. The attractions of this theoretical viewpoint may not have had such long-term effects, if it had been more widely understood how little of this early work justified or required the use of a single channel and selective filter mechanisms as explanatory concepts.

1.3.0. Early Criticisms of Filter Theory

Almost as soon as the complete formulation of a single channel of limited capacity prefaced by filter that could be 'switched' between inputs had been proposed, doubts began to arise. Broadbent (1958) concluded from the outcome of some of his own studies (Broadbent, 1957b) that parallel information processing was a possibility within the system he proposed. Firstly, he argued that information presented dichotically could enter the 'P' and 'S' systems simultaneously. Secondly, he acknowledged that the 'P' system could itself (given sufficient practise) act as a parallel processor. Broadbent went on to argue that in some respects the filter model ought to be considered as a special case largely due to the circumstances of dichotic listening studies.

However, the explanatory power of the filtering concept and the single channel model was such that their employment was continued and expanded. Indeed it could well be argued that the value of this conceptualisation as a source of research questions was instrumental in its persistent usage despite considerable theoretical problems.

1.3.1. Early Shadowing Experiments

One major source of empirical support for the continuous application of the single channel model was the work of Cherry (1953, 1954). This research was carried out in the fullest appreciation of information theory and the cybernetic modelling of human behaviour. Cherry (1953) reported how little the subject could remember of the unattended channel, when asked to verbally shadow the attended channel. The finding became one of the most widely reported in the whole of attention:

> The subject remained almost completely unaware of the content of, though not of the presence of another message.
>
> (Treisman, 1960, p.242)

This study deserves the fullest attention because it was the first important study to employ a technique which became paradigmatic in the experimental analysis of attention. Dichotic shadowing, repeating one channel aloud whilst ignoring the second, offered an apparently ideal method for controlling attention. It was this technique more than any other, that initially provided evidence of the limited and serial nature of human information processing.

The first goal for any critical appraisal of this work must be to supply alternative explanations for the results obtained in shadowing experiments. Unfortunately such a programme is hampered by the logical quality of the single channel model. It is insufficiently specific in many respects, so much so that a fine grain analysis of the results generated by the shadowing paradigm reveals more insufficiencies of the model than falsifiable aspects. However, the ultimate value of the model lies in its power as a descriptive mnemonic. It is therefore at the level of its descriptive capacity that the following critique is directed. After so much time and research, criticisms of the model on solely theoretical grounds would be wasteful.

The initial study undetaken by Cherry (1953) showed that whereas subjects were aware of a change in sex of the speaker, or the occurrence of a 400 cps pure tone, they could remember none of the words or phrases employed as the secondary channel, nor even their language of presentation. The subjects were instructed to repeat one ear and ignore the other; they were subsequently tested for their recall of unattended channel input. Due to the essential contradiction inherent in this type of design, namely the requirement for a subject to recall that which he has been instructed to ignore, Cherry considered that the procedure could be followed only once for each subject.

The implications of employing completely naive subjects on one trial with no prior training, are such that the value of this experiment as support for a single channel model is highly questionable. Underwood and Moray (1974) have shown that with experience of dichotic shadowing a subject exhibits a decrease in selectivity with an increase in the detection of unshadowed targets. Typically experimenters had had to employ some pre-test practice in order for the subject to be capable of shadowing, and more recently criterion measures of shadowing performance have been applied before subjects are tested (Triesman, Squire and Green, 1974).

It is fair to say that the experiment which had so much influence upon the subsequent development of attention theory, produced evidence in support of a single channel model more as a function of its design than any other factor. In essence, naive subjects faced with dichotic stimuli exhibit the behaviour indicative of the serial processing of one channel and the rejection of a second simply because of their naivety, not because of any underlying psychological mechanism of lasting explanatory or descriptive validity.

A further criticism of Cherry's (1953) study which is certainly relevant but more valid with reference to recent studies, is the fact that no control was exercised over possible effects of the ear of arrival of dichotic inputs.

> After a subject was comfortably repeating his right ear message, the left was changed to German.
>
> (Cherry, 1953, p.978)

It is now known that only the most sophisticated techniques will allow the left ear-right hemisphere to display any useful level of linguistic competence (Zaidel, 1976). Thus the finding that subjects could not recognise a change in the language of secondary inputs is placed in perspective, despite qualifications regarding the consequences of inexperience, the inefficiency of the left-ear right-hemisphere in processing verbal information would alone suggest a failure in this respect.

The lack of control for ear of arrival characterised all phases of the research:

> Subjects were presented at their right hand ears with spoken messages from newspapers, ... and again instructed to repeat these passages without omission or error. Into their left ears were fed signals of different kinds for different tests.
>
> (Cherry, 1953, p.978)

It is of course now known that the two ears vary in their efficiency of recall, (Kimura, 1961), and when functioning as the unattended channel (Treisman and Geffen, 1967).

A third source of the effect reported by Cherry (1953) undermines the importance of filtering even as a description of this effect. The use of recall as a measure of the level of attention afforded unattended material could well have restricted the generalisability of these findings. Details of the recall procedure make it clear that a large amount of forgetting could have taken place. Targets were embedded in between two sequences of English prose, so that recall was both delayed and exposed to interference effects from subsequent material. This "sandwiching" was undertaken as a precaution so that the subject would already be shadowing adequately when test items were received. Norman (1969) has demonstrated a very rapid rate of decay for 'unattended' information, a phenomenon which clearly contributed to Cherry's finding that a subject had no recall of unattended inputs.

The study reported by Cherry (1953) was important in influencing many subsequent researchers, who typically modified certain aspects of the model of selectivity rather than reject it. This situation arose because the finding of a complete failure to report unattended items, was easy to replicate. The reason for this replicability lay in the technique rather than the validity of the theoretical constructs. An early replication of Cherry's work neatly illustrates this last point, and reflects the continued lack of control over the ear of arrival of dichotic inputs.

1.3.2.

Moray (1959) presented a message upon the rejected channel as many as 35 times without it giving rise to subsequent recognition. The unattended message consisted of isolated words, whereas the attended message was presented in a far more integrated fashion. There were no contextual cues to aid the recall of the unattended message. Nor should the high level of redundancy of the unattended material be viewed as helping recall, this mode of presentation would make the secondary message far less likely to break through and attract attention (Treisman, 1960).

The important procedural detail in this study is the time interval between the presentation of the unattended material and its subsequent recognition. Firstly, the secondary message was faded out before the end of the primary message, and a further 30 second delay was imposed before recognition was tested.

The consequences of these delays were examined by Norman (1969), who showed that no memory for unattended materials remains twenty seconds after the end of presentation. Therefore we would not expect any demonstration of recognition for unattended material in this condition. Of perhaps less importance, but essential in order to develop some perspective on this research, is the fact that Moray employed the left ear as his unattended channel. Of great interest is the fact that Norman (1969) reversed this situation in the first demonstration of memory for unattended material.

The second feature of this study, Moray (1959), is the finding that an individual's own name could break through the barrier and be remembered. Although this finding has had strong support from other studies (Oswald, Taylor and Treisman, 1960; Howarth and Ellis, 1961), it is important to examine it closely with respect to the shadowing paradigm, if only because the study had such an impact upon theories developed from this technique (Treisman, 1960, 1964; Deutsch and Deutsch, 1963).

The first point to be made is that in this study (Moray, 1959) the subject's name did not 'almost always break through' as has been reported. Furthermore, when it was apparent that the subject had heard his own name, this effect could equally well be attributed to the function of memory as to an elaborate filter mechanism. The experiment compared the subject's recall of instructions to switch ears or stop shadowing, which were presented as part of the unattended message. The intrusion of these instructions only caused one subject to obey them, and this subject's results were therefore discarded.

Subjects recalled instructions prefaced by their own name and presented to the unattended channel on one third of all presentations. However, recall improved to four-fifths of all presentations, when subjects were made aware at the start of the shadowing task that such instructions were to be expected. Thus, although the subject's name was 'breaking through', a more powerful effect was the conjunction of the subject's name with a prior presentation of an explanatory phrase. In other words, the frequency with which a subject's name breaks through the barrier is greatly increased by an experimental condition which invites the subject to sample the unattended message.

The problem with this result is that in subsequent models much effort was expended to incorporate the phenomenon of relevant, or emotionally charged words breaking through the 'attentional block' (Moray, 1959). However, it is clear from a close analysis of the data that when sampling of the unattended message was encouraged then the highest level of breakthroughs occurred. Thus, an explanation was required, not of the mechanism of breakthrough but the process by which such large changes in sensitivity were achieved without obviously impairing performance on the primary task: shadowing. Such was not however the orientation of subsequent workers who noted the phenomena of a subject's own name breaking through the attentional blocks, and attributed great importance to the fact (Treisman, 1964).

There is further evidence contained in Moray's (1959) study which can be interpreted in terms of items breaking through an attentional barrier. Because of the importance of the work by Moray, this evidence must be studied in some detail. Subjects remembered instructions which included their own names five times more frequently than they remembered instructions that did not contain their own name.

This result is open to a number of interpretations; it could have been the case that instructions once heard were more readily recalled because they were associated with the subject's own name. Indirect support for this contention comes from Moray's own observation that:

> Most of the subjects ignored even the instructions that were presented in the passages that they were shadowing, and said that they thought that this was just an attempt by the experimenter to distract them.
>
> (Moray, 1959, p.58)

Obviously the subjects were not under the impression that they had to remember instructions embedded in the message. Only one subject, as we have noted, actually obeyed the instructions. Therefore it would seem reasonable to assume that instructions including the subject's own name were recalled because that fact alone rendered the instructions more memorable. Indeed, they must certainly have provoked more consideration in that instructions presaged by a subject's own name, would appear to be more authoritative than those without. Thus, they would be more liable to be recalled than instructions not containing the subject's name, even if both types of instructions were heard by the subject.

The final experiment reported in Moray's (1959) paper,was a control experiment whereby Moray sought to measure the effect of 'neutral' stimuli in breaking through the 'barrier' of selective attention. Subjects were required to shadow dichotic messages which had had target items, digits, inserted towards the end of the message on both channels. One group were required to recall any targets that occurred in the shadowed message, and a second group were required to report all the targets they could. Moray concluded that as the two groups displayed no difference in their overall level of recall, then unattended digits were insufficiently 'important' to break through the attentional barrier.

In evaluating the validity of this control experiment it is important to consider two facts. Firstly, the subjects in condition two were given no more training than the subjects were given for task one, and yet the two tasks were of unequal difficulty. Training on such a task can in fact result in a very high level of recall for unattended material (Underwood and Moray, 1974). The second point is that subjects in condition one, did not recall all of the digits presented on the shadowed channel. Arguably this reflects limitations imposed by limits upon memory rather than a perceptual failure. If this is the case, then subjects with a similar memory capacity could not be expected to remember any more items, simply as a result of being exposed to more targets. Moray compared only the absolute number of targets recalled, not their source, and therefore we have no way of knowing the relative contribution of 'unattended' material.

It is clear from the foregoing analysis that the phenomenon of the 'identity paradox', the awareness, by a subject of the presentation of his own name, need not pose any problems for Broadbent's model of selective attention based upon a filter (Broadbent, 1958). The experiments reported by Moray (1959) do not give clear support for the view that selectivity can fail as a function of the 'importance' of a subject's own name. As indeed the control experiment failed to show that 'unimportant' targets such as digits could not break through the attentional filter.

It can be argued, however, that these studies did successfully demonstrate that instructional set, in the form of a subject's active interpretation of the experimenter's requirements can directly affect the distribution of attention. In the present case the experimenters own conclusions are further prejudiced by the fact that the subject was required to shadow the right ear, there being no control for the effects of ear of arrival. The results of this discussion can be seen to contrast sharply with the subsequent interpretation of Moray's work by Treisman (1960) in her formulation of the attentuation model of filtering.

1.3.3. The Concept of the Selective Filter as Strategical Control

A further study is of importance in so far as it brought about an elaboration of the single channel model, rather than an intrinsically new theory. This is the work reported by Gray and Wedderburn (1960), who tested the validity of conceptualising the filter proposed by Broadbent (1958) as a mechanism rather than a strategy for example. They agreed that subjects in dichotic listening experiments could use ear by ear recall, but they argued that such an "optional tactic" (Gray and Wedderburn, 1960, p.180) was determined by task characteristics. It was further suggested that such a strategy was adopted because it had been learned as an effective mode of operation in other situations, where subjects have had difficulty in extracting the meaning of a message.

Gray and Wedderburn accordingly devised an experiment where the most efficient tactic would be to exploit the dominant cue, semantic cues when these were distributed between and not within ears. Thus channel one became "Mice 5 cheese" and channel two "3 eat 4" (Gray and Wedderburn, 1960, p.182). This design opposed meaning and ear grouping as cues, causing a conflict of strategies that was absent from Broadbent's earlier studies. They biassed subjects towards the use of the meaning cue as a strategy by asking for the recall of words and digits separately. Their results showed that when subjects were given cues for recall that were independent of ear of arrival, then they were readily employed. The'built-in'mechanism proposed by Broadbent was seen to be a strategy, the deployment of which was open to the subject's conscious control.

Gray and Wedderburn made it clear that the notion of subject strategies was important in understanding behaviour during the dichotic listening task:

> The odd idiosyncratic variations, not reflected in the quantitative results, support our view that subjects are searching for an optional strategy and if helped by instructions readily adapt.
>
> (Gray & Wedderburn, 1950, p.184)

The factors affecting the results of Broadbent's earlier research were those of technique and materials, rather than the emergence of basic structural constraints upon cognitive functioning.

The implications of the study by Gray and Wedderburn were quickly taken up by Broadbent himself in that the concept of 'channel' was redefined. Previously, the 'input' channel had always been clearly defined by operational circumstances. Indeed not nearly so much defined, as obvious when considering a pair of headphones or loudspeakers as sources of homogenous messages. By channel, Broadbent had previously meant the sense organ involved, or the perceptual location of its inputs as in auditory localisation where messages can be placed to the left, right, or at the midline (Broadbent, 1958, p.15). However, this concept of the channels was extended to include any input in one sense modality and subsequently to include inputs which shared the same meaning class (Broadbent and Gregory, 1961, 1963).

1.3.4. Critical Analysis of some Quantitative Effects of Filter Theory

Before going on to discuss the second generation of models of attention, there is a study to be reviewed which completes the pattern of empirical failings inherent in the system proposed by Broadbent (1958). It is important to note that although the study by Moray (1960) can be seen as invalidating Broadbent's position with respect to any quantitative analysis, Moray felt it to be inadequate as a basis for the rejection of the qualitative aspects of the model. This caution appears to be unwarranted in view of the preceding arguments.

Moray (1960) showed that the assumed measure of perception time employed by Broadbent (1958), was at least twice that actually required. By showing the different error rates associated with similar material presented simultaneously and in a staggered or overlapping fashion at various rates of presentation, Moray demonstrated that recall by ear was best conceptualised as an interference rather than a rate effect. That is that subjects could process more information if inputs were staggered, therefore it was the interference between simultaneous inputs rather than an upper limit upon the processing capacity of a limited channel that necessitated filtering. Thus subjects recalled by ear of arrival because of interference rather than because of the rate of input. However, his results did show a lesser but consistent effect of rate of presentation, implying that both factors interacted with a second variable; the subject's own strategies, to determine the overall level of performance.

A further point made by Moray (1960), concerns Broadbent's original postulate of a memory store on the peripheral side of the filter. The overall number of errors in Moray's study were far too low to support such a position. Certainly, the distribution of errors did not conform to a prediction based upon such a model. Errors of transposition accounted for some 40% of all errors, and yet they are of course impossible in a store located down-stream of a filter sited before the single channel. Because at this point in the system the two channels are entirely separate. If on the other hand errors are held to occur in the short-term store, on the other side of single channel operation, then Moray concludes:

> The number of errors in all is even further reduced to a level now far, far below what would be expected in terms of the time constant given by Broadbent.
>
> (Moray, 1969, p.220)

1.4. Filter Attentuation Theory

Treisman (1960) performed an experiment designed to enlarge upon the findings of Moray (1959) and Cherry (1953), who had demonstrated the effect of certain types of material in breaking through the attention 'barrier' and the dependency of shadowing efficiency upon the conditional probabilities between attended words. A further study, Peters (1954), (cited in Broadbent, 1958, p.121) showed that the content of a rejected message caused greatest difficulty when it was similar to that of the desired message. It was this body of results that Treisman addressed the experiments reported in her 1960 paper.

Subjects in the study were instructed to shadow prose passages fifty words in length, drawn from a novel, a technical work, or approximations to English of the 2nd or 5th order (Miller and Selfridge, 1950). The shadowed message was switched between ears during the course of shadowing; and the errors made immediately before, after and not at the switching were compared.

The results showed that sudden changes in the conditional probabilities within an input channel could provoke a change in the ear of arrival accepted as that channel. However this change was short-lived, and the subjects in Treisman's experiment were reported as being unaware of any transitory deviation from the appropriate ear of input. However, the distribution of errors in the experiment revealed that although subjects had remained unaware of the content of the secondary channel, it had influenced the extent of the switching effect. No subject had shadowed the rejected channel with the previously shadowed message for more than a few words, but the extent of this influence varied as a function of the type of unattended material. The Novel and the technical passage provoked more intrusions than did the two approximations to English. Conversely, the shadowed messages showed no difference in their susceptibility to intrusions from the secondary message. The effect of switching between messages as influenced by the conditional probabilities between words was not accounted for by the mechanism suggested by Broadbent. It was, however, viewed as being in keeping with several previous studies (Cherry, 1953; Peters, 1954; Moray, 1959).

Treisman (1960) went on to propose a model of the filter which would encompass these results and other findings which exposed further deficiencies in Broadbent's original formulation (Broadbent, 1958). A primary problem involved in the reformulation of the filter theory was the question of the importance of the information content of the simultaneously presented messages. Broadbent had originally stated that the information content of the competing messages caused an overloading which necessarily involved the wholesale rejection of a secondary message. However Fairbanks, Guttmond and Miron (1957) had presented single passages at twice the rate which had apparently induced 'filtering', and they remained almost completely intelligible. This study removed information overload as a major determinant of filtering. Similarly in experiments employing passages of double the previous information value, by using low order approximations to English (Moray and Taylor, 1958; Treisman, 1964a), it was found that subjects achieved shadowing scores considerably more than twice the level of their previous performance. The new theory was therefore required to address itself to such questions as the number of different inputs that could be accommodated and the way their demands interacted in affecting task performance.

There was a further body of evidence, which called for some specific readjustments to the notion of a filter. Bruce (1956) had shown that subjects recognised words, the class of which they were aware of (e.g. types of food) at a significantly lower signal to noise ratio than words not classified in such a fashion. Oswald, Taylor and Treisman (1960) supported and extended the results of Bruce (1956) and Moray (1952) when they showed that sleeping subjects could make both an overt response (clenching the fist) and an EEG arousal response to their own name. Howarth and Ellis (1961) went on to show that subjects had a significantly lower intelligibility threshold for their own as opposed to other names.

Treisman (1960) proposed a model of the filter which was based upon the concept of attenuation, this notion was required in order to provide a sufficiently flexible mechanism. It is unfortunate, however, that subsequent difficulties in testing models based upon this important consideration, have arisen due to this emphasis. Treisman (1960) had shown how the attentional barrier could be affected by the semantic congruency of unattended material when attention itself was affected by the probabalistic relationship between attended words. The saliency of particular items had been shown to affect their recognition, and Moray's (1959) experiment was held to demonstrate the particular effect of a subject's own name in the attentional paradigm of dichotic listening.

Treisman (1960, 1964, a,b,c) reported and elaborated upon a theory based upon the 'firing' of 'lexical units' or 'logogens'. Such units were thought to exhibit variable thresholds for firing. Some units, such as a subject's own name, could have permanently lowered thresholds, giving rise to such effects as were reported by Moray (1959) and Oswald et al (1960). Other words could vary in their firing threshold due to context or a transitory emotional loading, for instance 'Fire!' in some situations or the name of a current girlfriend (as reported by Moray,(1969) who exhibited an EEG response whilst asleep to the name of his then current girlfriend). These effects were extended to include the known importance of contextual constraints such as those in prose, where certain links are more likely than others. Similarly the effects of recent usage would be apparent in such a model.

The firing of each lexical unit was supposed to occur when sufficient information had accumulated to exceed the threshold for firing. By reason of the mechanisms outlined above, this 'firing' does not relate directly to the physical intensity of a stimulus. One important feature of this model in view of subsequent debate was that the 'firing' of a logogen involves or constitutes the conscious awareness of that unit. Thus if sufficient evidence accrues for the perception of a word, the word is consciously recognised, effectively then they are one and the same occurrence.

The negative side of the filter, the mechanism whereby unwanted material is prevented from entering the single channel, was not immediately apparent. At first the filter was understood to act by reducing the physical intensity of the rejected message. However, Treisman redressed this misinterpretation in an explantory note to Neisser (1967), discussed in his book Cognitive Psychology. Neisser pointed out that holding a conversation in a crowded room does not lead to a perceived decrease in loudness of any irrelevant speaker within the room. However, this position has been queried (Davies and Chapman, 1970; Chapman and Cumberbatch, 1971). Treisman pointed out that the filter attenuates these sources by adding noise to any secondary signals. This reduces the capacity of messages of the same physical intensity as selected messages, to exceed the firing threshold and therefore enter conscious awareness. This does not, of course, prevent such intrusions recurring, but only reduces the likelihood of their doing so. Broadbent and Gregory (1963) reported findings in keeping with the proposal when they showed that the unattended ear exhibits a sensitivity rather than a criterion shift.

Although this model pursued an economy of explanation, it still included the notion of a single channel, the attenuating filter being placed before such a mechanism. It is unfortunate that the work directly related to the importance of the central channel notion was not critically reviewed, since the logical and empirical basis for such an hypothesis was already under some strain (Peters, 1954,a,b; Moray, 1960). Similarly, the concept of permanently lowered thresholds was derived from Moray (1959). This study does not provide evidence for the importance of such a phenomenon to attention theory, whereas the other studies afford only indirect support for the attentional consequences of single channel phenomena.

Treisman went on to report a series of experiments (Treisman, 1964a,b,c) which largely confirmed the attentuation model. The first study Treisman (1964a) was an attempt to analyse the effect of using words or word class as a cue for channel separation, rather as earlier studies had demonstrated subjects' proficiency in selecting between two channels on the basis of apparent localisation or voice. One study replicated these effects to a certain extent, when it was shown that for messages in the same voice there was no difference in the errors made when selection was supposed to be based upon subject matter or language. It was further noted that only subjects of an intermediate proficiency in the two languages employed could detect the nature of the irrelevant passage. Other subjects realised the passage was not English but could not identify any further details. It was also found that the more familiar the language of the irrelevant passage, the lower the efficiency of shadowing. This final result was entirely beyond the scope of Broadbent's earlier model and yet admissible in support of filter-attenuation theory. The model was supported by the demonstration that a same voice irrelevant message, the reading of a novel, caused more interference than when reading a piece of technical prose.

It was argued that the results of the experiment constituted a rejection of Broadbent's suggestion that word classes could be described as channels of input. Instead, a hierarchical and progressive series of tests were proposed as the mode of action of the filter. The decision tree of the filter was represented by comparing the two inputs on several levels. The differential results given on each test helped to separate the two channels on progressively more complex grounds. Therefore the system can proceed to the highest level of analysis required to separate the two messages, and can be set to function at any particular level by reasons of economy or experimental demands. Treisman (1964a) further developed this view in proposing that each decision could be viewed as a signal detection problem, the selection criteria being the adjustable facility which reflects the influence of contextual probability in each situation.

Treisman (1964b) employed both dichotic and binaural presentation to determine the relationship between the number of channels and the number of messages and their effect upon shadowing efficiency. The number of channels used by irrelevant messages was manipulated by presenting them both on the left channel, both localised at the midline by sound pressure differences, or one at each position. There was a significant effect of channels, the highest being achieved when both irrelevant messages were supplied to the left ear, i.e. there were least intrustions of all in this condition. This study revealed that the number of channels to be rejected was important, perhaps more so than the number of messages to be excluded. A further finding of importance for filter theories was the effect of verbal content upon shadowing efficiency.

This experiment seems to provide little support for the attentuation model that is not subject to qualification. Of primary importance is the fact that the rejected channel was the left ear in the dichotic conditions. Similarly, the fewest intrusions were found when this ear was used for both rejected messages. Any conclusions drawn from this lack of control (the right ear was never the unshadowed ear), must complicate any interpretations of the data. The first problem is that left ear inputs in a dichotic listening task do not seem to share the same meaning class as right ear inputs, confounding any notions of a channel by message interaction effect.

The final experiment in this series, has long been construed as being at best equivocal in its implications for a filter theory based upon attenuation. Treisman (1964c) attempted to measure the running memory span for attended and unattended material by developing a procedure first reported by Cherry (1953). This technique involves reducing the time lag between the two channels, until the subject spontaneously comments upon their identity. This phenomenon lies within the scope of the filter attentuation theory, but only with post hoc explanations can the model be held to explain effects arising from the comparison between two languages. The rejected message was shown to be remembered, or rather recognised as similar, at a significantly shorter lag than when the accepted message recognised was lagging behind. The effect remained when one channel was a translation although the lag had to be reduced to the lowest of all when the rejected channel was leading. There are two points to be mentioned here, the first is with respect to Treisman's post hoc explanation of the translation effect. She suggests that:

> one can suppose that the conditional probability of a word in one language given its translation into the other, is high at least for bilinguals who have had considerable practice at translation between the two languages. Thus the occurrence of a word in one language will lower the test criteria for its translation in the other language in the same way as the contextual probabilities between consecutive words within each language.
>
> (Treisman, 1964c, p.454)

This explanation is vulnerable to the observation that under these circumstances the reason for any translation occurring, a phenomenon not easily understood in the context of filter theory despite the foregoing quotation, is that it is conditionally related to the prior analysis of the attended channel. How then does such a model explain the finding that subjects could detect a similarity even when the rejected message was leading? By the same token, how can such a complex procedure, the conditional linkage of two entire language systems, operate in the role of an economical filter placed before the single channel?

It has been argued that some of the results of this series of experiments are not entirely compatible with an attenuation theory, Kahneman, (1973). Certainly, they provide some reasons to support the early-selection model as proposed by Treisman (1964c). They have also been cited in part, as evidence in favour of late selection theories, a class of models of selective attention which has been proposed as an alternative to Treisman's early selection theory since Deutsh and Deutsch's (1963) paper.

The first of two main approaches to the study of selective attention has been described, namely theories based upon the issue of how extraneous information is excluded from consciousness. In this type of model, the early selection theory has predominated particularly the work of Treisman (1969). The basic assumption of this model is that the unwanted information is attenuated and thereby denied entry to the system which would ensure complete processing of all the attributes of a stimulus.

The early selection position represents a view of attention which it has been claimed is almost entirely contradictory to the late selection model which will next be discussed. The criticisms contained in this appraisal, would seem to suggest, however, that the evidence in favour of an early selection model is equivocal. So much so that the status of a contradictory argument attributed to the early versus late selection models (Treisman and Geffen, 1967; Deutsch and Deutsch, 1967), might well be regarded as drawing more apparent than real support from the empirical evidence.

1.5. Late Selection Models

Deutsch and Deutsch (1963) argued for the rejection of models of attention based upon selection between inputs. A model based upon the same evidence reviewed by Treisman (1964c) was proposed because the evidence

> leads us to the probable conclusion that a message will reach the same perceptual and discriminating mechanisms whether attention is paid to it or not.
>
> (Deutsch and Deutsch, 1963,p.83)

They reasoned that the quality of information required to discriminate between two inputs is at least equivalent to that required for normal perception. The findings of Peters (1954), Gray and Wedderburn (1960), Moray (1959), and Treisman's own (1960) study had shown the importance of the content of the rejected channel. Of particular importance was the finding of Treisman (1960) that transition probabilities between channels was important in determining selective attention.

The Deutsch model also included the evidence from the field of neurophysiology which indicated the complete analysis of all inputs. Sokolov (1960) and Voronin and Sokolov (1960) demonstrated that if habituation occurred to words similar in meaning but different in sound, then arousal occurred to words of a different meaning. This kind of evidence would indicate a filter capable of acting in as complex a fashion as the single channel processor it was supposed to presage. Therefore, the Deutschs suggested that all inputs pass through perceptual and more complex discriminatory analysers before any selection occurs.

The Deutsch and Deutsch (1963) model assumes the fundamental nature of the concept of 'Importance' of an input to the subject. The most important input would set a 'level' which any other input must exceed in order to set in motion the motor output, the memory storage, or

> whatever else it may be that leads to awareness.
>
> (Deutsch & Deutsch, 1963, p.84)

This general criterion 'level' is held to have a physiological concomitant; the message which sets the highest level of analyser output will have this registered in a "diffuse and non-specific system" (Deutsch and Deutsch, 1963, p.88). The 'gain' level in this system is used as a yardstick to determine whether or not the output from any particular analyser will achieve access to awareness. If below this general criteria then the output of analysis will not reach conscious awareness; if it exceeds the criterion, then it will automatically reset the level of the non-specific system.

The model also provides for the incorporation of arousal effects upon the system of selection between inputs. As a subject becomes more aroused, then this acts to lower the general threshold of the system. Thus the overall sensitivity of the system relates to the level of arousal within it. Incoming information produces a specific level of activity in the system of analysis, this level of activity may or may not lead to the conscious awareness of the information being processed as this depends on the overall level of arousal. Material can be fully processed therefore, but the consequences of the anslysis need not reach awareness if the material exceeds the 'capacity' of consciousness set by the arousal system. In this way the model affords some explanation for the variability in the number of features of the environment that we can attend to at one time. As 'consciousness' becomes a variable rather than a constant limit upon 'awareness'.

They further proposed that the level and direction of interanalyser activity varies the threshold for excitability by incoming stimuli. In this way the model proposed above is extrapolated to the detailed phenomena of attentional behaviour. For example, this model can therefore predict permanent and context dependent excitability thresholds. Thus processing capacity can increase in the face of increased demand, and also this system would reflect the importance of conditional probabilities within a message (Gray and Wedderburn, 1960; Treisman, 1960). Furthermore, the model can readily accommodate the 'identity paradox' as proposed by Moray (1959) and discussed earlier in this chapter.

1.6. Comparison of 'Early' and 'Late' Selection Models

To a considerable extent, the two models reflect their common experimental basis. Both, either directly or indirectly, employ the concept of 'importance' and give expression to this concept by the 'level' or 'threshold' of some output device. They both include the ubiquitous 'analyser unit', but differ on the point of access to consciousness. For Deutsch and Deutsch, the analysis of an input does not necessarily lead to conscious awareness of that input. Treisman, on the other hand, makes no distinction between awareness and full analysis; for her the completion of analysis involves the subject's awareness of an input.

The neurophysiological considerations of the Deutsch and Deutsch model would seem to give their model an added flexibility. The general level of stimulation can affect the level of arousal, and therefore the number of inputs that a subject can be aware of. This model also by-passes many of the problems posed by Treisman's own findings, and thereby affords considerable economy of argument. There are numerous elements in Treisman's own research (Treisman, 1960, 1964c) that would seem to argue against the selection inputs being made before access to the single channel processing device.

What is more, the Deutsch and Deutsch (1963) position can far more readily accommodate the data which suggests that the single channel does not exhibit a fixed capacity, insofar as capacity is at the disposition of the subject to a certain extent, Moray (1967). Processing capacity can therefore be relatively independent of the stimulus set, unlike the model proposed by Treisman (1960) where it is the qualities of the stimuli rather than any strategy of the subject which determine the phenomena of attention.

A major problem in comparing the two models derives from the lack of detail in which they are described. Firstly, there is the elastic nature of several concepts that the two models both employ; concepts such as 'importance', 'weighting', and 'novelty', which are imprecise both in their usage and implications. Similarly, both theoretical positions employ particularly vague expressions: "whatever else it may be that leads to awareness" (Deutsch and Deutsch, 1963, p.84). For example, it is on this point, the path to awareness, that the two models differ in their predictions and it has therefore been the subject of many studies.

There is one final, and perhaps fundamental, problem in comparing these two models; operationally they have proved, so far at least, to be indistinguishable in that they are both capable of explaining the results of studies designed to test between them. In one sense because the theories are so loosely defined, they could arguably provide post hoc explanations of most attentional phenomena. Insofar as attempts to differentiate between the two models have been based upon the dichotic shadowing technique, then they were bound to fail, an observation that was made at the very beginning of the early versus late controversy by Deutsch and Deutsch (1967).

1.6.1. Experimental Tests of the Two Models

As an example of this problem, we shall examine the study reported by Treisman and Geffen (1967) in which they set out to test what they suggested were differential predictions derived from the two models. Target words such as colours or digits were placed either in or out of context in a prose passage. One such passage was provided to each ear, the experiment required the subject to repeat aloud the right ear message as it arrived. For the first time such a study involved a low, but not entirely absent memory load, as subjects were to make their response to targets by tapping with a ruler.

The effect was a large one; 87.9% of attended channel targets were responded to, whereas only 8% of non-attended targets were detected. Treisman and Geffen reported that the effect arose from a sensitivity difference, a change in d', between the two ears and not from a change in criterion. Lindsay (1967) and Moray (1969) noted the extension of the assumptions of signal detection theory that this analysis represented, and concluded it to be largely unsatisfactory.

Treisman and Geffen (1967) concluded that their experiment had required identical responses to the two kinds of input, and therefore the Deutsch model would have predicted no difference between the two in terms of target detection. The difference between channels would, however, have been predicted by a model based upon selection between inputs.

Before discussing the response of Deutsch and Deutsch (1967), the lack of control exercised in this design deserves comment. Treisman and Geffen had subjects shadow one ear as an 'attentional control', and this was " always the right ear" (Treisman and Geffen, 1967, p.5), a feature the study shares with many previous studies, (Cherry, 1953; Moray, 1959; Treisman, 1964b,c). This fact was regarded as unimportant by Treisman and Geffen (1967) but this may well be an important oversight, since the left ear/right hemisphere has been shown to be worse at perceiving and remembering words (Kimura, 1961; Bryden, 1963).

Bosshardt and Hörmann (1975) have shown that this input channel has less ability to store the order of inputs, a factor which is clearly linked to short term recall (Atkinson and Shiffrin, 1968). The importance of this argument lies in the fact that all the aforementioned studies failed to control for ear of arrival, and included at least a small memory component. They all reported subjects as shadowing with a lag of two or more items, and Treisman and Geffen (1967) report this lag as being three words. Thus, material was always briefly stored, a condition which particularly prejudices the recall of left ear inputs. A control study for these conditions exists in that Norman (1969) required subjects to shadow the left ear at very high rates of presentation. This was the very first study to demonstrate clear evidence for the recall of unattended information. Similarly Forster and Govier (1978) report effects of context that differentiate between the two input channels, another source of artefact in the Treisman and Geffen (1967) design.

The response made by Deutsch and Deutsch appeared concurrently with the publication of the original Treisman and Geffen (1967) paper. They began:

> We cannot understand why Treisman and Geffen (1967) think their experiment argues against our theory.
>
> (Deutsch & Deutsch, 1967, p.362)

Their rejection of Treisman and Geffen's experiment was based upon the shadowing requirement imposed upon subjects, this 'control' of attention was, they argued, a response in itself. As a result, secondary targets were not identified because of response competition, a factor Treisman and Geffen had apparently thought to be absent because the primary response, tapping, was common to both inputs.

Deutsch and Deutsch (1967) suggested that response capacity could not be split between shadowing and tapping, and so the unattended message received far less attention and so fewer targets were identified. The greater weighting on importance attached to the shadowing response in this technique would preclude any high level of efficiency in reporting unattended targets. They concluded that their model would have produced predictions in line with the results published by Treisman and Geffen (1967) and as both models accommodated the findings, then the design was inappropriate for testing between them.

Another study of the same period, provided what was interpreted as evidence in contradiction of the late selection theory. Lawson (1966) reported that subjects instructed to shadow and respond to tones superimposed on either channel of a dichotic message could do so. However, Deutsch and Deutsch claimed that their model could also accommodate this finding. Moray and O'Brien (1967) appeared to settle the issue and in favour of an elaborated attentuation model (Treisman, 1969). The experiment included targets that varied by voice, content or both features. When targets differed from context on both criteria, i.e. male voiced letters versus female voiced digits, there was a 99% detection rate for targets presented on either attended or unattended channels. This compared with a detection rate of 70% for attended and 39% for unattended items, that differed from context on only one feature.

This finding was in keeping with early selection theory in that when inputs vary along more than one dimension, the subject is free to employ a parallel processing strategy. This capacity for parallel as opposed to serial operation increases as the number of dimensions along which attributes vary increases. The finding of increased processing capacity as a function of attribute proliferation, does not fall within the predictive range of late selection theories. Differences between inputs on any dimension would not influence the processing issue because inputs should all complete this stage and enter competition for awareness afterwards.

Unfortunately the ill-defined quality of both theories ensures that the problem of selecting between theories remains unresolved. The attributes of an input are at one and the same time the contextual cues as to its importance, so this study confounds the issue because

> any stimulus which is different from its fellows, or unexpected, will demand attention on the grounds of importance.
>
> (Underwood, 1976, p.228)

This observation invalidates most of the techniques previously discussed in this chapter and which were addressed to the problem of selective attention.

1.6.2. The Elaborated Filter Attentuation Model

Treisman's (1969) paper was an extensive review of the literature, which also included a description of an elaborated attentuation filter model The theory proposed was based upon a general model of perception, the key to this model being the concept of 'analyzer units'. An analyzer was characterised as a device for describing one of the range of mutually exclusive dimensions or features of a stimulus. The registration of the levels of these independent perceptual dimensions such as size, brightness, and shape, is further subject to a higher level of analyzers which operate to identify particular conjunctions of attributes and their levels. Treisman proposed for example, that perception of shapes depends upon the analysis of the way in which a number of elements common to a variety of shapes come together in a particular fashion. The collection of curves, straight lines, and intersections that differentiate a 'P' from an 'R' are largely held in common for example.

Treisman (1969) proposed that a system composed of such analyzer units could exhibit parallel processing without causing any response decrement. This would occur only whilst stimuli did not demand processing within a single analyzer. If two stimuli require access to the same analyzer unit, then serial processing would ensue.

This system has, however, been criticised insofar as it would require a large number of analytical units or analysers (Kahneman, 1973, p.153). The complex hierarchically organised system proposed by Treisman (1969) would appear on the contrary to be an economical system. Evidence for the mutually exclusive nature of the initial level of stimulus descriptions, is well documented in Treisman's (1969) paper. The subsequent level(s) of analysis based upon the surveying of primary levels for particular combinations of attributes would appear to be an economical organisation for elaborate analysis.

The real problem of the system proposed by Treisman (1969) would appear to be the question of why such a sophisticated system should be devoted to the task of selecting between inputs. For despite acknowledging that other forms of attention could occur, this is the form of attention which Treisman (1969) favoured in terms of explanatory power. It must be remembered that this process of selection or filtering is envisaged as a system designed to protect the central processor from overloading.

However, it is interesting to speculate as to what remains for the limited capacity processor to do, given such a sophisticated filter mechanism. Indeed, it would appear that as the filter is carrying out what was once presumed to be the processing burden of a central limited capacity channel, little remains as a rationale for the existence of that mechanism other than the subject's inability to repeat more than one word at once as in the shadowing task.

Ultimately then, the problem of separating those characteristics of an early selection model that differ from a late selection model was not resolved by the elaborations set out by Treisman (1969).

The position adopted by (Treisman, 1969; Treisman and Davies, 1972) has been described as perceptual set, while that of Kahneman (1973) and the late selection models have been described as response set models after the terminology proposed by Broadbent (1970, 1971). This categorisation acknowledges that the differences between the two models are often a question of emphasis. Treisman (1969) for example, suggests that both kinds of selective attention can occur.

Also the description proposed by Broadbent (1970, 1971) suggested the conclusion that both sides in the argument were frequently forced to draw; that the underlying mechanisms were common to both systems of selective behaviour.

Indeed, as the theories were elaborated in the face of the new experimental data, their capacity for producing contrasting predictions seemed to decline as some inverse function of their increased complexity.

In order to justify this assertion, the most recent efforts to resolve the issue using the dichotic shadowing technique will be considered. Treisman and Riley (1969) and to a certain extent Treisman and Davies (1972), produced evidence in support of the early selection model, when they demonstrated that it was easier to respond to different attributes of a single object, than to attend to the same attribute of various objects. Treisman and Davies (1972) also showed that using different modalities for simultaneous monitoring was superior to using one modality for two messages. However, the same experiment provided only equivocal support for the concept of strictly parallel processing between analyzers.

An earlier result, (Treisman, 1970), had already indicated that both serial and parallel processing was possible both within and between analyzers. This study appeared to confuse more issues than it clarified, and underlined the difficulty of generating and testing in a straightforward manner the predictions of an early selection model. There were a number of findings thrown up by this study (Treisman, 1970) which proved difficult to incorporate in post hoc explanations. It would not be appropriate to pursue the issues in any great detail here, but some of the issues are very relevant in the context of criticisms already advanced.

To a certain extent the problems hinge upon the practise of employing the two ears as the separate input channels for information. The first problem is the one outlined above, in that the action of the filter is so elaborate and yet insufficient to account for all that occurs. This issue is outlined by Treisman (1970) when she writes that:

> this would confirm the paradox mentioned earlier that S's can select by verbal class which two simultaneous items to identify first (Yutema and Trask, 1963), although they are unable to identify both items in parallel.
>
> (Treisman, 1970, p.147)

The problem is that it would seem as though the quality of information required to distinguish between the two inputs in the first place should be sufficient for their accurate identification. Which implies that the analysis carried out by the filter can take place in parallel but not made explicit, a problem for early selection theories.

However, the paradox outlined by Treisman (1960) depends upon a presumption that processing of inputs to the two ears is identical. As this is clearly not the case (Searleman, 1977), then perhaps the problem requires an interpretation that takes this fact into account. If, as the research into lateral differences in the processing of auditory inputs would suggest, (Cohen, 1977) there are qualitative differences in the analysis afforded inputs to the right and left ears, then the issue becomes far less complex. It only remains to suggest that whereas both hemispheres can be engaged in identifying the verbal class simultaneously (Levy, 1974), and therefore selection can occur in tandem. Insufficient evidence may accumulate from the right hemispheres inferior capacities with regard to the semantic content of material (Searleman, 1977) for parallel identification of inputs.

In support for the contention that ear of arrival effects may be important in this area, there are the findings of Martin (1976). Using similar stimuli to those employed by Treisman (1970), Martin (1976) has shown that the left hemisphere exhibits serial processing capacities, whereas the right hemisphere behaves as a parallel processor. This, of course, would provide the basis for the 'paradox', identified by Treisman (1970), insofar as there exists a disparity between the two ears as input channels in a dichotic shadowing situation.

One further study designed to select between the two theories reveals the ambiguities involved in interpreting evidence in favour of either model, and further demonstrates the tendency to neglect the differences in functional capacities exhibited by the two hemispheres. Kahneman (1975) devised an experiment in which subjects were required to recall items of a particular class from the unattended ear. Subjects showed a lack of flexibility in meeting this requirement as evidenced by the large number of intrusions from the unattended ear that were reported. A response set, or late selection model would have predicted far fewer such incidents, whereas the stimulus set, or early selection model could be claimed to predict the results.

However, there was but one target placed in the unattended ear, and a requirement to recognise all the items presented to the other attended ear, meant that there was a difference in the 'weighting' given to the two ears. This design therefore favoured one type of response rather than the other, memory for attended channel items rather than for unattended items. This would suggest that a late-selection model could also be said to incorporate the results of the study.

The experiment reported by Kahneman (1975) failed to include any control for ear of arrival effects, the unattended channel containing the single item for recognition was the left ear. It has already been established that the left ear is more prone to intrusions than the reverse case (Treisman and Geffen, 1968), a fact which should have influenced Kahneman's design. That there should have been an effect of ear of arrival upon such a task if clear from the evidence that subjects respond less accurately (Kimura, 1966) and more slowly (Springer, 1976; Fisher and Kinsbourne, 1972) to the left than right of dichotic speech inputs.

Kahneman (1975) however felt justified in drawing the conclusion that an early selection model could be employed to explain the results of his study. Because there was too high a level of recall of unattended non-target words to justify the use of a late-selection model. The number of intrusions could however have changed if the reverse arrangement of presentation had been adopted. Thus invalidating his employment of the rate of intrusions as a variable affected by stimulus set rather than response set.

It is hoped that the discussion of this study highlights two principal areas of inadequacy common to a number of studies designed to test between early and late selection theories of attention. Such research rarely, if ever, establishes an experimental design that could satisfy both parties as critically independent in terms of predictions generated by the two models. Secondly, such tests when carried out frequently ignore the full implications of using verbal dichotic stimuli, especially the ramifications of hemispheric differences.

1.7. Other Models of Selective Attention

Before attempting to draw some conclusions from this body of work, two further aims must be realised. Firstly, a brief review of attention theories that are not easily encompassed within the polarised early-late argument. Followed by some general points about the nature of the dichotic shadowing technique.

1.7.1. General Capacity Models

In order to complete the review of attention theories, one further class of theories must be addressed. The general capacity theories have provoked research which places the earlier models in perspective, especially with regard to such issues as training, and the perception of unattended information which will be developed later.

The conceptual development that raised the question of a general capacity model, was the theoretical paper by Moray (1967). In this he called for the replacement of the notion of the brain as a limited capacity channel, Broadbent's (1958) postulate A, with the concept of the brain as a limited capacity processor. The processor was described as being flexible in its choice of inputs, outputs, and modes (parallel or serial) of processing. Such a system would vary it's channel capacity in the sense employed by Shannon (1949) from task to task. Moray also argued that the system requires capacity to organise as well as perform these functions.

Cited in support of such a model were the findings of Moray and Jordan (1966), who demonstrated that practised subjects using compatible input output systems would cease to exhibit the filtering behaviour noted by Broadbent (1958). This was achieved by providing the subject with the opportunity to make dual responses to dual stimuli. They further demonstrated that both perception time and switching time could be reduced by practice, subjects could eventually successfully report lists by alternating vocal recall. This was achieved by increasing the practise afforded subjects by a factor of 5, in excess of that used in earlier work (for example, Broadbent, 1954). This study revealed that the single channel was not fixed in its capacity, nor could switching between dichotic inputs be determined by perception time. Subjects were able to perform this task at input rates in excess of those used by Broadbent (1954).

Moray (1967) concluded that the results supported a general capacity view of the brain as being essentially flexible in meeting task requirements. The capacity demands of a task were related to the compatibility of output and input, and were also affected by practise, which changes that relationship. As has been previously argued, the demands of Broadbent's earlier task were complicated by a large memory load, due to the inability of a subject to make simultaneous vocal responses to dichotic inputs. The problems facing Broadbent's subjects were increased by their very low level of training prior to the experiment.

Further support for this model can be drawn from the work of Lindsay, Cuddy and Tulving (1957) and Tulving and Lindsay (1967), who used tasks which required subjects to identify the intensity of auditory and visual signals. They reported that performance was only slightly degraded when both stimuli arrived at once, in comparison with a condition where the stimuli were staggered. Similar work by Moore and Messaro (1973) required subjects to identify one or both dimensions of a tone varying in terms of loudness and quality (waveform). Performance was equal in the two conditions, divided attention was as efficient as focussed or selective attention. The findings of such divided attention studies are not directly compatible with early selection models, although certain findings such as those of Moore and Massaro (1973) may be explained by the use of two analysers operating in parallel, one for tone quality and the other for loudness. Certainly other studies (Treisman and Geffen, 1967; Gillion and Sorkim, 1974) have shown that when two stimuli, both requiring a response, occur together then there is a breakdown in performance.

A further study by Messaro and Kahn (1973) indicates the difficulty of isolating effects that are independent of models based upon early or late selection. They presented subjects with two simultaneous stimuli on each trial, a tone that varied in quality and a light varying in duration. On some trials subjects simply had to judge the tone, and on others a decision was required about both the light and the tone. In the dual response condition there was no interference between the tasks. The experimenters decided that this was due to the low demands made by the tone duration judgement, which was subsequently increased in complexity. As a result the subjects experienced difficulty in making the tone judgement in trials where the stimuli were presented simultaneously.

The model proposed by Treisman (1969) cannot accommodate this finding because the excessive demands made upon the analysers devoted to the light task, could not affect the performance of an independent tone analyser. Nor could response competition of the kind proposed by Deutsch and Deutsch (1963) be invoked as an explanation, as the response was not varied. The importance of this study lies in the fact that there is a statement on behalf of the early selection theorists to predict the outcome of such an experiment:

> There may well be some common pool of capacity, perhaps that involved in control processes; but there may also be some more specific limits within the relatively independent perceptual analysers.
>
> (Treisman & Davies, 1973).

It is the independence of these perceptual analysers that is violated by the results of Messaro and Kahn (1973), results which indicate a general capacity model rather than the other two 'bottleneck' theories.

1.7.2. Effort Theory

Kahneman (1973) proposed an effort theory of attention which can perhaps be described as a capacity model which incorporates several features of both early and late selection models. The model predicts that in the case of simultaneous inputs, the ability to make dual responses is related to the processing demands of the two activities between which attention is divided. The assumption is that should two tasks exceed available capacity, then they must suffer from mutual interference.

Kahneman categorises the resultant interference into two types: central and structural interference. Central interference occurs when the capacity of the central processor is insufficient to meet task demands. Structural interference is the result of tasks which make demands on the same perceptual and response mechanisms. Such a model therefore represents many elements from the spectrum of theories hitherto proposed, and of course is extended to take cognisance of arousal, and the changes in capacity which underlie the system's response to difficult or novel conditions.

The general capacity type of model would seem the only theory that can accommodate the entire range of findings that research in this field has generated. Some experiments have clearly demonstrated that parallel processing can occur

(Lindsay, 1970; Lindsay and Norman, 1969). Other studies have shown that parallel processing can occur, but not without interference between inputs (Treisman, 1970; Treisman and Fearnley, 1971). Experiments such as those reported by Moray and O'Brien (1967), Moray (1969b, 1970a,b) have shown that in certain circumstances the full processing of one input makes any response to a second stimulus impossible. This range of results would seem to favour the later type of model, in that as well as lacking specificity, earlier theories also fail to explain all these findings.

1.8. The Shadowing Paradigm

In order to develop the arguments in favour of the various models of selective attention, it is essential to examine the primary technique employed in research upon them. The technique in question is dichotic shadowing, which has been used in almost all the studies mentioned up to this point. The criticisms of dichotic listening, the other major technique, having already been elaborated earlier, will not be repeated here. Dichotic shadowing involves the subject in repeating aloud the primary message whilst (usually) ignoring a second message delivered to the other ear. There have been changes in technique which have probably influenced the results obtained but these cannot be dealt with here. In more recent times, dichotic tapes have been computer matched, Treisman (1970) being one of the first to do so, and the tendency has been to move away from continuous prose passages towards lists of unrelated words.

1.8.1. Practice Effects

There has been one essential variable which has not received the attention it deserves, and should certainly influence theories of selective attention. The effects of practice upon shadowing performance represent the dynamic nature of systems which were often modelled as having fixed characteristics, i.e. described as mechanisms. This is clearly apparent when considering the results of Moray and O'Brien (1967) who showed that ear by ear reporting was not an effect of a fixed rate for switching between inputs, but was a factor susceptible to training. Similarly, Norman (1969) trained his subjects for 18 hours and demonstrated memory for 'unattended' material. Other studies had employed a 'few' practise trials or as in the case of Cherry (1953), one practise trial and one experimental run.

The best example of training effects upon a selective attention is afforded by a comparison of the two studies of Underwood and Moray (1971), and Underwood and Moray (1974). In the first study, a highly practised subject, Moray himself, was employed in detecting targets presented in the same or in a different voice, which were directed to either the attended or unattended ear. The second study involved a larger number of subjects who were not as highly practised at auditory tracking or shadowing. Although Moray had no prior knowledge of the distribution of targets or their exact nature, he was able to perform at a higher level of efficiency. Moray proved to be superior in detecting targets in both accepted and rejected channels, and same/different voice combinations.

The effect of practice was significant only for the comparison of detections of same voiced targets in the unattended channel. Moray detected 83.3% of these targets, whereas less proficient shadowers successfully reported only 4.2%. The authors concluded that the more experienced subject had been in a position to devote more capacity to the analysis of the secondary message. These findings were extended to the detection of semantic targets in both focussed and divided conditions by Ostry, Moray and Marks (1976).

These studies make it clear that a subject's performance at one level of training may change as competence improves. This finding can be generalised to earlier studies which led to conclusions about fixed capacities and behaviours in respect of the shadowing paradigm. Models which fail to incorporate the importance of training effects cannot fully describe behaviour in selective attention tasks. Unfortunately, the effects of practice were not considered in early attempts to provide a theory of selective attention.

The general capacity model proposed by Moray (1967) does however include the supposition that the compatibility, and therefore the processing demands of inputs and responses, can change as a function of practice. Certainly the effects of training would demand further revision of both early and late selection models of attention.

1.8.2. Efficiency of Shadowing as a Device for Focussing Attention

A further series of experiments poses problems for theories of selective attention based upon the shadowing paradigm. Firstly, because of the doubt cast upon the efficacy of the shadowing task in focussing attention, and secondly because the consequences of such studies are not easily encompassed by either a late or an early selection model.

The experiment reported by Salter (1973) confirmed earlier reports of the effect of using different types of material as the secondary message, (Peters, 1954; Treisman, 1964b,c). Salter required his subjects to shadow prose or unrelated words, presented at a 'normal' rate of 130 words per minute. The unattended channel consisted of a similar message or the same message as reversed speech. A second condition required subjects to repeat the secondary input where this was possible without reducing the efficiency of shadowing the primary message. This condition, therefore, required subjects to make overt use of any surplus processing capacity available during dichotic shadowing. It must be remembered that shadowing has been used as a 'control' for attention, and was assumed to fully occupy the subject so as to leave no capacity for the analysis of secondary inputs.

The results showed that subjects could shadow connected prose more efficiently than unrelated words, and that the rate of shadowing was affected by nature of the material presented on the ignored channel. Although reversed speech had an effect, the consequences of using connected prose on the unattended channel were even more marked. This leads to the conclusion that sufficient capacity remains after performing the shadowing requirements to allow for a fairly sophisticated analysis of secondary inputs. This was made clear by comparing the number of words shadowed when Ss were instructed to repeat the unattended message where possible, with the condition in which they were required to simply shadow the attended message. There was a significant superiority with respect to the number of words shadowed, in the former condition. This superiority would seem to be due to the spare capacity available during shadowing.

A further experiment revealed the quality of processing that the surplus capacity can achieve, and completes the evidence for a rejection of the notion that shadowing 'locks' attention onto the primary message (Moray, 1969b). Lewis, Honeck and Fishbein (1975) embedded content and gender targets, on both channels of a dichotic message. The gender targets, words spoken in a female voice embedded in a message spoken by a male, were reported so efficiently that the results were discarded. The results came, therefore, from an analysis of targets that were words derived from a certain class, e.g. Cow from the class of animals. This type of distinction represents a complex level of an analysis, hitherto deemed impossible with respect to nonattended inputs (Treisman, 1964).

There were four experimental groups: group one shadowed one channel but were instructed to report targets from both ears by ruler tapping. A second group shadowed one channel and reported targets, there was no distracting second channel in this condition. The third group simply listened to the dichotic message and reported all targets. The final group listened to one channel only, and reported all targets. The group which simply listened to both channels, reported the largest number of targets. The group shadowing the solitary message reported more targets than the subjects in the ordinary shadowing situation.

An important comparison is the superiority of the group who made no response other than tapping, with the group who were locked onto one channel by shadowing. This shows not that shadowing focusses attention, but that it is a requirement which partially reduces the capacity of the subject to monitor even the shadowed channel. Overall, the results suggest that the shadowing requirement does not fix attention upon one channel, but that it demands an uneven division of attention between the two inputs.

Lewis et al (1975) argued that this represented a differential unlocking of attention; it is focussed on neither message but unevenly split between the two. Finally, this study indicates that although the amount of processing capacity devoted to each channel is different, the quality is similar at the level of sensitivity required by their task. This experiment therefore reveals the inadequacy of dichotic shadowing as a technique for examining selective attention.

Theories based upon the use of this technique do not need to explain high levels of processing of unattended inputs, because they are not unattended. Such a finding complements a general capacity model, in that such a device would distribute available attention between the various demands made by a particular task. The differences between the levels of analysis afforded the two inputs, where such differences exist, represent the attempts of the general capacity processor to allocate resources in a given situation. The breakdown of resource allocation can be understood within a framework of structural and perceptual interference as proposed by Kahneman (1973).

1.9. New Techniques in the Development of Theories of Selective Attention

There are two final lines of evidence which will complete this appraisal of current models of attention; the evidence for the parallel processing of inputs, and the studies which have directly examined the level of processing undergone by unattended material. The first of these, parallel processing experiments, can be seen to support a general capacity model of attention. In that such phenomena cannot be explained by reference to early or late selection models, and also because they represent the dynamic consequences of a flexible, if ultimately finite, processor.

1.9.1. Dual Task Studies

Typically experiments which have revealed the subject's capacity with respect to meeting dual task requirements, have been explained in terms of the automaticity of one or both of the tasks involved. James (1890) for example, describes parallel performance in terms of the extent to which a subject can perform part or all of the task requirements 'automatically'. Woodworth (1921) and Posner and Snyder (1975), have declared such 'automatic' actions to be outside of consciousness, because they agree such behaviour is characterised by poor recall and a very low level of understanding. It is also useful to note that they make the implicit assumption that consciousness is a unitary concept. That by definition we can be truly conscious of only one thing at a time, and therefore accurately recall and understand only one input at a time. It is essential in order to demonstrate parallel processing of inputs that some clear evidence of the conscious awareness of both channels is provided.

The operational definition of 'automatic' behaviour provided by Posner and Snyder (1975), makes this problem appear all the more difficult. They contend that any activity or mental process which does not interfere with any concurrent attended activity or process, is automatic. This definition therefore allows for any demonstration of processing occurring on the secondary channel to be deemed automatic and therefore represents no problems for models of serial rather than parallel processing, for example Treisman, (1969).

An experiment that demonstrates evidence of conscious awareness with respect to both channels must therefore be an example of parallel processing. Previous studies using dichotic listening have exhibited only a very brief memory for unattended inputs (Norman, 1969) or none at all (Moray, 1959). Similarly, the quality of processing reported for unattended targets has often, but not always, been low. However, Spelke, Hurst and Neisser (1976) report an experiment which would seem to fulfill all the requirements for a proof of parallel processing.

The experiment by Spelke _et al_ (1976) is a development of the early studies of automatic reading and writing, Stein and Solomons (1896), Dorney and Anderson (1915). They employed two subjects for an entire semester, in learning to write down dictated words whilst engaged in the silent reading of short stories. At first subjects directed their attention to reading, and their performance was tested by a comprehension measure. The dictation task remained automatic in that the Ss failed to notice successive lists of word categories which they were required to write down. Such lists, for instance a sequence of twenty rhyming words, were immediately recognised on subsequent presentation.

The level of performance reached in this initial experiment is very similar to that achieved by the barely competent shadower, who may remember the presentation of his own name (Moray, 1959), or words of other emotional significance (Treisman, 1960), but nothing else. Of the thousands of words dictated during the reading, only thirty-five were remembered:

> Diane recalled Diameter which she at first thought was her own name, and John recalled several related to his studies such as 'luncheon' and 'finances'.
>
> (Spelke et al, 1976, p.222)

This analysis is supported by an examination of the intrusions that occuring during dictation:

> John noticed 'ecumenical' while reading a story about a priest, and 'aversion' whilst reading the word 'aversion'.
>
> (Spelke et al, 1976, p.222)

This is the same pattern of phonetic and semantic intrusions reported in early studies of dichotic listening (Treisman, 1964b).

The parallel between the barely competent subject in a shadowing task and the results of this experiment are very close. The pattern would suggest that the process of acquiring proficiency in shadowing may follow this path. If so, the continuation of this study, discussed below, and subsequent work of a similar nature (Hirst, Spelke, Reaves, Caharack and Neisser, 1980) suggest that theories of selective attention are even more context dependent in terms of the stimulus materials used and a subject's experience, than has hitherto been suggested.

The subjects were then called upon to note down the meaning of each word that was dictated, as it arrived. After considerable practice they were able to do this without any decrease in the rate or comprehension of the reading. It is clear that both tasks are being performed at a level which requires the subjects' conscious awareness. This experiment shows therefore, that parallel processing is not an impossibility built into the system, a 'hard' program might be an analogy, but instead represents an advanced state of proficiency with regards to the demands of a particular task.

The ability of the subject to use the same analysers as a parallel processor is in contradiction to the later versions of an attentuation theory (Treisman, 1969). Similarly this study reveals that two identical responses, namely the meaningful categorisation of two words (one read and one dictated) are possible, which is difficult to understand within the context of a model based upon response competition (Deutsch and Deutsch, 1967). A general capacity model would seem to be capable of explaining such effects, certainly the importance of prolonged training lies within that realm of explanation.

Studies of parallel processing help to place the concept of the 'single channel' in perspective. Neither Deutsch and Deutsch (1967) nor Treisman (1969) ever developed theories that were independent of this concept. Both theories are 'bottle-neck' theories, the point of contention being the location within the information flow system of the bottleneck. Allport, Antonis and Reynolds (1972) reported evidence which they claimed to be a disproof of the single channel model, in much the same way as Spelke, Hirst and Neisser (1976).

In their study, Allport et al trained subjects to sight read music, while shadowing a dichotic speech input for which they had to demonstrate understanding. Although subjects proved to be quite capable of performing in this way, the authors included a caveat to be placed on any interpretation:

> We do not wish to deny that the brain may in certain circumstances, exhibit 'single channel' operation as a whole.
> (Allport et al, 1972, p.233)

It may be deduced from this usage, that the single channel has become the brain itself, and that it constitutes a device which acts as a general capacity processor. The notion of a processing 'channel' protected by a filter from overloading seems to have been abandoned, or perhaps more accurately, extended beyond the point at which it retains any real value. This last study represents the difficulty of using a terminology developed to describe an information flow system, to explain the phenomenon of a process.

1.9.2. Shadowing Techniques

The final section of this review will be devoted to an examination of the effects of unattended inputs in studies where overt responses or discontinuities are avoided in dichotic shadowing. These experiments were designed to test between early and late selection theories insofar as they propose different levels of processing for unattended material. They represent an advance over studies which involve a large memory component, Cherry (1953), Moray (1959), and experiments which superimpose tapping or other responses upon the shadowing requirement (Treisman and Geffen, 1967; Treisman and Riley, 1969; Underwood and Moray, 1971, 1974).

The majority of studies designed to test the point of selection between inputs assumed that the processing of an unattended input must involve the subject's conscious awareness of that input. It was on these grounds that subjects were asked to report any targets that occurred on the secondary channel. Late selection theories do not presume the awareness of an input, as a direct consequence of analysis. The requirement, therefore, was for a design which allowed for the consequences of unattended inputs to be made explicit without making any further requirements of the subject beyond the shadowing response.

A subsidiary problem with designs which called for an overt acknowledgement of the presence of targets on the unattended channel, arises from the nature of dichotic shadowing itself. It is now known that the shadowing of one channel calls for a relative and not an absolute distribution of attention between the two channels (Salter, 1973;Lewis,Honeck and Fishbein, 1975). It could therefore be argued that superimposing a further requirement, for instance tapping to targets, on top of shadowing will have different effects upon the two messages. Whereas the tapping response may well be possible within the capacity allocated to the primary message, it might be impossible to acknowledge secondary targets in the same fashion. This explanation does not preclude the possibility that a secondary channel is analysed in such a situation, only that it may not be possible to respond to it.

1.9.2.1 Studies using Verbal Reaction Time

Although the range of studies designed to test the phenomenon of 'automatic pick-up' (Neisser, 1976, p.93), 'semantic processing of unattended messages' (Lewis, 1970), and 'discrimination without awareness' (Forster and Govier, 1978) is considerable, they represent a common search for evidence of some kind of subliminal analysis. As a result the choice of a dependent variable has required great ingenuity, a characteristic shared by all such studies. Perhaps the most subtle technique was that amployed by Lewis (1970), who measured the verbal reaction time of the subjects as they shadowed the attended message.

The materials for the Lewis (1970) study were dichotic lists which contained pairs of synonyms, antonyms and homonyms at various positions. Analysis of the lag times associated with the repetition of the attended items of such word pairs revealed differences between word types. Synonyms caused longer shadowing latencies than either antonyms or unrelated words. The antonym latencies were significantly shorter than either unrelated and synonym word pairs. Lewis argued that this was clear evidence that the meaning of unattended words could influence the primary task of shadowing. Evidence for the semantic processing of unattended material which he argued could only be interpreted within a late selection model of attention.

This experiment was the subject of a replication by Treisman, Squire and Green (1974), which it was claimed, revealed certain limitations of the Lewis effect. Treisman et al (1974) placed a control pair at position 3 and a synonym pair at position 7 in a 10 item dichotic list. Reversing this arrangement on one half of the trials, and thereby controlling for the effect of serial position. The synonym effect was found to occur on comparisons of latencies for synonyms and controls at position 3, but not for such a comparison at position 7.

This effect, they argued, arose from the fact that it took several pairs of items before the single channel was 'filled', and selection could begin. As both these experiments will be examined in some detail later, it is sufficient to note here one factor which makes an acceptance of the qualifications proposed by Treisman et al (1974) difficult.

The authors of the replication study noted that synonyms presented at position 3 caused subsequent and unrelated words to exhibit longer lag times, this preservation of the 'synonym effect' could have lasted as far as position 7. The control words at position 7 were compared with the synonyms at position 7, and yet they could have been artificially longer in their verbal reaction time due to interference from the earlier synonym. It is certainly true that synonyms in position 7 gave rise to longer Rt's than words at positions 6 and 8 in the same list. The constraint of list position noted by Treisman et al could therefore be due to an experimental design which confounds the effects of synonyms and controls because they are placed too close together in the same list.

1.9.2.2 Disambiguation Studies

A development of the technique used by Lewis (1970) allowed for a more sensitive appraisal of the type of analysis undergone by secondary material. The study by Lackner and Garret (1972) employed a technique whereby the effect of the secondary channel was measured with regard to its influence upon the simultaneous paraphrasing of an ambiguous passage.

The disambiguating 'context' led to a small but significanteffect upon subjects' responses, when presented before, during or after the ambiguous shadowed passage. A further result was that there were more word level than phrase level disambiguations. A single word therefore, was more likely to influence the interpretation of a shadowed message, than an entire phrase.

Although this study would seem to support the notion that unattended messages are analysed, there remains some doubt as to the efficiency of the technique employed. Although subjects reported no awareness of the contents of the unattended channel, nor did they show any hesitation in their paraphrasing, the control over attention exercised by a paraphrasing requirement is too variable to be satisfactory.

Mackay (1973) used simple dichotic shadowing, when he employed a very similar technique to that of Lackner and Garrett (1972) to explore the level of processing of unattended material. The results of Mackay's study are therefore more appropriately compared with traditional experiments upon attentional selectivity.

The model tested by Mackay (1973) was based upon the assumption of two memory states: M_1 and M_2. M_1 memory, it was argued, is shared by both attended and unattended inputs, a finite state device capable of performing only a limited analysis of linguistic input. The M_2 device was reserved for the primary input and produced an analysis of the underlying relations between the primary items previously contained in the M_1 device. This model predicted that material from the unattended channel could only affect surface ambiguities present in primary material, and could not influence the interpretation of any deep structure ambiguities in the shadowed message. Mackay (1973) generated nine hypotheses from this model, although his experiments provide only partial support for the theoretical memory devices.

The results did indicate that selection must occur after the attribution of 'lexical meanings' to words, which agrees with the findings of Lewis (1970) and of Kahneman (1969). The experiments supported Mackay's original model insofar as the results showed that the deep structure relations between words were only analysed when the input was attended. This finding is, however, in contradiction to the model of Deutsch and Deutsch (1963), who predicted no such limitation upon the processing of unattended inputs.

There is an important feature of this study, which might influence the acceptability of Mackay's suggested contradiction of Deutsch and Deutsch (1963). Several studies have indicated that selective attention prevents the allocation of conscious perception, rather than the allocation of processing capacity, (Corteen and Wood, 1972; Moray, 1969; Ostry, Moray and Marks, 1976). The last study, Ostry et al (1976) also indicates the influence of practice upon these effects, and Norman (1969) indicated the very brief persistence of unattended material. It is possible therefore, that the limits to the processing of unattended material as observed by Mackay (1973) could arise from any or all of these factors. They would certainly indicate the inappropriate nature of modelling the level of processing of unattended material by finite state devices such as the proposed M_1, M_2 system.

1.9.2.3 Studies employing the Galvanic Skin Response Technique

Perhaps the most recent experimental paradigm to be developed for research into the fate of unattended dichotic inputs, is the use of conditioning techniques. In this technique a very unpleasant conditioning phase, shock-associating target words, allows for unobtrusive testing to occur during dichotic shadowing. Following this technique as first outlined by Moray (1969), Corteen and Wood (1972) shock-associated a series of city names until they provoked a significant Galvanic Skin Response. These target stimuli were then embedded in the unattended channel of a dichotic message, and the subject was asked to shadow the other, right, ear.

The shock-associated city names gave rise to a significant G.S.R., which generalised to other non-shock-associated city names contained within the unshadowed list. A control comparison revealed that city names in lists where there had been no shock-association, gave rise to a spontaneous G.S.R. that did not differ from that of other names. The generalisation effect was viewed as evidence in support of late-selection theories of attention. The spread of the significant G.S.R. response to other items of the same meaning class, represents a level of processing in excess of that predicted by a model incorporating early selection between inputs.

The results of Corteen and Wood (1972) remain equivocal, in that it could be argued that shock-associated words have their firing thresholds, the sensitivity of their logogenic identifiers as it were, changed by such treatment. The conditional target words would have been fired by the degraded input that had passed an attenuating filter, Treisman (1969), if its threshold had been reduced by conditioning. Similarly, the model proposed by Treisman (1964) would predict the generalisation of such an increase in sensitivity to other contextually or probabilistically linked items such as words of the same class, city names.

In order to ascertain the validity of this explanation, Corteen and Wood (1974) replicated the earlier study. However, they included a procedure proposed by Treisman and Riley (1969), which allowed subjects to make overt any conscious awareness of targets embedded in the secondary message; they were to stop shadowing and press a buzzer should they hear a city name in either ear. Out of 114 opportunities to press the buzzer, only one subject did so, and then on only one occasion. This second study would seem to rule out explanations based upon a filter attenuation hypothesis.

Von Wright, Anderson and Stenman (1975) employed this technique, and extended it so that subjects were conditioned during experimental trials, when the target word occurred on the attended channel. Although Von Wright et al (1975) replicated the G.S.R. effect, they had certainly enhanced the probability of successful replication by the extensive conditioning.

Before mentioning the most recent example of this type of study, it is necessary to attempt some explanation of a failure to replicate G.S.R. effects, as reported by Wardlaw and Kroll (1976). Although they made every possible effort to replicate Corteen and Wood's results by modifying procedures, they failed. The answer to this paradox could well be due to the fact that they also failed to employ any pretest criteria of conditioning.

The importance of this fact lies in the observation made by Corteen in a personal communication to Wardlaw and Kroll (reported in Wardlaw and Kroll, 1976) that the upward adjustment of shock intensity required for adequate conditioning, normally lost him about one third of his subjects. Subjects refused to continue to participate when the shocks had to become so 'unpleasant', when lower levels of shock failed to provoke an adequate conditional response. Wardlaw and Kroll (1976), however, lost none of their subjects due to exposing them to levels of shock they would not tolerate.

Unless we make invidious comparisons about the relative courage or indeed good sense of American and Canadian undergraduates, then we can assume that Wardlaw and Kroll failed to shock-associate their target words effectively. A conclusion their own post-testing would seem to support; it was revealed that the shock-associated names gave only a marginally higher G.S.R. than did other nouns.

A further feature of this replication study leads to some conclusions about the applicability of the paradigm. Some 66.7% of their subjects heard and remembered unattended words, and 16.7% heard and reported city names, the targets, when they were presented to the unattended ear. This result is in direct contradiction to the low level of awareness reported by Corteen and Dunn (1974).

The contradiction can be resolved if consideration is given to the wider consequences of presenting people with electric shocks to their fingertips. Corteen et al (1972, 1974) and Wardlow and Kroll (1976) told subjects of the relationship between the shock and a particular word, this being a prerequisite for achieving a consistent Galvanic skin reaction to a stimulus. It would seem, then, that the subjects employed by Wardlaw and Kroll carried this awareness in the form of a high level of apprehension, into the testing phase of the experiment. They were prepared for words which they expected to be accompanied by an electric shock. This situation promoted the processing of unattended inputs in the search for preparedness or in unpleasant anticipation of the shocks.

The latest report of the G.S.R. technique and an extremely elegant test of the processing of unattended inputs, is that of Forster and Govier (1978). Using shock association, they placed a target word or a homonym of the target word in or out of context on both attended and unattended channels. They employed a pre-test criterion of conditioning, which must have contributed to their positive results. As well as demonstrating the processing of the target word to the level of lexical meaning, they showed the limitations of secondary message processing.

The homonym of a target word was far more likely to elicit a G.S.R. when presented on the unattended rather than the attended ear. Similarly contextual constraints, indicating a broader comprehension of the text, only helped accuracy in the attended channel. This result supports the finding of Mackay (1973) that unattended material is only available in limited units of approximately two words.

Although the authors argued that this result could be interpreted in favour of a late selection theory, the results must remain equivocal for the following reasons.

First, there is the positive element of the G.S.R. studies; they afford valuable evidence that the polarisation of views about an early-versus late argument is not supported by the empirical facts. Words presented in a dichotic shadowing task are not subject either to analysis based upon 'perceptual' qualities, nor their meaning. Instead, it would seem that there is a continuum along which the evidence for any input may be graded. This may well lead to the polarisation of evidence either about an input's physical qualities, or its semantic content. This, however, reflects the experimenters emphases in the design and control of the study, rather than the mechanism of selective attention.

A second problem that contributes to the equivocal nature of this series of studies, which at first seemed to offer so elegant a solution to the problem of identifying the level of processing of unattended inputs, is that of ear of arrival effects. Unfortunately, Corteen and Wood (1972), Corteen and Dunn (1974) and Von Wright et al (1975), failed to balance the ear of arrival of messages, the shadowed ear always being presented to the right ear.

It is also the case that Forster and Govier (1978), who attempted to make fine distinctions about the quality of processing of unattended, always presented it to the left ear. An unfortunate choice, in that so many studies have revealed a disparity in the performance of the two ears with dichotic speech inputs. Unfortunately, these disparities do not favour the left ear as the source of verbal input, when analysis involving the meaning or the recall of inputs is required (Searleman, 1977). It is interesting to note that the one study which did include a control for the ear of arrival of dichotic inputs, was the failure to replicate G.S.R. effects reported by Wardlaw and Kroll (1976).

CHAPTER TWO

REVIEW OF THE EVIDENCE FOR THE CORTICAL LOCALIZATION OF FUNCTIONS AND HEMISPHERIC ASYMMETRIES

2.0 Introduction

In order to review the experimental literature concerning laterality effects it is first necessary to discuss the concept of cerebral localization. The reason for this lies in the fact that the study of laterality effects is based upon a model of the location of function within the brain. Such a model must presume certain features of processing behaviour and thereby direct research and theory in the study of hemispheric asymmetries of function.

It is the purpose of this review therefore, to consider our knowledge of functional localization and relate this to current theories of functional asymmetries in cognitive psychology. The first topic of this review, theories of localization of function, is based upon the widest possible range of evidence. The more specific task of placing current theories of laterality effects in the context of cognitive psychology will be largely based upon work which has employed auditory stimuli; principally the dichotic listening paradigm.

2.1 Historical Overview of theories of localization of function

The notion of attributing higher mental functions to locations within the brain, derives from the search for the origin of consciousness. The first contributions of historical value came from the Greek philosophers, particularly the works of Plato and Aristotle although some historians trace the antecedents of the larger philosophical issue, the 'mind-body problem' as far back as two of three thousand years before Christ. The ideas of the Greek philosophers exerted a considerable influence upon succeeding generations. Although they differed in detail, Plato and Aristotle did begin the attempt to locate mind or consciousness.

Aristotle argued that the heart was the site of the mental functions and by implication the circulatory system was closely involved in the transmission of the will and control of the body. Plato concluded that the brain was the site of mental functions and he progressed so far as to differentiate between the brain and the upper and lower levels of the spinal cord with regard their functions. The brain was the organ of mind whereas the upper and lower sections of the spine controlled 'passion' and the 'lower drives' respectively.

Subsequently Galen (ca. A.D.129-199) the famous doctor and teacher achieved a synthesis of these earlier theories. The brain retained its role of 'mindfulness' but a hydraulic model was proposed in which the fluids of the body represented mind. These fluids were thought to flow around the body and converge upon the ventricles of the brain which were held to be the storage sites for the 'mind stuff.' Galen's model was therefore a theory of mind, with localisation centred upon the brain. This hydraulic model persisted in a largely unaltered form for almost fourteen centuries, indeed in so far as he apportioned different functions to various regions of the brain, it remains current.

The Renaissance period heralded an upsurge of interest in the physiology of mind, the close scrutiny of the brain which this involved, brought forth a number of facts incompatible with the long held hydraulic model. Andreas Vesalius (1514-1564) was amongst those who studied anatomy using the technique of dissection, a prime source of the new knowledge which overthrew the hydraulic model. Vesalius failed to find any passages for the 'vital spirits' through the nerve connections of the brain, a finding entirely at odds with the hydraulic model.

At about the same time Jean Fernal (1497-1558) developed the localization of function model by suggesting that different nerves had different functions, some being responsible for motor and others for sensory functions. Other workers began to stress the contribution of the solid parts of the brain and a steadily increasing knowledge of brain structure led to the conclusion that various parts of the brain might themselves serve different functions.

The work of Descartes (1596-1650) cannot be ignored, since the problem of the relationship between mind and body has been a central feature of theories of cerebral localization. Descartes was concerned to locate the soul or mind of man, believing that this function would differentiate human beings from the lower animals which he viewed as mere automata or empty systems of mechanical reflexes.

Consciousness, the higher function which separated man from lower animals was regarded as an interaction between the soul and the mind, the two elements of the Cartesian dichotomy. Consciousness was argued to represent the interaction between soul and mind and was thus regarded as an essentially unitary phenomenon. The problem of location was therefore resolved by selecting an organ close to the brain which did not display the bilateral symmetry common to the internal organs, limbs and the brain. Thus Descartes arrived at his famous conclusion that the pineal gland was the seat of mind, because of its lack of bilateral symmetry.

Subsequent to the work of Descartes came the great effort of the anatomists in understanding the nature of the nervous system in relation to the reflexes. Robert Whytt (1714-1766) clearly understood that reflexes could be mediated by spinal mechanisms, and Georgius Prochaska (1749-1820) advanced one stage further when he suggested that there existed a functional dichotomy between input and output nervous pathways and that the brain acted as way-station for redirecting these lines of information. This line of research was logically extended, when the physiological distinction between the afferent and efferent systems was completed by Alexander Walter (1779-1852) and formalised in the work of Francois Magendie (1783-1855).

At the turn of the 18th century interest began to be focussed upon the brain itself, and the polarization of ideas occurred, that has lasted almost to the present era. The dominant theory of that period characterized the brain as an undifferentiated organ acting as a receptor site for incoming stimulation. This model, known as the theory of brain homogeneity was the most powerful at the time, and was supported by one of the periods most eminent physiologists, Albrecht von Haller (1708-1777). A further model held the brain to be a collocation of 'centres' or 'little organs', that were responsible for the different brain phenomena, whether (strictly) mental or behavioural. This view was to find increasing empirical support towards the end of the 18th century, as neurosurgeons located specific sites for the control of respiration and the control of the fore and hind legs of the dogs, Polyak (1957, p.122) cited the Frenchman Saucerotte as having performed such studies in the 1760s.

The localization model was quickly carried to an almost farcical extreme in the development of Fancis Gall's theory of Phrenology. In their paper of 1808 Gall and Spurzheim forwarded the most elaborate theory of localization that had ever been attempted. It was too complex for a variety of reasons; the detail in the mapping of function onto the brain far outstripped the contemporary knowledge of localization. More damning in the view of many scientists of the period was the attempt to locate such complex functions as cleverness and criminality where previous work had only found functions at the level of the simple reflex. The extension of their model to the surface topology of the skull, placed the phrenological doctrine outside reasoned critical appraisal and Gall's contribution was entirely ignored by his contemporaries. It has been suggested however, that this episode helped to concretise emerging notions that distinctive areas of the brain could be isolated by reason of their structural differentiation and that these could in turn be identified with particular functions (Uttal, 1978).

It is appropriate to consider the evolution of the concept of a speech area, as representative of the development in efforts to localize the functions of mind within the brain. As well as being amongst the earliest of 'areas' to be considered, the concept of a speech centre reflects the task involved in identifying and locating particular functions. Furthermore developments in this area have been at the forefront in developing conceptions of localization for over two hundred years.

An early report of the speech centre concept was made by Jean Bouillaud (1796-1881). Post-mortem studies led Bouillaud to conclude that there existed a relationship between lesions to the anterior region of the frontal lobe and difficulties in speech. Subsequently Dax (1836) reported to the French medical society evidence which supported the view that a link existed between left hemisphere lesions, right hemiplegia and speech loss.

A further study again based upon post-mortem evidence, was to have far greater impact than previous studies and give new impetus to the concept of cerebral localization of function. Broca (1861) studied a patient called Leborgne who had been without the power of speech for 15 years. Although the patient exhibited ephemia he was closely questioned and examined by Broca prior to his death.

Leborgne retained the capacity to understand speech and express himself through simple sign language, thereby providing Broca with clear evidence of his relatively unimpaired power of reason and a history of his disorder.

The patient's speech behaviour was confined to the use of the word "Tan" and as Broca described it 'a gross oath', "sacre nom de dieu." The finding that patients recovering from left hemisphere lesions are limited to expletives and phrases of an automatic nature has since been confirmed many times (Smith, 1966; Zaidel, 1973). Similarly Simernitskaya (1974) noted that left cerebral damage removes the ability to write in a well organized manner, a characteristic which is not apparent when patients are asked to write out well-known phrases. However it is important to point out that such remnants of speech behaviour can be located at the sub-cortical level (Eidelberg and Stein, 1977).

To a certain extent, the importance of Broca's work lies in the way it highlights the limited nature of the concept of function and the 'centre' in which it was deemed to be located. The concept of functions was hampered by the lack of definition enjoyed by any particular function. Instead functions were described by somewhat gross labels, thus they lacked the specificity required in order to resolve apparent contradictions arising from the study of deficits particularly those in the cognitive domain.

It is also important to remember that the essentially integrated nature of the brain does not lend itself to the drawing of direct conclusions as to the localization of function, from the consequences of brain damage. The implications of this will be drawn out in the subsequent discussion, but it is essential to make explicit two early problems; the difficulty of defining the various higher mental functions and the consequent impossibility of drawing unequivocal inferences from data arising from brain damage.

2.1.1 Gross Models of Cerebral Localization

An early attempt at a theoretical synthesis of the growing literature concerning the localiz ation of cerebral function was that of Hughlings Jackson (1884). The theory had to encompass a variety of phenomena; there was already evidence for the very specific locali ation of motor behaviours, (Fritsch and Hirtzig, 1870; Ferrier, 1876). As well as evidence for the variability of dysfunctions exhibited by lesions of other areas, notably those designated as being responsible for speech behaviour (Broca, 1861; Wernicke, 1874).

In keeping with the dominant intellectual model of the period Jacksons theory incorporated many aspects of Dawin's account of evolution. Jackson proposed a model which represented an evolutionary organization for the nervous system; a hierarchy of increasingly complex levels of organization characterized by a high degree of interdependency.

The system envisaged by Jackson was susceptible to interference at two different levels; the uniform and the local. Deficits arising from damage to a uniform level of organization would give rise to generalised dysfunctions and damage at the local level would have specific behavioural consequences. Thus Jackson embraced the concept of equipotentiality, as it had earlier been proposed by Flourens (1824) and was subsequently to be promoted by Lashley (1929). In an important sense, however, the model proposed by Jackson (1884) did retain the notion of a particular location within the brain for specific functions.

In agreement with Jackson (1876), Gowers (1887) maintained that both the right and left hemispheres could analyse speech, especially automatic speech, which as previously noted consists of expletives and overlearned phrases. Even Broca proposed that the right hemisphere played a significant role in speech (Broca, 1865). Thus evidence which could be interpreted as supporting a global model of brain activity, had accrued from the most intensively researched function with respect to neuropsychology. The most widely used model of research activity, that of anatomoclinical observation based upon discrete cerebral pathologies had focussed largely upon speech.

The dominant school of thought in the emerging discipline of neuropsychology was however the localiz.ationist and associationist movement (Charcot, 1887). The nature of these theoretical positions is analysed in the next section. It is important to introduce them at this point to suggest the element of reaction that was an important feature of globalist models proposed around the turn of the century.

Continuing the emphasis upon speech phenomena it is useful to note that a number of globalists denied that particular memories were affected by cerebral damage in the way that the associationists proposed. Instead they suggested that the continuous process by which memories were held to develop was somehow interrupted (Jackson 1864, 1876; Bergson 1896). In the same conceptual framework Marie (1906,a,b) attacked the localizationists' position, denying the various forms of Wernicke's aphasia and their putative locations, asserting rather that Wernicke's aphasia represented a specific intellectual dysfunction. The holistic approach adopted by Marie (1906) was successfully prosecuted by Pick (1913) whose research centred upon

Jackson's earlier theoretical statements of the globalist position (Jackson, 1876).

Although interest in the relationship between functional damage and localization continued in the holistic vein (Von Manakow and Mourque 1928; van Woerkom, 1921), the theories of the developing school of Gestalt psychology were beginning to influence research (Gelb and Goldstein, 1920; Gelb, 1933). The neurophysiologist Lashley who was to have great influence over the localization movement produced evidence in keeping with the Gestalt position during this period (Lashley, 1922). Lashley (1922) demonstrated the difficulty of locating or isolating, specific functional systems either before or after injury.

Lashley had worked with Franz, a physiologist who had showed that there existed cerebral asymmetries for the site of motor control of the hind limbs of a dog (Franz, 1915). Evidence of asymmetries of function and for relearning after critical damage, even where there was no regeneration of tissue, was argued by Franz to reflect the limitations of the concept of discrete motor centres such as that proposed by Fritsch and Hitzig (1870). Impressed by these findings Lashley sought to expand them (Lashley, 1923) and finally offered an integrated interpretation of the results (Lashley, 1929). In his discussion Lashley proposed that individual variation in location can arise from two sources, namely anatomical and physiological variation. Furthermore he proposed that physiological variation represented the independence of structure from function, functional localization arises as a dynamic quality of the system and is inherently variable.

Earlier work (Lashley, 1926) had led Lashley to adopt the principles of 'Mass Action' and the 'Equipotentiality of parts'. In his 1926 study, Lashley had revealed a link between the amount but not the location of cerebral damage in reducing the level of post injury learning of new material. Equipotentiality was used to designate the capacity of intact remains of a functional area to carry out without any corresponding loss in efficiency, the functions of the intact whole. However, Lashley was careful to qualify this concept by suggesting that this capacity varies from one area to another, and that it was most probably only important in relation to damage in the association areas and for functions above the level of simple sensory or motor coordination.

The concept of equipotentiality was itself qualified by the concept of mass function; equipotentiality was not absolute but governed by a law of 'mass-action', in essence mass action only occurs when the damage is in an area where the component parts are not more specialized for one component of a complete task than for any other component (Lashley, 1929). Thus equipotentiality as a property was restricted to only those areas of the brain which exhibited common functional capacities, but not outside of such areas. The value of this approach lay in the assertion that the execution of complex tasks would involve a number of these areas and that any future advances would develop from an understanding of how the various functionally distinct areas integrate cooperatively. Radical localization models of the same era (e.g. Charcot 1887; Campbell, 1905; Brodmann 1909; Von Economo and Koskinas, 1925) proposed a static conception of structure which precluded such an insight.

Lashley specifically addressed the problem of the neural site for memory when he concluded that "The learning process and the retention of habits are not dependent upon any finely localized structural changes within the cerebral cortex." (Lashley, 1929, in Hernstein and Boring (1965, p.247). This theoretical position was further supported by evidence that cerebral insult interfered with new learning, independent of its site of action (Lashley, 1926).

The phenomena of mass action is now considered to be a property of the brain that arises from the very high levels of interconnectivity between and within the two hemispheres of the cortex and the lower regions of the brain. For an example we shall consider re-education which was and still is a very important issue in the study of cerebral localization. The problem is centred around a subject's reacquisition of skills presumed to be located in a site that has been destroyed. The reasons for such a recovery can be found in many qualities of the organization of the brain, but it is sufficient to point out here that they need not include the property of mass action.

Re-education in particular is very much dependent upon at least one phenomena which has little to do with mass action. Diaschesis is a theoretical concept which describes the temporary disruption of function affecting neuronal complexes remote from the site of cerebral insult or lesion itself. Thus a general deficit of a temporary nature can occur, as dormant functional complexes recover. The interrelated nature of large areas of the cortext is reflected by these temporarily functionally disabling non-operative areas. When finally these areas regain their previous levels of activity the so-called 're-education phenomena' occur, which arises not from the ability of other cerebral areas to take over their roles, but simply from a renewed capacity to carry them out in their original location.

In some respects it could be argued that the mature statement of Lashley's position (Lashley and Clark, 1946; Lashley, 1950) constituted something of a reaction against the radical localization theories that had earlier proposed. Cytoarchitectural knowledge had advanced greatly with research based upon the large number of head wound victims it had been possible to study at the end of the Second World War (Conrad, 1947, 1949, 1954). This work had inevitably led some researchers to conclude from the variety of evidence with regard to specific deficits which arose from cerebral damage, a stricter localization hypothesis (e.g. Nielson, 1946).

Lashley (1950) however maintained that there are no localized 'stores', for items stored in memory such as those which had characterized the associationist model (Charcot, 1887). Instead he argued that memoranda are ubiquitously represented and hence distributed throughout the brain. Insofar as he proposed the absence of any unique site for memory, at the same time as he suggested localized centres where particular functions were carried out, his conclusions would appear to be currently valid (Pribram, 1969; Gazzaniga, 1970). Principally it would seem,because Lashley's thinking was never as polarized in terms of radical localization or global models as some might seek to represent it.

2.1.2 Radical theories of cerebral localization

The first paper which made a significant contribution to the modern theory of cerebral localization was that published by Broca in 1861. Although this paper has already been discussed, it is important to add that Broca's findings were crucial to the rejection of the principle of hemispheric equivalance, previously the dominant conception of the way in which the hemispheres operated. It is also true that Broca's aphasia served as an example of how behavioural effects of cortical damage could be linked to specific locations. This conceptual model was to have a profound influence upon subsequent research and theory construction.

After Broca, the work of Fritsch and Hitzig (1870) offered further evidence in support of the notion of discrete brain centres, the localization model of cerebral function. Their research, carried out on dogs, was based upon the electrical stimulation of the cortex, a new development technically, as hitherto the belief had been that the brain could not be excited by discrete stimulation. Fritsch and Hitzig (1870) however established the existence of a series of motor centres in the precentral region of the cerebral cortex. Moreover they showed that the foci for particular muscle groups were separate from one another and of limited size, thereby providing evidence of direct cortical representation of behaviour, which could only be interpreted in terms of a radical model of cerebral localization of function.

Further work concerned with the location of motor control led to the development of a more precise map of the motor cortex, important in this effort were the writings of Ferrier (1843-1928), Beevor (1854-1908) and Horsley (1857-1916) (see Uttal, 1978). Betz (1874) had already shown that the constituent cells of the motor cortex distinguish that area cytoarchitecturally.

During the same period advances had been made in localizing sensory functions, particularly those related to vision (Munk, 1890). Thus by the beginning of the present century, the distinction between sensory, motor and speech functions as cerebral centres had largely been settled. Throughout the first 40 years of the twentieth century, a strict or radical model of cerebral localization flourished. The conflict between upholders of this position and those who embraced a globalist position continued for some years. (See Hécaen and Albert, 1978). The conflict was concerned both with the evidence surrounding speech deficits and theories of the localization of sensory and motor functions.

The work of Kleist (1934) exemplifies the position of the radical localization school of thought. He published a detailed mapping of psychological functions onto cerebral locations in 1934. Although Kleist's model represented an advance upon an earlier associationist school of strict localization, which had proposed a model based on the ultimate mapping of every memory of a unique verbal event (Charcot, 1887).

As has been mentioned, the extensive and vigorous research upon head wounds during and after the Second World War provided new impetus to localization-associationist models and global theorists. Subsequent work carried out on pateints undergoing surgical treatment for epilepsy, enabled Penfield and his colleagues to advance our knowledge of the location of motor and sensory cortical projection areas (Penfield and Roberts, 1959).

The situation with regard to the cortical localization of function is still somewhat confused, adherents to the localization model are however, still in evidence (Geschwind, 1970). However a quotation from Penfield's important work Speech and Brain Mechanisms exemplifies the difficulty of drawing any conclusions for the present:-

> "No discrete localization of lesions producing various types of Agnosia and Apraxia have yet been found." (Penfield and Roberts, 1959, p.78).

Theories of strict cerebral localization developed from evidence that localized damage to the cortex, whether through illness, accident or extirpation led to specific behavioural deficits. Early studies were based on small, largely uncontrolled samples, the anatomoclinical method was long restricted in the quality particularly the replicability of its results. Work on animals, based as it was on deliberate and systematic lesion and excitation studies was rather inclined to support the localization model. Largely because they could not be considered with higher functions such as speech which are more diffuse in their cortical representation. For this reason only limited attention will be paid to such studies in the course of this discussion of speech localization and laterality effects.

In the present era the wealth of evidence from a number of converging lines of research has forced the recognition that for many factors, especially speech, dysfunctions caused by cerebral damage give rise to a syndrome of disorders and not discrete behavioural disabilities. A theory based upon functional zones, couched in an extended localizationist vocabulary, would seem to have closed much of the gap between the previously othogonally opposed theoretical positions (Hécaen and Albert, 1978).

2.2 Current theories of the Localization of Mental Functions

Having established the development of thought upon the problem of locating mental functions in cerebral space, an attempt will now be made to relate the localization of function hypothesis, in its current form, to the study of asymmetries in cerebral functions. It is now widely accepted that cytoarchitecturally different parts of the brain subserve different functions (Penfield and Roberts, 1959; Geschwind, 1970; Mountcastle, 1978). The quality of definition assigned to the word 'function', would still appear to be a subject for vigorous debate. For the present, however, we will consider work largely based upon the cortical mapping of sensory functions and leave a full discussion of the concept of function until later in this section.

The representation of function in cortical space is dependent upon the relationship between structure and organization. These related levels of description are both required in order to attempt an explanation of functional localization. The concept of organization has increased in importance as our knowledge of the nature and extent of the connectivity of the neocortex has developed. It has now been shown that each brain area enjoying a different cytoarchitecture and particular functional capacities also exhibits a unique set of extrinsic connections. In that the range of functional characteristics a specific area can exhibit is determined by its pattern of physical connections with other parts of the brain.

The experimental work that has laid the foundations for this connectivity model is extensive and based upon a variety of paradigms. Beginning with the studies of Rose and Woolsey (1948 a,b) which were based upon cats, an effort has been made to correlate the findings from a close analysis of the cytoarchitecture of an area and the consequences of electrical stimulation. Rose and Woolsey (1948 a,b) defined the auditory cortex, with reference to its peculiar cytoarchitecture, as the cortical zone of projection for the medial geniculate nucleus of the dorsal thalamus and that area of the cortex which was activated by electrical stimulation of the spiral osseous lamina of the cochlea. In all three cases the zone of the cortext that was isolated, proved to be almost entirely coextensive.

This system of converging operations has contributed to our knowledge of other functions; Mountcastle and Powell (1959a) worked upon the somatic sensory system, Hubel and Wiesel (1968, 1970) similarly added to our knowledge of the visual system, and Evarts (1964), Duffy and Birchfield (1971) among others have successfully examined the association areas. These later findings have led to the conclusion that the static and dynamic functional properties of cortical neurones are related to their area of cortical location. Mountcastle (1978) has characterized the importance of the systematic and extensive cortical interconnectivity in the following way:-

> "These patterns are in no way accidental. They are detailed and precise for each area; indeed they define it. (Mountcastle, 1978, p.15)

Mountcastle (1978) has gone on to propose a model which emphasises that these facts do not presuppose any intrinsic differences of structure or function <u>within</u> a given area of the cortex. Indeed he suggests that such areas are made up of a basic unit, functional uniformity is therefore based upon the replication of a basic neural module. Thus he argues, cytoarchitecturally differentiated areas are therefore defined almost exclusively by their particular arrangement of input-output connections. The basic unit of the neocortex is therefore of a remarkably uniform intrinsic design and consequently its functional role must be defined in terms of its dynamic connectivity with other units.

Mountcastle (1978 a) has described this neural unit as a column which is:-

> "A vertically arranged group of cells heavily interconnected in the vertical

axis running across the cortical layers
and sparsely connected horizontally."
(Mountcastle, 1978, p.36)

Details of this system are not relevant to the present discussion, it is sufficient to recognise that those modules or 'mini-columns' are far more numerous than has previously been appreciated (Mountcastle, 1978 b) and that their degree of connectivity have similarly been found to be much greater by recent research (Rockel, Hiorns and Powell, 1974; Szentagothai, 1978).

The model developed in the light of this research indicates a system of enormous complexity which is inherently flexible. A functionally homogenous cortical region can be connected internally in many ways, and consequently can exhibit many subsets of organizational levels. These subsets can also be linked with subset levels of organization within other functionally specified areas. This numerous, highly selective and specific pattern of organization has been described as a 'distributed system' (Mountcastle, 1978 a, p.40).

The large number of those 'distributed systems', can be said to reflect the degree of overlap between the major functional areas. Effectively this level of organization would appear the neural representation of Kinsbourne's 'functional cerebral distance' concept. The direction and number of associations that constitute a distributed system determine the functional distance between functional sub-elements. A single module could well be a member of several such 'distributed systems'.

A distributed system can be said to represent a variety of flow paths for information, the dominance of each path being inherently variable, representing the dynamic properties of the system. The distributed system, as a level of organization, includes many inputs and outputs, potentially the contribution to outflow systems can occur at many levels.

The model also recognises the possibility of a distributed system enjoying a variability of command loci, the systems command function will originate at different points within its organization, as a function of the current demands made upon it. Different weightings arising from changes in the internal and external environment will lend authority, within the system, to that location which processes or holds the information most immediately required. However, the system design proposed by Mountcastle (1978) suggests that the function of the network, in a control or execution mode is not localized at any one point within the network. As Mountcastle describes it,

> "The function is a property of the dynamic activity within the system: it resides in the system as such" (Mountcastle, 1978a, p.48)

This model precludes the total destruction of particular functions by localized lesions, instead the size and locus of the damage will involve subtle deficiency patterns (Hécaen and Albert, 1978). The role of the destroyed site may, for example, represent a non-critical, complementary or redundant sub-process which can be relocated or abandoned. Thus a change in processing strategy in terms of reorganization, may circumvent some long term deleterious consequences of neocortical damage. The short-term consequences of importance are those linked with diaschesis.

As Mountcastle's work on the concept of 'command centres' is based upon research into the functioning of the visual system (Mountcastle, Lynch and Georgopoulos, 1975), it is possible to suggest an example of the process outlined above. McKay (1978) has proposed that the centres described by Mountcastle and his colleagues represent an executive rather than a dominant level in the supervisory system. Thus damage will affect the integration of visual functions rather than vision itself. In support of this proposal there is the evidence of "blindfield" vision in human beings with lesions of the occipital region (Weiskrantz, Warrington, and Saunders, 1974).

In blindfield vision, a 'cortically blind' subject can accurately 'guess' the location of an illuminated spot which they cannot report seeing. Evidence of a strong dissociation between sensory capacity and awareness. Furthermore recovery from cortical blindness almost always occurs when it arises from head injury or vascular lesions (Teuber, Battersby and

Bender, 1960), although it can take months or even years.

The point has now been reached where some attempt can be made to relate this conception of cortical organization to the speech function, and with particular reference to asymmetries in verbal processing. Although evidence of asymmetries of function has been available for more than a century (Broca,1861), it has never been clear exactly how these relate to normal functioning and more importantly, to what extent they are a product of the lack of a precise definition of function.

For example Broca (1861) failed to distinguish between speech production and speech comprehension; when his aphasic patient clearly exhibited an ability to comprehend speech, this residual capacity was attributed to the undamaged right hemisphere. Subsequent research has underlined the importance of separating these two functions of comprehension and production, for a complete understanding of speech localization (Zaidel, 1976). The necessity of specifying the sub-processes involved in languages, is highlighted by the very imprecision of the cortical representation of language. Luria (1966) has described this situation:-

> "The higher mental functions may be disturbed by a lesion of one of the many different links of the functional system; they will be disturbed differently by lesions of different links". (p.71)

The situation with respect to language, perhaps the most frequently examined of the higher mental functions, characterizes the difficulties faced by the radical localization model in recent years:

> "In many aphasiologists' opinion, the exact anatomical substrate for language remains elusive, especially for the cognitive side of language". (Lenneberg, 1974, p.524)

Radical localization theories of language organization which have flourished since the work of Wernicke (1874), still gather support (Geschwind, 1970), even to the extent of an attempt to locate discrete sites for specific sub-processes of speech (Marsland, 1971).

The findings which suggest that patients have recovered normal speech functioning after the total destruction of Wernicke's and Broca's areas (Lenneberg, 1974) must make the radical localization position a difficult one. Uttal (1978), for example, has summarised the evidence that lesions to supplementary motor areas located away from Broca's area, can give rise to the same deficits as lesions located within that area. Results of this nature are highly problematic if considered from a radical localization viewpoint. In fact present opinion would seem to have moved away from this position; Uttal (1978) placed much of the recent work in context when he stated that:-

> "The primary sensory projection regions and the region from which motor signals emanate do seem to have more sharply defined boundaries, and to possess at least topologically consistent topographic representation of the external world. Establishment of the limits of a

> circumscribed "speech" centre or, worse yet, of a courage center, however, is far less easily achieved". (Uttal, 1978, p.286).

The difficulty in locating specific features of language functioning are partly due to the inexactitude with which the concept of function must be employed. For example it is highly likely that characteristic processes within the meaning of speech function consist of a multitude of sub-processes. For instance as they cannot all be defined, it could well be that they only exist at that level of organization during a particular task. Then the task of mapping psychological functions onto cortical space becomes profoundly difficult.

On the other hand it must be obvious that certain psychological constructs will not have a cortical representation as such. If the structure of the cortex in relation to function, is a dynamic rather than a fixed property of the system then it is unlikely that we ever could 'locate' in cortical space, certain psychological functions. In so far as we have failed to define in exhaustive and exclusive terms the content of speech behaviour, it is also possible that we shall continue to fail in locating some sub-processes which may well reside in a particular cerebral location.

So far the data have reflected the consequences of a complex system which is extensively interconnected in a dynamic fashion. The temporal lability of system characteristics such as control of speech function, is not as yet an integral part of theories of localization of function. Although many authors consider it a useful strategy to regard symptoms of language disorders arising from whatever cause as representing language 'zones' (Brain, 1965; Luria, 1970; Hécean, 1972). Such zones are, it would appear, characteristically larger and less discrete in their attributed capacities, than was previously considered to be the case.

In conclusion it is suggested that the obvious unifying and integrative qualities of trans-callosal and sub-cortical inter-hemispheric transmission (Milner, 1974; Ellenberg and Sperry, 1980) imply that the distributed systems described in this chapter are organized between as well as within hemispheres. The weight of evidence would suggest that this fact is of paramount importance when considering asymmetries in language behaviour. Global descriptions of function as employed in dichotic listening research, combined with poorly specified sub-components of tasks would suggest the inevitability of variation in results. Furthermore, the tendency to modify procedures from one study to another (Westland, 1978) ensures a low level of replicability.

Overall we must be cautious of attributing hemispheric differences in performance as direct consequences of the structural organization of the cortex. Mountcastle has suggested that cerebral function does not reside at a particular cortical location. It is argued that function is defined by the current pattern of neural activity, which places any particular function by defining its dynamic relations with other areas of the cortex.

This implies that the functional organization of the cortex is a reflection of theprocessing behaviour which is underway at any particular moment. The structural organization of the cortex underlying any given function is actively determined by the pattern of connectivity. As this pattern is constantly changing in keeping with changes in the environment, then functional structures are plastic rather than fixed characteristics of the cortex.

It follows therefore that cerebral asymmetries arise from the extent to which each hemisphere represents a distributed processing system for the execution of a particular task. The wealth of connections which join the two hemispheres suggest an integrated rather than dichotomous processing system (Milner, 1974; Ellenberg and Sperry, 1980). Consequently the search for lateral asymmetries of the higher mental functions, should be tempered by the knowledge that it is unlikely that they are uniquely resident in either hemisphere.

2.3 The study of cerebral functional asymmetries in man

This section of the chapter is concerned with the evidence derived from the study of functional localization in man, with most emphasis being placed on asymmetries of function. An attempt will be made to provide the psychological background to current theories of asymmetry from the perspective of research on selective attention. Once again the emphasis is placed upon the question of asymmetries in the cortical representation of speech behaviour. Finally this material will be drawn together in the form of a critical analysis of the dominant theoretical conceptions of cerebral asymmetries. It is intended that this should form the basis for drawing some conclusions concerning the relationship between theories of functional localization and theories of selective attention.

2.3.1 Studies of Split-Brain Patients

The study of patients who have undergone a partial or complete section of the corpus callosum, the hippocampal commissure and perhaps the massa intermedia forms one of the most important sources of data for modern theories of functional hemispheric differences. The operation is performed upon human subjects, as part of a programme of treatment undertaken to relieve severe epileptic attacks. By eliminating direct cross-communication between the hemispheres, this technique allows for the independent assessment of functional capacity forthe right and left hemispheres (Sperry 1968; Gazzaniga and Bogen, 1969; Gordon and Sperry, 1969; Levy, Trevarthen and Sperry, 1972).

In many aspects the commissurotomized patient offers an ideal opportunity for comparisons between the hemispheres, all major individual factors can be equated; for example background, age and sex. Direct comparisons on the same task can be made in the same individual and fine distinctions as to the independent performance of the two hemispheres can be studied where previously none were apparent.

The literature includes several extensive reviews of the disconnection syndromes as they occur in animals and man (Sperry, Gazzaniga and Bogen, 1969; Dimond and Beaumont, 1974; Kinsbourne, 1975 b). The present discussion is therefore limited to the literature on hemispheric disconnection only insofar as it bears upon the question of speech analysis and comprehension.

Early studies of hemispheric disconnection syndromes in animals (Myers, 1960; Sperry, 1961), implicated the corpus callosum and other neocortical commissures in the inter-hemispheric transfer of learning and memory. Similar work upon human patients supported the pattern of functional asymmetries developed from the evidence of lesion studies and other types of damage to the cortex (Sperry, Gazzaniga and Bogen, 1969). The left hemisphere was demonstrated to be the main centre for language and calculation (Sperry, 1970). The right hemisphere was found to be without expressive language capacities; unable to express in speech or writing objects placed in the left hand or presented to the left half of the visual field (Gazzaniga and Sperry, 1976).

The most salient feature of split-brain research for the purpose of the present work, is the impact it had upon the model of right hemisphere capacities in the domain of language. Even in the literature based upon studies of brain damage, little attention had been paid to the effect of right hemisphere damage upon language function (Hécean and Albert, 1978). It has been noted, however, that right-sided lesions gave rise to a visuospatial constructional apraxia (Zangwill, 1964) and this finding was closely corroborated by split-brain studies which showed a right hemisphere superiority in the construction of block designs and the copying of complex figures such as the Necker Cube and the Greek Cross (Bogen and Gazzaniga, 1965; Bogen, 1969).

The right hemisphere has been found to exhibit a high level of language comprehension for both spoken and written words (Gazzaniga and Sperry, 1967; Dimond, 1972). Auditory comprehension was shown to be restricted to nouns and some adjectival forms, the use of tests based upon the visual presentation of verbal stimuli however called for an extension of this description of right hemisphere linguistic capacity.

One of the most important gains brought about by split-brain research, would seem to be the evidence which supported the separation of speech comprehension from speech production (Gazzaniga, 1970). Research based upon this dichotomy has led to several developments in our understanding of the right hemispheres language functions.

The principal source of evidence regarding the detail of right hemisphere language capabilities has come from the work of Zaidel (Zaidel, 1976, 1977). Employing a specially constructed battery of tests (Zaidel, 1978) and a technique enabling the presentation of visual stimuli to a particular area of the visual field during ocular motion, the unique quality of right hemispheres speech capacities have become apparent. Although the language processing capacities of the right hemisphere have been compared to that of the aphasic (Kinsbourne, 1971) Zaidel, (1978) showed that a close analysis of errors committed by the right hemisphere revealed differences between the right hemisphere and aphasics and children. Particular differences were the right hemispheres sensitivity to auditory and short-term memory constraints.

The auditory vocabulary of the disconnected right hemisphere was shown to be as large as that of normal subjects, a finding which has an obvious bearing upon the experiments presented in this thesis. Auditory comprehension however was found to be severely limited, although the right hemisphere was shown to be capable of understanding verbs, names of actions and nouns.

The evidence from the comprehension of test sentences is illuminating in the context of the criticisms made of G.S.R. studies in the previous chapter; whereas component words of each sentence were understood, they were not integrated, there being no evidence of any deep encoding of sequences. This confirms the findings of Forster and Govier (1978) but by no means supports their conclusions, since they exercised no control over ear of arrival effects.

Although the work which has served to correct the underestimation of right hemisphere linguistic capacities is obviously important, much of the work based upon studies of split-brain patients has emphasised the complementary and cooperative relationship of the two hemispheres and it is to evidence of this kind that we now turn.

Nebes (1971) designed a task which required the matching of portions of a circle-segment of an arc, performance on this task was entirely mediated by touch. Performance on this task and a further study conducted by Nebes (1971) indicated only a chance level performance by the left hemisphere on tasks mediated by touch.
It would seem therefore, that to a certain extent the functional capacities of the hemispheres fail to overlap. Sperry (1974) has speculated that this reflects the incompatibility of the two different modes of processing

represented at the left and right hemispheres and that they would be in biologically wasteful conflict were these functional styles to be bilaterally represented. Levy (1969 a) characterized the difference in the processing characteristics of the two hemispheres, when she argued that the performance of the right hand was dependent upon a serial process of verbal reasoning, and the left hand upon a rapid and silent process, unaccompanied by the verbal commentary that characterizes left-hemisphere right-handed decisions.

There are some interesting data which have a bearing upon the manner in which the different processing systems interact. De Renzi (1971) has shown that patients with right hemisphere lesions suffer a performance decrement on a rod orientation test. This result was in apparent contradiction to previous results from a similar test where intact normal subjects had been employed (White, 1971).

Umilta, Rizzolati, Marzi <u>et.al</u>., (1974) have provided evidence that this contradiction can be accommodated by an explanation of the relative effectiveness of the two processing systems, in the face of changes in line orientation. They showed a right field dominance, represented by a faster reaction time, to the upright, horizontal and two lines tilted to the left and right. This they argued, indicates the relative facility with which these orientations can be verbally encoded.

The intermediate line orientations gave a pronounced left field reaction time superiority. It was concluded that in this situation a suitable level of discriminatory efficiency was not possible through the medium of language. In effect there was no verbal description which could allow a subject to represent with any accuracy the difference between rod orientations which were less than 45 degrees apart. Consequently, the task demands were more appropriately met by the right hemisphere which is superior in visuospatial processing Zaidel, (1976). Thus we have evidence that even though there are clear differences in underlying hemispheric capacities, they need not be expressed in a direct fashion. Hemispheric superiority on a given task would appear to be relative rather than absolute.

The effect of commissurotomy upon memory reflects the integrated nature of the relationship between the intact hemispheres. Associated with the commissurotomy operation there is a pattern of memory loss which has been closely studied (Sperry 1968 a, Zaidel and Sperry 1972) and this work led Sperry (1974) to state that:-

> "A specific role of the forebrain commissureo in mnemoric functions is suggested." (Sperry, 1974, p.15).

It is apparent therefore that although the left hemisphere is the source of language production and exhibits a superiority in speech analysis, it cannot be considered to be the sole repository of memory.

The pattern of deficits associated with commissurotomy indicates a role for the right hemisphere in 'working memory' (Baddeley & Hitch, 1974). Skills such as those required in card playing, or storing a telephone number are particularly effected. Although the effect would seem to be retroactive in its influence upon memories over a span of several years prior to the operation, an absence of any consequences for long-term memory indicates the left hemisphere's independence in this respect (Sperry, 1974).

A final line of evidence as to the nature of the interaction between the cerebral hemispheres derives from experiments concerned with inhibition phenomena. Levy, Nebes, and Sperry, (1971) provided evidence that the left hemisphere interfered with the right hemisphere's effort to write the names of objects presented to the left visual field. Smith (1969) reported that focal lesions within a hemisphere can result in deficits which are not found subsequent to the removal of the entire hemisphere. Searleman (1977) has interpreted this phenomenon as indicating that the malfunctioning area was responsible for 'disruptive influences', which following hemispherectomy were no longer transcortically transmitted. Various lines of evidence such as this have formed a major facet of a number of theories concerned with the lateralization of language (Gazzaniga, 1974;Kinsbourne, 1972).

The evidence from split-brain studies supports a view of the lateralization of language which takes into account the various independent and interactive capacities of the two hemispheres. Furthermore it must be accepted that certain aspects of normal language including some features of comprehension and memory, are based upon a co-operative effort.

The integrated nature of the two hemispheres is reflected in their neurophysiology, which is most apparent when consideration is given to those sensory functions which enjoy bilateral representation following commissurotomy. For example there remains a considerable degree of bilateral representation of auditory information, due to the sub-cortical cross-overs which are intact after commussurotomy (Sperry, 1964; Uttal, 1978). Similarly, the face and other axial structures are bilaterally represented along with somewhat gross representation of the extremities. The proprioceptive system is also represented bilaterally in the split-brain patient (McKlosky, 1973). It is also known that bilateral representation of the visual system persists in patients who have undergone the operation for midline callossal section. The cross-over of information involves pathways through the superior colliculus; pulvinar and inferior temporal area (Graybiel, 1974).

The evidence that the split-brain patients do not exhibit a complete structural decussation of the two hemispheres must influence any interpreation placed upon the results of research based upon this technique. Similarly some caution must be exercised in generalizing from the results of the subject population employed in split-brain reearch.

The limited size of the patient group involved in these studies reflects the extreme nature of the operation and the fact that it was usually the final alternative with regard to treatment. Sperry (1974) has pointed out the violence and danger of the epileptic attacks suffered by these patients, who were only operated upon when medication and unilateral lesions had proven inadequate for the purpose of relieving their symptoms.

It has long been argued, however, (see Levy and Trevarthen, 1977) that the uniformity of the deficits observed would not be consistent with their having a pathological origin. Levy and Trevarthen suggested that reorganization of function as a result of long-standing epilepsy, would have given rise to a much more diverse pattern of results when comparisons were made between subjects. This argument is dicussed by Cohen (1977), who suggests that a close look at the data reveals a considerable range of individual differences.

This last point is an important consideration as would appear that that total commissurotomy patients, a very small subject group as we shall discuss shortly, give rise to divergent patterns of results; which in turn suggests the history of a disorder and the individual pathology of an epileptic patient influence the hemispheric differences they might exhibit after a complete section of the corpus callosum. If this were to be the case, a number of problems arise in generalizing from the results of split brain studies.

The size of the subject group has always been limited, few reports in the literature are based on more than a dozen patients, frequently far less are employed. Furthermore the opportunity for expanding the size of the subject population has now passed, which is unfortunate in the sense that a larger subject population might here afforded an opportunity to disentangle some of the consequences of different pathologies as they influence the pattern of hemispheric differences. A new operation based upon a more localized section of the corpus-callosum is likely to supersede the total commissurotomy (Sperry, 1974). This development in surgical technique promises to reduce the number of disabling side-effects which follow the more complete section of the corpus callosum. It will also to a certain extent inhibit the progress of the line of research which has been based upon the unique opportunities afforded by the earlier operation.

A major problem with split-brain research remains that of distinguishing between those patterns of organization which might have arisen as a consequence of long-term epilepsy, any strategies for meeting the demands of testing procedures which develop and those behaviours which reflect the pattern of hemispheric organization in normal subjects.

Before going on to discuss these topics it must be pointed out that the intact brain exhibits characteristics such as inter-hemispheric facilitation and inhibition which do not govern the behaviour of split-brain patients. As Teuber (1974) has suggested the ability of one hemisphere to suppress the other or stimulate it depending upon the circumstances is an important feature of normal behaviour which might influence the interpretation placed upon the results of split-brain studies.

Subjects in split-brain research have been found to exhibit a number of compensatory strategies, for example they employ cross-cueing to transmit information between hemispheres; the right hand under the control of the left hemisphere can attract the attention of the right hemisphere via the visual system for example (Sperry, 1974). This system of subtle compensatory behaviours must be carefully guarded against in split-brain research (Zaidel, 1978). Allied to our knowledge of sub-cortical transfer of information occurring in split-brain patients, the problem of drawing conclusions from split-brain studies is intensified.

To conclude this discussion of split-brain research, we can enumerate a number of findings which might be of importance notwithstanding the reservation made above. First there is concrete evidence that right-hemisphere linguistic capacity is neither residual, in that it has been argued to represent a small degree of linguistic competence which is bilaterally represented nor disordered in so far as it was considered to be the source of aphasic speech (Kinsbourne, 1971). Instead it would seem to be appropriate to consider right hemisphere language as a distinct but complementary level of linguistic competence. The work of (Zaidel, 1976, 1978) has clearly demonstrated that right-hemisphere representation of language, particularly the spoken word, is highly efficient. Also we now know that the emphasis of the right hemisphere is both more diffuse and connotative in terms of its semantic structure.

Second it is also possible to conclude that the right hemisphere makes an important contribution to the memory capacity of the intact system, especially with regard to short-term memory (Sperry, 1974; Jaccarino, 1975; Milner, 1978). Once again emphasising the complementarity of the relationship between left and right hemispheres in so far as they both make a significant contribution to memory. Obviously these characteristics of right hemisphere speech must be important in any analysis of laterality effects as they might occur in the dichotic shadowing task.

2.3.2 Studies employing the dichotic listening technique

Dichotic listening was perhaps the first technique which demonstrated dual function asymmetry in the normal brain (Kimura, 1961 a). Since then there has been a tremendous increase in the number of studies concerned with laterality effects using this technique and the principle theoretical statements are largely based upon its use (Kimura, 1964; Kinsbourne, 1974). As the experiments reported in this thesis employed auditory stimuli, the discussion of techniques will largely be confined to studies of dichotic listening. Research employing split-hemifield and tachistoscopic techniques for the presentation of visual stimuli will not be dealt with here (see White, 1971).

As much of the reported literature is concerned with one of two competing theories, which will be discussed separately later in this chapter, the present section will be devoted to a study of the rationale behind the use of the dichotic listening technique itself.

In the sense that dichotic listening represents a technique for exploring functional asymmetries in the intact individual, it is based upon the assumption that auditory stimuli presented simultaneously to the two ears give rise to a functional decussation (Darwin, 1974). It follows therefore that such a technique is an attempt to achieve the same conditions as exist when the structural decussation of split-brain patients is established. In this respect, dichotic listening studies do not represent any conceptual advance upon split-brain studies and must be subject to some of the criticisms of that technique outlined earlier.

Dichotic listening studies are certainly not free from the suspicion that sub cortical transfer can occur as in split-brain studies. There is also recent evidence to suggest that there is a complex system underlying the ipsilateral transfer of information in the intact human being. Milner (1974 has characterized this possibility in the following manner:-

> "Normally a significant fraction of the input from the left ear to the right hemisphere comes via the corpus callosum." (Milner, 1974; p.77)

It can thus be argued that even if blocking of the ipsilateral pathways occur as a result of dichotic stimulation (see below), then information can still arrive at the ipsilateral hemisphere via the corpus callosum. Strong evidence that even if the basic assumptions behind the use of dichotic listening were to prove correct, there would be grounds upon which to query the models based upon the use of this technique. Indeed these reservations are discussed with reference to structural theories of attention in the next section.

The assumption behind the initial use of the dichotic listening technique (Kimura,1961 a) was that crossed auditory fibres are stronger than the uncrossed, an assumption based upon the work of Rosenzweig (1951) with cats. It has been argued that a relative superiority in the efficiency of contralateral as opposed to ipsilateral transfer of information would be insufficient to explain hemispheric differences (Milner, 1974). There is however a second line of evidence which supports the assumption of functional decussation arising from dichotic stimulation.

Rosenzweig (1951) presented simulataneous (dichotic) click stimuli to cats and noted that the ipsilateral flow of information, the representation of clicks presented to the right ear at the right hemisphere, is impeded by the simultaneous contralateral flow of information between each ear and the opposite hemisphere. This occlusion of ipsilateral transfer as reported by Rosenzweig (1951), is central to a structural interpretation of dichotic listening studies. It is important therefore that the experimentation which underlies this assumption, should bear close inspection.

Firstly some consideration must be given to the fact that the research was conducted upon heavily aneasthetized cats. Rosenzweig (1951) suggested that some restraint should be observed in generalizing from his findings, noting that:-

> "Since the cortical responses are affected so strongly by the physiological conditions of the experiment, great care must be used in attempting to correlate electro-physiological data with psychophysical functions." (Rosenzweig, 1951, p.879).

A more specific problem outlined by Rosenzweig was that the nature and time course of the ipsilateral blocking effect was considerably affected by a mis-match in the initial intensity of the click stimul. Very few studies in dichotic listening research have exercised control over the initial intensity of dichotically presented stimuli. Given that such research normally employs meaningful stimuliin the form of speech, such control is very difficult to achieve (Morton, Marcus and Frankish, 1976).

The 'tolerances in the temporal matching of words employed in dichotic listening have rarely fallen within the range where the blocking effect reported by Rosenzweig (1951) is likely to be strongest. Indeed typical reported error rates in the temporal matching of dichotic stimuli (for example Treisman, Squire and Green 1974), are so high as to jeopardize the validity of the assumption that ipsilateral blocking takes place at all. Furthermore it has frequently been the case that dichotic lists consist of continuous prose, a case not covered by Rosenzweig's results and one where attentional as well as structural factors are likely to have an influence.

A further problem with generalizing from Rosenzweig's results to human performances in a dichotic listening task throws into question the validity of a structural interpretation of laterality effects. Essentially the argument is that competition between neural pathways, and therefore ipsilateral blocking, should be at a maximum when inputs are presented simultaneously (Rosenzweig, 1951).

In fact, there is evidence that the right ear advantage for the identification of dichotic nonsense syllables is most easily established when left ear inputs arrive after rather than before right ear inputs (Studdert-Kennedy, Shankweiler and Schulman, 1970; Berlin, Lowe-Bell, Cullen, Thompson and Loovis, 1973). It is clear therefore that dichotic listening does not soley give rise to direct transmission between ear of input and the contralateral hemisphere. These data cannot therefore be attributed to a simple model of differential hemispheric capacity. Interpreting the results of studies based upon dichotic listening would appear to be an altogether more ambiguous exercise than would follow from a model in which it is assumed that the input from each ear is directly transferred to the contralateral cerebral hemisphere.

As a final comment upon the assumption of direct contralateral transfer of information there is the evidence of ear advantages arising from studies employing monoaural stimulation. Such effects have been widely reported; Bakker 1969, 1970; Frankfurter and Honeck 1973; Cohen and Martin 1975; Murray and Richards 1978). Clearly these results are not dependent upon competition between simultaneous inputs, indeed they fall outside any explanation based upon a fixed, structural contribution of hemispheric differences to laterality effects.

Before leaving the subject of the dichotic listening task itself, there is one further level upon which the methodology, or rather the use to which it has been put, has been criticised. Although none of the evidence reviewed here is new, nonetheless there has been a tendency in the literature to undervalue its implications, as notably underlined by Bryden (1978):-

> "We have become too accepting of the relation between behavioural laterality and cerebral organization." (Bryden, 1978, p.119).

This failure derives from two sources. Firstly little attention has been given to the evidence from neuropsychology which undermines such a simple model of hemispheric specialization. Secondly there would seem to be only a limited recognition of the failings inherent in the dichotic stimulation technique. Both Bryden (1978) and Cohen (1977) have drawn attention to the tendency to employ the dichotic listening task as an index of speech lateralization, and relate this measure to any other variable such as sex, age, reading age, profession, and hypnotizability (Zurif and Bryden, 1976; Geffner and Hochberg, 1971; Bryden, 1970; Ornstein, 1972; Bakan and Strayer, 1973).

Bryden (1978) has suggested that subjects can evolve a variety of strategies for meeting the demands of tasks such as dichotic listening. There are a number of sources of bias which he claims, have hitherto been inadequately controlled. These include attentional characteristics, the memory component in experimental tasks and a variety of mnemoric strategies.

In conclusion, it must be stated that the weight of evidence militates against the possibility of drawing unambiguous conclusions as to the relationship between lateralized behaviour and functional hemispheric asymmetries from the data of dichotic listening studies. The words of Uttal (1978) make clear the position of physiological psychology with regard to some of the uses to which the dichotic listening task has been put:-

> "It is totall inapropriate, therefore, to suggest that without a commissurotomy,

the effects of a single hemisphere are assayed by a visual task, even if the stimulus had been positioned so that it was sent to only one hemisphere (as was done by Patterson and Bradshaw, 1975) - or that differences in left ear and right ear performances indicate differences in auditory hemispheric capability (as was claimed by Bever and Chiarello, 1974). In addition to the possible cross-connections through the corpus-callosum and other commissures, it should also be noted that the auditory system sends signals to both hemispheres from either ear with cross-over occurring as low as the medulla. Not only should an auditory experiment not be used in the normal patient to study this problem, but it would be an inappropriate stimulus in all but the most deeply split-brain preparations!" (Uttal, 1978, p.327).

2.3.3 Structural nodels of hemispheric differences

First used by Broadbent (1954), the dichotic listening task was taken up as a tool for examining hemispheric differences by Kimura (1961 a). Using digits as the competing verbal inputs, Kimura was able to show a consistent superiority for the recall of material presented to the right ear (Kimura, 1961 a,b).

The explanation forwarded by Kimura (1966, 1967) was based upon the assumption that one hemisphere is more effective in processing certain types of material, or processing information in a particular fashion. It was further argued that information arriving at one side of the body has more direct access to the contralateral hemisphere; consequently the left hemisphere superiority for speech gives rise to a right ear advantage and a left side advantage would reflect the specialization of the right hemisphere.

It has already been suggested that the assumption that simultaneous stimuli give rise to an occlusion of ipsilateral pathways thereby inhibiting the transfer of information between each ear and its ipsilateral hemisphere, is dubious (Section 2.3.2). Furthermore the argument that contralateral transfer of information is the most effective was placed in perspective by Milner (1974) when she concluded that a significant fraction of the information from the left ear reaches the left hemisphere via the corpus callosum. Thus even if ipsilateral blocking did take place, interhemispheric transfer through the corpus callosum would seem to provide a similar function.

Notwithstanding these reservations, there has been a large number of studies, the results of which are in keeping with the model proposed by Kimura (1966). Apart from the evidence that shows a right-ear advantage for verbal material in dichotic listening (Kimura, 1961; Studdert-Kennedy and Shankweiler, 1970), there are studies which indicate a left-ear advantage for melodies (Kimura, 1964) and sound effects (Curry, 1967). There is therefore a body of evidence which lies entirely within the range of the model described by Kimura (1966).

Converging evidence from a different source would seem to add further support to structuralist models of laterality effects, where functional asymmetries of the hemispheres are considered to be directly related to the consequences of dichotic stimulation. In order to confirm the proposed correlation between the left hemisphere representation of speech and the right-ear advantage in dichotic listening, Kimura (1967) carried out a study comparing subjects who exhibited left hemisphere speech with those found to have a right hemisphere site for speech.

For the independent evidence as to which hemisphere was the site of the speech centres, the Wada technique was employed (Wada and Rasmussen, 1960). This method involved the use of intracarotid injections of sodium amytal to inactivite one hemisphere, when the dominant hemisphere for speech is involved the patient becomes mute for some minutes, if otherwise speech is barely effected (Milner, 1974).

Using this technique Kimura (1967) was able to demonstrate that when the Wada test revealed a right hemisphere location for the speech centre, then a left-ear advantage for dichotic listening ensued. Similarly she confirmed her own finding that the majority of right handers exhibit a right-ear advantage in dichotic listening and left hemisphere speech on the Wada test.

There are however a number of problems associated with the Wada test which cast doubt upon the support drawn from the findings of Kimura (1967) for a structural model of hemispheric differences. The use of the Wada test is restricted, due to its inherent dangers, to patients undergoing brain surgery usually in order to resolve the symptoms of long term epilepsy. Levy (1974) has pointed out that the subject population who have undergone the Wada test may not be representative of the population as a whole, suggesting that the language lateralization they exhibit may arise from their cerebral pathology. This topic is pursued in the literature upon the relationship between handedness and laterality, which we shall not deal with here (Searleman, 1977).

A second problem arises when the results of the Wada test are compared with patients who have undergone a complete section of the midline commissures (Milner, Taylor and Sperry, 1968; Sparks and Geschwind, 1968). Although both ears are represented at each hemisphere (Sperry, 1970), subjects reported very few if any of the items presented to the left ear. Under monaural conditions none of these patients failed to report digits presented to the left ear, indicating that the ipsilateral pathways, although intact, were not employed during dichotic stimulation (Milner, Taylor and Sperry, 1968).

The results of Milner <u>et al</u> (1968), stand in complete contrast to the results of normal subjects in dichotic listening tasks, where the difference between the ears is typically less than 3% (Kimura, 1964). The magnitude of the right ear advantage, would suggest that factors other than the efficiency of contralateral transfer and hemispheric specialization are required to explain the performance of intact subjects in the dichotic listening test.

The magnitude of the ear advantages noted in the dichotic listening literature has been the stimulus for a further range of studies that further highlight the problems faced by a structuralist interpretation. It has been noted for example that the test-retest reliability of the dichotic listening task is so low as to be incompatible with the model proposed by Kimura (1966).

Blumstein, Goodglass and Tartter (1975) estimated from their data on test retest reliability that 15% of subjects would exhibit a 'true' left ear superiority for dichotically presented consonants. As they pointed out the disparity between this estimate and the incidence of aphasias from right-cerebral lesions, indicates a difference in the lateralization of the language processing skills measured by dichotic listening and those involved in simple speech production. There is a large and growing body of literature that suggests a very poor re-test reliability for dichotic listening in normal subjects, who exhibit such high levels of individual variance, that the value of the dichotic test as an indicator of individual lateralization patterns is seriously questioned (Pizzamiglio et al 1974; Shankweiler et al, 1975; Blumstein, Goodglass and Tartter, 1975; Sulman et al, 1977; Spellacy and Watson, 1978).

In line with the repeated finding that the results of the dichotic test are not stable over time, there is considerable evidence that they are influenced by training (Perl and Haggard, 1975; Sidtis and Bryden, 1975). The finding that both practice and strategy effects are apparently capable of influencing the dichotic listening test (Perl and Haggard, 1975), has called for some development of the structural view of laterality effects arising from the use of the test.

According to Cohen (1977), the component stages theory can account for some of the variability in hemisphere differences arising from dichotic listening and techniques involvdd in the presentation of visual stimuli. Following the suggestion of Blumstein et al (1975) that the processes involved in dichotic listening are lateralized in a different manner from speech production alone, the component stages theory assumes that the various sub-components of a verbal processing task might exhibit different laterality patterns.

The processing of verbal stimuli can be decomposed into three stages (Cohen, 1977); the physical analysis, nominal or phonological analysis and finally a semantic analysis. Using a task based upon the comparison of pairs of upper and lower case letters, Cohen (1972) and Geffen, Bradshaw and Nettleton (1973) have succeeded in separating the physical analysis, analysis based on shape alone, from those associated with the name of letters, nominal matching. Their results indicate a left hemisphere superiority for the task based upon a nominal analysis and no difference or a small right hemisphere advantage for the physical match.

There is evidence to support this model. Studdert-Kennedy and Shankweiler (1970) analysed the ear superiorities associated with the recognition of stop consonants and vowels. The purely physical analysis of vowels betrayed no ear differences, recognition of consonants based upon a nominal analysis gave rise to a right-ear advantage. Spellacy and Blumstein (1970) reported an effect of subjects 'set' by establishing expectations with instruction they biased the results of identifying dichotically presented vowels; when subjects were led to expect speech sounds a right-ear advantage ensued, when they were expecting non-speech sounds a left-ear advantage was found. It is clear therefore that even the modified component stages account of a structural model has a number of weaknesses and is unable to explain all the data.

Before considering an entirely alternative model of laterality effects, we shall discuss one final development in the structural account of asymmetries in performance. The 'mode of processing theory' as outlined by Cohen (1977) reveals an orientation which differs from earlier structural models; being concerned with the process requirements rather than the stimuli involved, whilst maintaining many of the assumptions of the stimulus centred version of the model.

The process orientation of the 'mode of processing model' is largely concerned with the consequences of linguistic versus non-linguistic analysis of inputs, thereby preserving the dichotomy inherent in the structuralist position. Cohen (1973) exemplified this characteristic when she stated:-

> "The serial vs parallel processing difference is a concomitant of hemispheric predilection for nominal vs physical analysis," (Cohen, 1973, p.355)

The findings reported by Cohen (1973) supported the view that the left hemisphere could be categorized as a serial processing device, whereas the right hemisphere behaved as a parallel processor. The task employed by Cohen (1973) required the subject to judge a set of items as same or different, (one item differing from the rest) as a function of set size. The right hemisphere reaction times, did not increase as a function of set size, whereas the reaction time to stimuli presented at the left hemisphere increased with set size.

These findings are also in accord with the conclusions of Nebes (1974) who characterized the left-hemisphere as an analytic serial processor, and the right-hemisphere as an integrative processor capable of perceiving the Gestalt properties of a stimulus (Levy, 1974, 1978). Kimura (1976) has carried this further by relating speech lateralization to sequential motor control.

Ultimately this theory would seem to suggest that serial processing is a necessary quality of linguistic analysis and that certain kinds of stimuli are best processed in terms of language whereas other stimuli either cannot or would not be processed in such a fashion for reasons of perceptual economy (Umilta, Rizzolatti, Marzi et al, 1974, see Section 2.3.2). It is fair to conclude therefore that the question of hemispheric asymmetries is not directly resolved by structural models, rather they presuppose a left-hemisphere superiority for language processing. Any results which fall outside the direct interrelation of the structural inposition, are deemed to be accommodated by referring to the component stages of a particular task and the characteristic processing styles of the two hemispheres.

In effect then, the structural analysis of laterality effects has been adapted to accommodate a variety of findings which would appear to contradict such a position. This has been achieved by extending the consequences of the assumed basis for laterality effects; a left hemisphere predilection for linguistic and hence serial processing, and a right hemisphere capacity for parallel processing, largely because it is outside of the constraints imposed by a linguistic representation of stimul. These developments in structural models continue to be based upon the assumption that lateralized stimuli are analysed at the contralateral hemisphere. Therefore they do not represent any advance in the conceptualization of hemispheric differences which underlie laterality effects.

2.3.4 Attentional Models of Laterality Effects

It has been argued (Bryden, 1978) that purely structural determinants of laterality effects, such as those proposed by Kimura (1966) would give rise to larger and more consistent asymmetries in performance. The results of research concerned with laterality effects arising from non-verbal stimuli are particularly equivocal, the size of the predicted left ear advantage being less than the right ear advantage for verbal material, and less than an explanation based upon structural constraints alone might suggest (White, 1971).

Inorder to deal with these problems and the known impact of variable such as memory laod (Hellige and Cox, 1976) and expectancy (Spellacy and Blumstein, 1970) upon laterality effects, Kinsbourne (1970, 1973, 1975) proposed an attentional model of laterality phenomena. The core of Kinsbourne's model is not hemispheric differences in performance, but rather the relative activation of the two hemispheres at any one time. The model is based upon the assumption that performance is best for items located in space contralateral to the most activated hemisphere, and that the degree of activation can be determined by preceding circumstances. Thus verbal activity will lead to a right-side bias and non-verbal behaviour of certain types, to a left side bias.

An experimental analysis of laterality effects either establishes a 'set' for processing behaviour by instruction, or the subject's interpretations of instructions, or the subject's own though processess create an attentional predisposition. Kinsbourne (1973) accepted the importance of the left hemisphere's superiority in processing verbal stimuli and right hemisphere's efficiency in processing spatial materials; once processing commences the appropriateness of the hemisphere at which a particular type of information is provided will determine the overall size of the laterality effects. Thus non-verbal stimuli are more likely to give an unclear pattern of results, due to the frequency with which an attentional 'set' established by verbal thought misdirects incoming stimuli.

In suggesting that the hemispheres of intact human subjects are in reciprocal balance Kinsbourne (1975) afforded an explanation of the disparity between the results of dichotic listening tests performed by split-brain patients and intact subjects. Whereas split-brain patients are unable to report almost any left-sided dichotic inputs (Milner, Taylor and Sperry, 1968) there is by no means so large a disparity in the recall of dichotic inputs with intact individuals.

Kinsbourne (1975) proposed that the reciprocal action of the right hemisphere, when speech stimuli are presented to the left hemisphere is to transmit negative feedback so as to offset the attentional bias. As this feedback is postulated to travel to the left hemisphere via the corpus callosum, there can be no such reduction in a right ear bias once it is established in split-brain subjects.

Once activated by verbal activity, the left hemisphere will remain dominant and split-brain patients therefore fail to exhibit the normal level of right hemisphere linguistic functioning. Instead it is argued that such subjects display a level of lateral asymmetry uncharacteristic of normal functioning due to the destruction of the means whereby there exists a dynamic balance between the hemisphere and their respective proficiencies in stimulus analysis.

Kinsbourne (Kinsbourne, 1970, 1972, 1975) has reported a large number of studies which appear to corroborate his attentional theory of laterality effects. Kinsbourne (1970) showed that maintaining a list of six words in memory increased the efficiency of the right visual half-field and reduced that of the left visual half-field on a gap detection task. Thus an experimental bias towards the left hemisphere improved right visual half-field performance on a nominally right hemisphere orientated task. Kinsbourne and Cook (1971) demonstrated an interference effect between two tasks centred upon the left hemisphere, the time for which a dowel rod could be balanced was reduced on the right hand whereas the left was unaffected when subjects were required to repeat sentences. This result was interpreted as reflecting the fact that the left hemisphere had to simultaneously maintain both motor control and speech which reduced the overall level of performance.

Kinsbourne (1972) suggested that eye and head turning behaviour corresponds to the activation of the contralateral cerebral hemisphere. In keeping with this corollory of his model, Kinsbourne (1972) found that most right-handers orientate their eyes and head to their right when solving verbal questions. Similarly Kimura (1973) reported that speaking in right-handers is associated with more free movements of the hands, than when they are engaged in silent activities.

An important paradigm for research based upon the attentional model, requires subjects to engage in verbal activity (e.g. maintenance of words or digits in memory) whilst performing another lateralized task (Kinsbourne, 1970; Hellige and Cox, 1976). In their study Hellige and Cox (1976) found that a form recognition task (detecting a polygon) gave a left visual field right-hemisphere superiority. Subjects who held two or four words in memory exhibited a right visual field left-hemisphere advantage. More recently this same technique has produced data which it is difficult to reconcile with an attentional model of laterality effects (Hellige, Cox and Litvac, 1979).

Before considering the most recent work upon laterality effects, there are a number of studies which have indicated weaknesses in the attentional model which will be discussed. Moscovitch and Klein (1980) have suggested that the attentional effect has been small and inconsistent, based as most experiments have been, upon neutral or weakly lateralized tasks such as gap detection and polygon detection (Kinsbourne, 1970; Hellige and Cox, 1976).

Perhaps a good example of results that support this view are those of Cohen (1975) who presented subjects with randomised sequences of words, digits and dots. When subjects were presented with a cue as to the nature of the material to follow, a right field advantage for words occurred, as did a non-significant left-field advantage for dots. Once again the non-verbal task was poorly lateralized and the common finding of non-significant trends for supposedly right hemisphere task occurred. It is interesting to note that before a pre-trial cue was employed no significant lateral differences were found. The view that attentional factors are of secondary importance, significant only when other factors are not involved is supported (Cohen, 1977; Moscovitch and Klein, 1980).

Failures to find attentional effects where they might have been expected (Geffen, Bradshaw and Nettleton, 1972; Gardner and Branski, 1976; Boles, 1979) have also been observed. These results can be interpreted as indicating the restricted validity of the model proposed by Kinsbourne (1975). However the argument that the effect is small in explanatory power because of its size and low replicability (Moscovitch and Klein, 1980) is a weak argument in itself. As we have discussed, the ear advantage demonstrated with dichotic listening tasks have been small (Kimura, 1961) and unreliable Pizzamiglio _et al_ (1974) from the very beginning. Instead we might conclude that Kinsbourne's theory does not have unequivocal support (Bryden, 1979).

2.4. Present status of models of lateral asymmetries in performance

As long ago as 1972 Dimond proposed a channel theory of visual perception with regards to tachistoscopidally presented visual half-field stimuli. Hines (1975) confirmed and extended the hypothesis that under controlled conditions of bilateral stimulation the left and right hemispheres functioned as 'independent channels' for the processing of information. Each hemisphere receives stimuli presented to the contralateral visual field and the success with which stimuli are processed reveals the relationship between the nature of the stimuli and the processing propensities of the hemisphere at which it arrives. The model therefore assumes the structural allocation of functional efficiency between the hemispheres; verbal material at the left hemisphere, visuospatial processing at the right.

More recently Moscovitch and Klein (1980) have attempted to update structural models in which response asymmetries are held to represent the differences between the two hemispheres in processing different kinds of stimuli. The concept of the two hemispheres as independent processors, each with distinct capacity limitations, has been considerably extended. In essence Moscovitch and Klein proposed a number of advantages of direct access models as amended with respect to the predictions of attention theory (e.g. Kahneman, 1973).

Their work is based upon dual task experiments (Moscovitch and Klein, 1980), and to explain fluctuations in performance associated with them, the concept of limited processing capacity was invoked. It was argued that the existence of a concurrent task reduced the detection of items presented to both visual fields. The affect of the concurrent task is argued to interfere more with the items in the dominant hemi-field, their superiority in detection being attributed to privileged access to a specialized limited capacity central processor. Moscovitch and Klein argued that slight differences, such as those which arise from poorly lateralized tasks such as face recognition (Moscovitch, 1979), would be reduced or even abolished in the face of competition from a concurrent task, a suggestion which they validated experimentally (Moscovitch and Klein, 1980).

Perhaps the most important feature of the model proposed by Moscovitch and Klein (1980) is the manner in which it seeks to explain the priming effect as reported by Kinsbourne (1970, 1975) and others (Hicks, 1975; Hellige and Cox, 1976). In accordance with Kahneman's (1973) effort theory of attention, Moscovitch and Klein suggest that the capacity of the most appropriate channel (in the context of a direct access model) can be affected by task demands, level of arousal, activation and so forth. Thus processing resources available to the specialized channel may be increased by the addition of a concurrent task if, of course, the primary task does not already utilize all the capacity that can be made available. As a result items located in the preferred field for a particular task can be more efficiently processed and their detection thereby improved.

The sequence suggested by Moscovitch and Klein (1980) can, of course, only operate when the hemisphere in question is not already functioning at maximum capacity and when the secondary task does not exceed the total capacity available. Thus it can be argued that priming effects can only occur in a restricted range of circumstances, affording some explanation of their variability and (small) size. It is also possible to use this model as an explanation as to why priming effects are so readily found with respect to poorly lateralized tasks such as facial recognition (Moscovitch and Klein, 1980).

Whereas Moscovitch and Klein (1980) have sought to extend direct access models by incorporating principles from attention theory, Kinsbourne (Kinsbourne and Hicks, 1980) has developed a model which replaces a single-channel theory of attention and at the same time extends to the problems of lateral asymmetries in performance. One thing at least is clear, the two bodies of research are of increasing importance with respect to one another.

In line with studies which have necessitated a revision of strict single-channel models (Allport, Antonis and Reynolds, 1972) Kinsbourne has acknowledged that subjects can successfully divide attention between concurrent inputs. Kinsbourne and Hicks (1979) introduced the concept of functional cerebral distance in order to explain the common origin of interference effects in divided attention studies and studies concerned with laterality effects arising from the dual-task paradigm.

The model as proposed by Kinsbourne and Hicks is based on the notion that the programming of continuous activity occurs at specific cerebral loci, which it is argued compete for 'functional space', by means of spreading activation. The amount of cerebral space occupied by any particular programme is assumed to increase until the individual reaches maximum performance. Consequently behaviours whose loci of programming are closer together in 'functional space' are more likely to interfere with one another. Interference is deemed to be a characteristic of the degree of neural interconnectedness any two control loci exhibit, as the functional distance separating them (i.e. their interconnectedness) increases, then the less interfering cross-talk they will generate when orthogonally active.

The concept of functional distance, can readily explain much of the existing data with respect to dual stimulation studies in both attention and laterality research (Treisman and Geffen, 1967; Kinsbourne and Cook, 1971; Hicks, 1975). Moreover Kinsbourne and Hicks (1979) have marshalled an impressive amount of evidence as to the neurological basis for the concept of functional cerebral distance.

In concluding this survey some interesting parallels will be drawn between the competing theories of laterality effects. As more recent work has tended to focus upon the dual task paradigm (Hellige, Cox and Litvac, 1979; Kinsbourne and Hicks, 1979; Moscovitch and Klein, 1980) then so to theories of laterality effects have increasingly turned to the conceptual framework of attention theory.

Hellige _et al_ (1979) suggested that the two cerebral hemispheres can be considered as separate processing systems. Dimond (1972) and Dimond and Beaumont (1974) have demonstrated the increased efficiency which arises when the two hemispheres can share the load of particular processing activities. The strength of the model of two hemispheres as each having different capacities and subsequently levels of activation with respect to various task demands and stimuli, is embraced by Moscovitch and Klein (1980).

It is therefore possible to suggest that Kinsbourne's achievement in proposing his notion of functional cerebral distance is to unify the various positions. Moscovitch and Klein (1980) and Hellige et al (1979) view the failure of direct access and selective priming models in explaining interference effects as being of primary importance. Kinsbourne and Hicks (1979) would seem to have resolved just this issue, in particular they have formalized the capacity problem central to models of interference effects.

Reversing laterality patterns or their occurrence where none has previously been apparent is the central concern of both Moscovitch and Klein (1980) and Hellige, Cox and Litvac (1979). The concept of capacity as expressed in Kinsbourne's cerebral space notion and the concept of functional distance would seem to encompass such effects. Competition between functionally close control centres would provoke lateral differences in performance as interference increased. Similarly, the functional distance between two centres can decrease as the space required by one or another of the active centres increases, thereby giving rise to more interference between tasks. In the case of a verbal task so much space might be required that performance on a concurrent task is impaired and performance superiority shifts between hemispheres.

The cerebral functional distance concept function may benefit research into laterality effects in another way. As Hellige Cox and Litvac (1979) have suggested:

> "The study of hemispheric processing would be much simpler if laterality patterns could be taken as a straightforward indication of permanent processing differences."
> (Hellige Cox and Litvac, 1979, p.277).

Such a situation does not exist, directness of pathway models (Kimura, 1966) are now defunct in their strong form. Research which has suggested that strategies can effect laterality patterns (Bryden, 1978), or mode of processing (Cohen, 1977) and memory load (Hellige and Cox, 1976), ensure the limited account that is currently taken of structural models.

Research based upon Kinsbourne's model must involve an early return to the study of laterality effects as a functional indicator of hemispheric differences. In contrast to the recent tendency which, as the evidence against laterality effects being direct indicators of hemispheric function has accumulated, has led to an increasing interest in laterality phenomena as an end in themselves. However many such effects are irrevocably linked to hemispheric differences and all the theories discussed in this section have made assumptions about the nature of these differences.

The postulation of control centres localized in functionally interconnected cerebral space, must be based upon some consideration of the evidence in favour of their existence. It is this which might force some attempt to reconcile the models developed by experimental psychologists and those being developed in the neurosciences. The proposal of the final section of this chapter is that at present a gap exists between the conceptions of hemispheric asymmetry and their underlying notions of cerebral localization, current in these two fields.

Finally, we must note the direct linkage between laterality effects and attention theory. Recent models of laterality effects strongly suggest that such phenomena should occur in the framework of the most frequently employed paradigm in attention theory; dichotic shadowing. The nature of such effects must throw light upon the relationship between the two fields of study and help increase our understanding of both.

In particular it would seem that recent research would suggest there would be some value in conceptualizing dichotic shadowing as a dual task paradigm. A variety of experimental techniques which, it would seem, affords a good opportunity for investigating laterality effects in relation to hemispheric differences (Hellige <u>et al</u>, 1979; Moscovitch and Klein, 1980).

CHAPTER THREE

RESEARCH METHODS

3.1 Research Outline

The plan of research for this thesis is based upon an original effort to replicate an important experiment in the field of auditory selective attention. This was carried out in such a way as to allow for the elucidation of laterality effects as they might influence attention. Subsequently there was a change of emphasis and recall was adopted as a measure more frequently associated with research into laterality differences, but compatible with the demands of auditory selective attention.

Experiments II, III and IV are concerned with the relationship between ear of arrival and serial position of items recalled. This is in itself something of a departure for studies of hemispheric asymmetry where the serial position of items recalled is rarely taken into account. Experiments V and VI are concerned with the problem of the nature of focussed attention, but with explicit reference to the limitations of the dichotic listening technique. These studies are an attempt to make explicit, some of the consequences that the close parallels between the dichotic technique as used in laterality research and attention research must have for the importance of explanatory concepts developed in one area of work for the understanding in the other area of concern.

3.2 Equipment and Materials

3.2.1 The experiments presented in this thesis are all based upon dichotic tapes which were prepared with the help of Mr Wight and his staff in the Electronics Laboratory of the Psychology Department at the University of Edinburgh. The tapes were produced by recording all the words employed in the experiments and then aligning them in dichotic pairs, which were then grouped according to the length of list required for each particular study.

The equipment employed in aligning the dichotic word pairs was a custom-built device labelled DITMA. This dichotic tape matching apparatus, shown in Appendix C, matched all pairs within a plus or minus 50m/sec tolerance range which is comparable with other experiments in this area (Treisman, Squire and Green, 1974) if not as accurate as the computer matched dichotic tapes which have been employed from time to time (Treisman and Fearnley, 1971).

There is no overall standard of dichotic tape production, techniques vary and the accuracy of alignment has frequently not been reported. Moreover there has been little discussion in the experimental literature as to what constitutes alignment of word pairs. Using automatic equipment as with DITMA the rise time, in the form of a period before which the voicing of a word reaches a particular intensity as preset on the equipment, determines the accuracy of matching. For example, a soft sounding word with a very slow start may trigger the device after it has substantially begun. A word with an explosive first syllable will trigger the equipment earlier, as a result more of its waveform will be contained on the experimental tape. This and a number of other issues are common to most techniques for matching words dichotically.

It can be reported here that such problems were dealt with in the present work by avoiding the matching of words which differed greatly in terms of those characteristics which effected the performance of the DITMA equipment. Each pair of words were therefore matched as accurately as possible in terms of onset time, and consecutive word pairs were placed exactly one second apart.

3.2.2 The equipment employed in the presentation of the dichotic tapes was considerably simpler than that required for their creation. The principle tool was a four channel (quadriphonic) tape recorder the TEAC A-23405X, which was specially purchased and maintained for the purpose of presenting dichotic listening material. A pair of high quality stereo headphones, Pioneer SE-50cc were used to relay the dichotic message to the subject and where appropriate, the subjects responses were recorded via a Foster DF-1X microphone.

3.2.3 Every subject tested for the purpose of this thesis carried out the experiment in the same laboratory. This room was approximately 10ft. by 12ft. and contained nothing except a table and two chairs. On the table was placed the tape recorder which always separated the experimenter from the subject and by blocking the subject's view of the only window in the room denied any opportunity for distraction.

The attempt to maintain a stable environment for experimental work, by maintaining room temperature, lighting and moderating external noise was made. There were no significant changes in any of the three factors mentioned or in the layout of the room at any period during which the research was being carried out. Although it must be reported that no systematic record of room temperature or the background level of noise was made during this period.

3.2.4 The materials employed in the experiments carried out for this thesis were drawn entirely from the A and AA categories of the Thorndike-Lorge word count (Thorndike and Lorge, 1944), essentially these were the most frequently employed words in the American language at the time of that study. Word pairs were generated by employing only monosyllables from that sample, and using Cassell's Modern Guide to Synonyms and Related Words (Cassell, 1971). This source included appropriate examples of synonym, antonym and homophone word pairs for the purpose of Experiment One.

Although there is general agreement that no word can be precisely synonymous with another (Treisman, Squire and Green, 1974) there was little difficulty in generating a sufficient number of appropriate examples of synonyms and antonyms. The problem in preparing word lists of semantically or phonemically similar words was somewhat greater. In this case a lead was taken from earlier work, the examples and guidelines reported by Baddeley(1966a,b) were employed.

It was found to be necessary to employ lists where the semantic relationship between words in a list was manifest in terms of common category membership, for example descriptions of size; high, wide, tall, etc. Clearly there could have been a difference in the strength of association between theitems of a particular list.

However, the number of words available was already severely limited by the control exercised over the frequency and length of any item included in a list. It was difficult, therefore, to further control for the strength of association between items of a list, particularly as association norms for all the words employed, are not available. It was felt, therefore, that any effect that a difference in the strength of association might have upon the recall of lists would increase the error variance of the effect of list types nonetheless this effect was consistently significant.

3.2.5 Finally, a description of the materials employed in collecting data from the experiments is appropriate. In Experiment 1, the subject's response latencies were generated by comparing the parallel pen read-out of the shadowed material and the subject's voice. This took the form of measuring the distance between the traces provided by a Beckmann type RP Dynagraph, which converted the vocal input to deflections of a pen on a continuous paper record.

In Experiments 2 to 6, the data was contained in booklets. The subject wrote down words from the recall, or recognition, task in a series of boxes, each one inch square. These were arranged in a sequence of 5 or 9 boxes as appropriate. The booklets contained one page for each list and were composed therefore of 15, 12 or for Experiment 6, 3 pages.

In Experiment 6, one box was provided for each item presented, attended or unattended. There were, therefore, three cards made for each word presented, the 5 x 3 index cards contained the target word and one distractor word of each type, semantically similar, phonemically similar or unrelated.

3.3. Experimental Procedure

The experimental procedure adopted was common to all experiments presented, each experimental session was planned and carried out so as to balance the time of day at which subjects were tested between and within experimental groups.

3.3.1 Subjects were matched insofar as they were drawn from a population of students so that the age range and educational background were representative of this population (see Table 3.1). As might be expected this choice of subject group is entirely in keeping with the majority of research in this area.

3.3.1.1 It was possible to employ groups balanced for sex of subjects, but only within certain limits. Unfortunately the population canvassed for subjects, students studying Psychology, or a Social Science degree with some Psychology content, contained a very large proportion of females. Although the subjects represent the proportions beteen the sexes on these courses, they are slightly over represented in some experimental conditions. For the implications of sex differences to this work the reader is directed to Section 3.4.

Table 3.1 Subjects

Expt.	Subjects	Males	Females	Students	Median Age	Age Range
1	24	12	12	24	20	18 - 23
2	45	18	27	40	20	18 - 25
3	45	25	20	40	21	19 - 24
4	20	11	9	20	20	17 - 26
5	20	10	10	15	22	17 - 27
6	60	22	38	50	23	17 - 29

3.3.1.2 The second major characteristic which influenced the choice of subjects was handedness. Every subject whose results are included in this thesis was self-reported as being right-handed. Furthermore, subjects employed in Experiments 2 to 6 were also required to complete a handedness inventory. This inventory reproduced as Appendix B, was derived from the Edinburgh Handedness Inventory by Dr Colin Wilsher of the Dyslexia Research Unit at the University of Aston in Birmingham. In practice any subject who was left handed on more than two examples drawn from the inventory was not tested further. Subjects were questioned as to their history of handedness in their family and also to determine any reasons why the pattern of results obtained by the inventory method may have been unrepresentative or otherwise invalid.

It was felt that the procedure outlined above gives reason for confidence in asserting that only right handed subjects were employed. The issues surrounding the concept of handedness are complex and some explanation of the position adopted for the purpose of this research and the implications of this problem are contained in Section 3.4.

3.3.1.3 One final subject characteristic was determined prior to the commencement of the experiment; every subject was asked to report any hearing defect known to him or her. Only one subject was discarded as a result of this question.

There are a range of audiometry tests which could be considered appropriate to the task of selecting subjects for experiments based upon the dichotic shadowing task. However, to the knowledge of the present author, such tests are not as yet carried out prior to research in this area. Certainly the possibility remains that relatively subtle deficiencies in hearing, particularly those confined to a particular band of audible frequencies, might influence work based upon the use of dichotic stimuli.

3.3.2 Having established handedness and the absence of any hearing deficiency, subjects were then appraised of the requirements of the dichotic shadowing task itself. All the subjects employed were previously unaware of the technique, nor had they previously attempted such a task or heard a dichotic tape. The task is a difficult one and subjects were allowed up to thirty minutes of practice in order to reach the performance criteria. The criterion of shadowing efficiency was two consecutive lists, totally correct. There would be no mispronounciation, omission or commission errors. There were sixteen practice lists, both tracks were employed and reused until the subject reached the training criterion. Several subjects had to be rejected because they failed to reach this criterion, although they were paid for their services they did not complete the experimental lists.

3.3.2.1 Before passing on to the experimental shadowing task it is important to note the arrangement regarding the input levels of the two channels. Firstly it must be said that as far as possible individual word pairs were matched for sound intensity during the recording phase. This was achieved by presenting the person recording the words (the present author) with a VU meter reading of the sound intensity.of each item. Items which were clearly above or below the normal level, were re-recorded until such was no longer the case.

At the presentation of the lists the two channels were equalized by the experimenter, employing a Brüel and Kjaer model 2203 sound-level meter. The level set in all experiments was 75dbA, once again this was dictated by the need to replicate conditions obtained in previous studies with which a direct comparison was being made, Treisman, Squire and Green (1974). Unfortunately, there is no apparent consensus as to how the sound level of the two channels should be equalized, some authors simply state that this was carried out 'approximately', (Smith and Groen, 1974); others adjust the two levels until 'they sounded of equal loudness', (Martin, 1978).

Systematic observation during a pilot study revealed that when dichotic word pairs are subjectively adjudged to sound the same, they are most certainly not the same sound level. Indeed, objectively equivalent levels generally sounded louder at the right ear. Consequently the sound level of the lists was set by adjusting the output of the tape recorder until the average sound intensity level was 75dbA for both channels.

This point obviously requires some clarification, for such a procedural detail as this represents a considerable potential for variation between studies and may lie at the heart of any attempt to transfer the research upon laterality differences to the study of auditory selective attention. At present procedure appears to vary, often this detail remains unmentioned or is only vaguely alluded to. There may for example be an interaction between the type of adjustment of levels, objective or subjective and the direction or degree of laterality differences. Such an effect would be of particular importance in comparing studies where each subject matched the levels and other studies where such was not the case and levels were equalized with respect to objective criteria.

3.3.3 The experimental task was always prefaced by the following introduction spoken by the experimenter:-

> "The aim of the dichotic shadowing task is for you to repeat aloud the word presented at one ear, the attended ear, immediately it is presented and before the arrival of the next item. No attention is to be paid to the other ear, the unattended ear, items are presented on this ear solely to distract you".

The subjects were then given an opportunity to ask questions of the experimenter. Emphasis was placed upon the requirement for accuracy in shadowing and subjects were asked not to attempt to correct themselves during an experimental trial. This being especially important in Experiment 1, where any such hesitation rendered the entire trial ineligible for analysis.

3.3.3.1 The instructions to subjects in the experiments where subjects were required to remember the attended list are contained in Appendix D. The instructions were presented, questions answered and the experimenter switched on the tape recorder. In Experiment 1, each list was prefaced by a sterophonic countdown 3-2-1. In the subsequent experiments subjects were given a constant, unfilled, 3 seconds gap before the first dichotic pair were presented.

During experimental trials the experimenter made a note of any errors, the misplacement, absence or incorrectness of a phoneme was the smallest unit of error that was noted. An arbitrary ceiling for acceptable error was set at an error on ten percent of trials. Operationally this meant that any subject who made more than 2 errors in a bank of fifteen trials was rejected. No subjects were rejected on the grounds of inadequate shadowing during experimental trials.

3.3.3.2 After each trial the subject was given 90 seconds to write down any items recalled. At the end of this period the subject turned the page and the tape recorder was switched on once again. In Experiment 6 the subject was presented with ten cards at the end of each list and was allowed 3 minutes to complete the appropriate page of the booklet.

At the end of the experimental session subjects were asked how they had approached the task, what they thought might have been the purpose of the design and how many, if any, of the words presented on the unattended channel they had noticed. They were then given a description of the aims of the experiment, if it was requested.

None of the subjects could report any of the unattended words, although this had been possible during the training phase of the experiment. All subjects were then paid, normally a sum of £1.50 for a full one hour session, which included preliminary testing and training.

3.4 Measuring Laterality

It is an implicit assumption of the present work that the comparison of right and left ear performance on a dichotic shadowing task reflects the lateralization of certain aspects of language behaviour. Following on from this, some attempt must be made to exercise control over the relationship between the ear of arrival of inputs and the hemisphere specialized for language. If such control is not achieved then comparisons between right and left ear performance become meaningless. For this reason the concept of handedness is of central importance in the context of research upon laterality differences.

Having established, as far as possible, that differences in performance between the left and right ear reflect asymmetries in the hemispheric reflect the localization of speech, the problem becomes one of defining this difference and armed with some model of such laterality effects attempting to measure the variable operationally. At present, however, as has been suggested in Chapter 2, the problem of modelling laterality effects is unresolved and attempts to measure laterality are surrounded by some controversy.

The purpose of this present section, therefore, is to elaborate upon the position taken with regard to these issues; laterality differences and implicitly the problem of handedness and its relationship with underlying cerebral asymmetries in the programme of work reported below.

3.4.1 The relationship between handedness and cerebral organization, particularly the lateralization of language, has been the subject of a considerable body of research (see Searleman (1977) for a review). For the purposes of the present work the importance of this relationship lies in the value of handedness as a predictor of cerebral organization. Handedness has been employed for some time as a convenient tool for determining the lateralization of language (Kimura, 1967). In order to underline conclusions drawn with respect to differences between the two hemispheres in relation to speech and memory, this technique was employed in such a role for the purposes of the present study.

The predictive value of handedness lies in the close link between the hemisphere responsible for speech behaviour and a preference for the use of the contralateral hand. Thus most right handed people exhibit a left hemisphere superiority or dominance for speech (Penfield and Roberts, 1959; Wada and Rasmussen, 1960). This has, however, been determined by clinical tests (see Chapter 2), and although such studies have determined that between 90% and 99% of all right handers are left hemisphere dominant for speech behaviour, only some 50% to 70% of non-right handers display a similar pattern of cerebral organization. Furthermore, there are rare right-handed individuals in whom the right hemisphere and not the left is dominant for speech (Milner, Branch and Rasmussen, 1964).

It would seem, therefore, that handedness is not an entirely reliable index of language lateralization. Recent work upon the definition and measurement of handedness suggests that the reason for the unreliability of this relationship may arise from the common origins of handedness and cerebral organization as functional asymmetries. Moreover, it would appear that, within certain bounds, handedness can be employed as a convenient indicator of underlying cerebral asymmetries.

It is argued that notwithstanding the convention of employing two discrete subject groups in handedness research, handedness should be viewed as a continuous variable (Annett, 1972; Shankweiler and Studdart-Kennedy, 1975), in which right-handers can be identified as a homogenous group both with respect to both the direction of the handedness effect and the corresponding organization of the hemisphere dominant for speech (Annet, 1972; Levy, 1974).

Non right-handers represent no clear pattern of relationships between handedness and cerebral organization. Instead it has been suggested that non-right handers exhibit a bilateral representation of the language function (Bryden, 1965; Kimura, 1967; Dimond and

Beaumont, 1974; Levy, 1974). Whatever the conclusions that are finally drawn from this body of work, there is abundant evidence that whereas right-handers are an homogenous group insofar as they consistently exhibit a left hemisphere dominance for speech, left handers are a heterogenous group in that even the clinical evidence as to their lateralization of language is confused.

In practice this taxonomy of handedness allows for a relatively reliable indication of cerebral organization on the basis of a strong preference for the right-hand. Problems remain, however, insofar as there is little consensus as to how handedness should be measured; there is great variation in the type of handedness index employed (Annet, 1972; Shankweiler and Studdert-Kennedy, 1975). What is more instruments employed in the determination of handedness are still geared in the main to isolate individuals as either right or left handed. As such they do not reflect the complexity of the phonemenon involved. Considerable room exists, therefore for errors in the classification of individuals in terms of handedness.

Shankweiler and Studdart-Kennedy (1975) have suggested for example that the variability of the ear advantage within groups of left and right handed subjects may reflect the position of individual subjects on the continuum of handedness. In effect this requires that laterality be considered as a continuum of specialization, or dominance, for language at one hemisphere or the other. At which point the discussion must move from handedness to the problem of measuring lateraltiy.

Finally, however, the position would appear to be one in which handedness in the form of extreme right-handedness can be said to predict a left hemisphere dominance for speech. Therefore even though it is impossible to explain the precise nature of the relationship between handedness and the lateralization of language, some use can be made of one concept in order to explore possible boundary conditions of the other. Handedness, rather than being viewed as sharing a causal relationship with localization of function, as a determinant of the hemisphere dominant for speech can instead be considered to reflect similar characteristics to language lateralization in terms of the distribution, direction and reliability of functional asymmetry.

The use of a strict right-handedness criterion in the selection of subjects may have restricted the generalizability of the findings. Perhaps more significantly however, it also increases the confidence with which the performance differences between the two ears can be claimed to represent intrinsic differences in the linguistic capacity of the left and right hemispheres. Although it must be stressed that the clinical data which supports the position adopted here (Milner, Branch and Rasmussen, 1964) only allows for definite conclusions to be drawn as to the pattern of localization for expressive language. The possibility remains that the picture may be quite different with reference to the localization of the capacity for language comprehension.

3.4.2 A measure or index of laterality differences is essential, if an attempt is to be made to explore the consequences of hemispheric asymmetries of function upon auditory selective attention. However there is a large body of recent research which casts doubt upon the laterality index approach on theoretical, logical and empirical grounds. Consideration of these criticisms of attempts to measure laterality influenced the choice of analaysis employed in the present work. Some discussion of the difficulties involved in an attempt to measure laterality must therefore be entered into.

3.4.2.1. The literature which is critical of attempts to measure laterality focussed largely upon the role of dichotic listening scores as an index of hemispheric dominance (Satz, 1977; Lee Teng, 1981). The arguments against such a practice are complex and will not be closely reviewed for present purposes. It is essential, however, to establish the major points of concern.

First amongst the issues is the question of the nature of laterality measures themselves. In effect the question as to what laterality measures are, remains outstanding, the assumption would appear to be that laterality differences are in some way a measure of the degree of cerebral dominance exhibited by the individual. In practice this assumption requires that all the significant components of performance on a dichotic listening task are represented, to some extent, with rather more efficiency at one hemisphere than the other. There is a large body of evidence which shows that other factors such as attention, set effects and varying subject strategies can influence performance on a dichotic listening task; Treisman and Geffen (1968); Spellacy and Blumstein (1970); Bryden (1978). Moreover, these effects are far from being insignificant, they contribute, for example, to the very poor reliability of laterality indices as will be discussed. It is also important to note that the size of the REA is typically very low, sometimes of the order of only a few percentage points (Bryden, 1963).

It is clear, therefore, that in order to measure laterality differences, care must be exercised in controlling a number of factors which can effect different scores whilst being themselves unrelated to patterns of hemispheric dominance. Attentional factors are clearly of central importance in the present work and consequently very close control over attention was involved. The shadowing requirement employed in the recent study can be argued to attention, although certain reservations must be made as to the efficacy of the technique (see Chapter 2).

The requirement for subjects to recall only those words presented to one ear, as in Experiments 1-5, circumvents the problem of report bias and to some extent those difficulties arising from the differential storage efficiency of the right and left ear presentations (Bryden, 1963, 1978). It is also the case that the REA is more stable in experiments where subjects are required to attend to one particular channel (Bryden, 1977) rather than passively listen to both left and right inputs (Kimura 1961a). Lee Teng (1981) has shown that where subjects are free to bias attention, there is a likelihood of increased variability in reliability measures.

The stability of the REA is a key factor with reference to the measurement validity of the difference between left and right ear performance, and the experimental evidence would suggest that there is a low test retest reliability for some of the standard indices of laterality differences (Pizzamiglio, Depascalis and Vignatia, 1974; Blumstein, Goodglass and Tarter, 1975; Spellacy and Watson, 1978; Lee Teng, 1981). Such work suggests that there is a great deal of variability in the direction of laterality differences for individuals. Both with respect to the stability of a particular subjects REA over time and when the results of alternative techniques are compared (Pizzamiglio _et al_, 1974; Blumstein _et al_, 1975).

In order to contain this source of variability, it was decided that there would be no attempt to compare individual scores. The variability of the individuals performance over a prolonged testing phase would certainly tend to obscure the consequences of hemispheric asymmetries along (Shankweiler and Studdert-Kennedy 1975; Blumstein _et al_ 1975). Furthermore, no attempt was made to change the nature of the material presented or the basic demands that each experimental task made of subjects. It is clear that the low interest correlations between verbal tests arise in part from the fact that they tap different aspects of language function which are themselves differentially lateralized. Thus in the present study the verbal material was standard throughout. As far as possible, therefore, possible sources of error were controlled in an effort to assess the consequences of underlying functional asymmetries.

3.4.2.2 In respect of the choice of a method for representing scores in a task involving dichotic stimuli there are two points to be made. First, the major laterality measures (see Stone (1980) for a review) are themselves usually derived in an effort to determine their correlation, as an index of hemispheric specialization, with other forms of recorded behaviour as displayed in different tasks and subject groups. However, such is not the case in the present work, indeed the practice of seeking correlations of this type has been subject to much criticism (Stone, 1980; Lee Teng, 1981). Therefore, much of the rationale for seeking such an index of laterality, and thereby assuming a level of quantifiability which it has been suggested is inappropriate (Colbourn, 1978), is removed. It is the aim of the present thesis to include experiments which are not based simply upon a right or left ear advantage, but rather to seek an understanding of the mechanisms involved by addressing the form or quality of recall, rather than simply than the relative quantity. Thus to some extent avoiding the pitfall, described by Colbourn (1978) of considering laterality solely in terms of ear advantages, where discrete right, left or no lateral advantage alternatives are considered to be key points on a continuum of laterality.

Finally, it can be suggested that by confining the handedness of subjects to strong right-handed, then the assumption of left hemisphere dominance for speech can be made independently of any REA or indeed in the absence of such an effect. Thus removing any dependence upon the use of dichotic stimuli as a predictor of cerebral lateralization, in which role it only indifferently serves (Lishman and McMeekan, 1977).

CHAPTER FOUR

VERBAL REACTION TIME : RIGHT AND LEFT EAR SHADOWING

4.0 Introduction

A theoretical issue of major importance in the study of selective attention has been the question of early versus late selection between inputs. A technique introduced by Lewis (1970) appeared to be an elegant solution to the problem. The dependent variable employed in this method was the shadowing latency; the delay before a subject repeats an item presented on the attended channel of a dichotic list. The independent variable was the relationship; synonomous, antonymic or unrelated, between target pairs placed in the dichotic message. This arrangement afforded an opportunity to indicate the level of processing of unattended items, and thereby judge as to whether or not selection is carried out early or late in the sequence of processing.

The results of Lewis's (1970) study confirmed that unattended words could influence shadowing latencies. A consistent relationship between the meaning of a dichotic pair and the shadowing latency, indicated a full analysis of unattended material. Furthermore as the dichotic pairs in the experiment were presented at a rapid rate, one per second, switching between inputs was not considered to be a viable strategy. Lewis therefore concluded that his study provided evidence that the processing of unattended inputs was carried out in parallel with that of attended inputs. Evidence that unattended inputs were processed in a parallel and not a serial fashion, and that this processing extended to the level of meaning was held to contradict the predictions of early selection theories.

The importance of this study was such that it was quickly replicated, Treisman, Squire and Green (1974). This further use of shadowing latency as a dependent variable provided only partial support for Lewis's initial findings. The principal difference between the two studies was the finding reported by Treisman _et al_ that post-perceptual analysis of both attended and unattended inputs could only occur during the early part of a dichotic list (positions 1 to 3).

There is however at least one reason why the study carried out by Lewis (1970), and its subsequent replication by Treisman _et al_ (1974) requires further elaboration. They both reflect a common disregard for the nature of laterality effects in so far as they might influence the results of experiments concerned with other issues, but which employ a technique known to exhibit their influence.

Although dichotic listening was introduced by Broadbent (1954) for the study of selective listening, Kimura (1961) revealed an important use for the technique in the study of pathological and normal asymmetries in memory performance. Subsequently research in the field of selective attention concentrated upon the use of dichotic shadowing, where the stimulus materials were passages of connected prose. Whereas research into the nature of laterality effects tended to be based upon dichotic messages made up of unrelated words. More recent work on selective attention has, however, tended to employ carefully aligned lists of unrelated words

(Lewis, 1970; Treisman, Squire and Green, 1974). Thus dichotic shadowing has become a close analogue of the dichotic listening task, a method which has long been known to exhibit ear of arrival effects.

The experiments carried out by Lewis (1970) and Treisman Squire and Green (1974) both included controls for ear of arrival effects. There is evidence to suggest that the close relationship between dichotic listening and dichotic shadowing already noted, indicates a form of laterality effect which invalidates the method of control they employed. The argument that control cannot be exercised over the impact of lateral differences in the perception of verbal stimuli is central to the present experiment, and will therefore be studied in some detail.

As is clear from the review in Chapter 1, up until recently few experiments even attempted to control for the ear of arrival of inputs in dichotic shadowing tasks. In the work under review experimenters sought to control for ear of arrival effects by presenting all levels of experimental treatments to both left and right ears as the shadowed ear. However for this control to allow for the statistical removal of the effects of ear arrival, there must be no interaction between the ear of arrival and an experimental treatment which is not complementary in its effects. That is such that the combined consequences of left and right ear presentation can cancel one another.

There is a large body of evidence that the consequences of presenting inputs to the two ears differ in a systematic fashion, particularly in relation to the perception of the meaning of words. For example right-handed subjects are known to react both less accurately Kimura (1966) and less rapidly (Springer, 1971) to the left than the right ear input of dichotic messages. The dominance of the left hemisphere right ear input channel for verbal stimuli is well recorded (Kinsbourne, 1970, 1973). Furthermore it is widely appreciated that despite evidence of some facility with simple words (Zaidel, 1976) the right hemisphere is restricted in the comprehension of verbal material (Levy, 1974) and exhibits very little capacity for the organization of verbal output (Sperry, Gazzaniga, and Bogen, 1969).

Given the preceeding evidence, it would seem dangerous to assume that laterality effects would not influence the outcome of a study designed to test the level of processing of unattended inputs in a dichotic shadowing task. However there is some evidence to suggest that laterality effects would not endanger the validity of the work carried out by Lewis (1970) and its subsequent replication, Treisman _et al_ (1974) as a test of the early and late selection hypotheses.

The evidence in favour of this supposition derives from an experiment carried out by Treisman and Geffen (1968). They showed thatalthough there were lateral differences in the accuracy of detecting a target item, there was no interaction between the ear of arrival and the verbal context of a shadowed target item. From this Treisman and Geffen (1968) concluded that laterality effects occur at the perceptual stage of processing, prior to entry into the single channel limited capacity processor. If this is the case, and laterality effects occur prior to the selection process suggested by both early and late selection theorists, then they cannot affect the outcome of a test between the two theories.

If, however, such is not the case, then an interaction between ear of arrival and the shadowing latencies associated with target pairs of phrenological and semantic similarity is important for the outcome of an experiment as crucial as Lewis's. Furthermore, an interaction of this nature would not be adequately controlled for by placing equal numbers of subjects in both left and right ear shadowing conditions, as was practised by Lewis (1970) and Treisman, Squire and Green (1974).

There is some evidence that an interaction effect of the kind suggested here did in fact influence the results of Treisman, Squire and Green (1974). Unfortunately neither Treisman et al nor Lewis (1970) made a separate report of the results from both left and right ears. Treisiman et al did report however that the variance of target shadowing latencies was higher than that for control word latencies. This was interpreted as indicating the intermittancy of the Lewis effect (Lewis, 1970), which it was argued, occurred only when dichotic pairs had been innacurately matched temporally. Consequently allowing for the serial processing of inputs where there was a delay between the presentation of the two (supposedly) dichotically presented words.

An alternative explanation of this difference in the variance of the shadowing latencies of target and control words, includes an assumption of ear of arrival effects. Obviously, if target pairs affected the shadowing latency as a consequence of the semantic relationship between the two words then there would be laterality effects. The left hemisphere shows a marked superiority in the analysis of the semantic content of verbal inputs (Kimura, 1961, 1966) and also bears the responsibility for organising the verbal (shadowing) response in the Lewis paradigm. It would follow therefore, that a difference in the effect of target pairs upon the shadowing latencies for left and right ear inputs would occur.

There need not be an absolute difference, that is an absence of effects due to meaning, on left ear presentations. A difference in the efficiency of the two ears would suffice to produce the effect noted by Treisman et al. This hypothesis would appear to be far more soundly based than the explanation provided by Treisman et al of their results. For example, not only would there have to have been systematic mismatching of word pairs in both their own study and that of Lewis (1970) but this error would have to have been directional. That is to say the error would have had to place one word shadowed or unshadowed systematically either before or after the other. Otherwise effects of decreasing and increasing shadowing latency in the case of Synonyms and Antonyms could not have occurred. The detail of this argument will be taken up in the discussion, it is sufficient here to note that for the Lewis effect to occur on the grounds suggested by Treisman <u>et al</u>, there had to be a large number of mismatching errors in a particular direction. Such an arrangement of contingencies would suggest even more variance than those reported by Treisman <u>et al</u>. What is more, both Lewis (1970) and Treisman, Squire and Green (1974) reported that there was no directional bias in the matching errors of their dichotic stimuli.

It would seem then, that there are strong grounds for expecting ear of arrival effects in the use of the Lewis paradigm. The theoretical value of such effects may well be considerable for several writers have suggested that the early versus late problem is insoluble, or potentially fruitless (Treisman, Squire and Green, 1974; Underwood, 1976).

The late selection model proposed by Deutsch and Deutsch (1963) does not make specific prediction about laterality effects, however, insofar as it assumes the full analysis of <u>all</u> inputs prior to selection, laterality effects pose a problem. The model proposed by Treisman (1969) on the other hand describes laterality effects as arising from the perceptual phase of processing. If however they can be seen to affect the processing of stimulus features such as the semantic relationship between one item and another then post perceptual processes must be involved.

A test of the implications of laterality effects in the Lewis paradigm has consequences both for the theoretical basis of selective attention, but also for the primary technique hitherto employed in its elaboration; dichotic shadowing.

Experiment 1 is therefore concerned with the following issues:-

1) What is the nature of the constraint of serial position of target items upon the relationship between the type of target and shadowing latency?

2) Is there any effect of ear of arrival upon the shadowing latency, and the relationship between shadowing latency and target pairs?

4.2. Method

4.2.1 Subjects

Twenty four undergraduates, 12 males and 12 females, aged between 18 and 24 years participated in the experiment and were paid for their services. Subjects were all right-handed as determined by self-report and had no known hearing deficiencies. They were randomly assigned to two groups: 12 subjects shadowed the right ear and 12 subjects the left ear.

4.2.2 Apparatus

Four basic lists of ten pairs of monosyllabic words drawn from the A or AA frequencies of the Thorndike-Lorge word count (Thorndike and Lorge, 1944) were compiled. A further series of 24 synonyms, 24 homophone and 24 unrelated word pairs were constructed, using words drawn from the same source. These materials were used to create 12 blocks of four dichotic lists each, every list containing two target pairs of a particular type e.g. homophone, at list positions 3 and 9. A further set of lists, sixteen in all, were drawn from the same source and used as practice material.

The lists were then recorded onto the upper and lower tracks of a Ferrograph Series Seven tape recorder at a presentation rate of one per second. Dichotic matching was achieved by presenting the person employed to record the stimulus materials, with a reference tone at a rate of one per second over head-pones. Channel one was recorded, the tape rewound to a reference point, and channel two was then placed alongside. After each list was completed, the message was analysed for errors in the matching of dichotic pairs. Due to limitations upon the sensitivity of this checking process an overall matching error of + or - 75m/sec was achieved. This is, however, comparable with the error involved in dichotic matching reported by Treisman, Square and Green (1974). There was no relationship between the direction and extent of matching error, any effect of matching error is therefore randomised.

Dichotic lists were presented over a pair of Pioneer SE-20cc headphones and each list was prefaced by a 3-2-1 countdown. Both channels of the dichotic message were presented at 65dbA as measured by a Brüel and Kjaer model 2203 sound-level meter. The subjects' vocal response was registered by a Foster DF-IX microphone and passed to a Beckman type R-P Dynagraph. The second channel of the Dynagraph was used to record the shadowed message as presented on the tape. Comparison of the parallel pen-write-out from the subjects' voice and the recording of the channel that was shadowed, allowed measurements of shadowing latencies to be made with an accuracy of plus or minus 5m/sec.

4.2.3 Procedure.

The subject sat in a chair with a microphone placed on a table before him and was given instructions concerning the nature of the dichotic shadowing task. After being given the instructions the subject practised shadowing until a criterion of two successive error-free trials was reached. Half the subjects from both left and right ear shadowing groups practised left-ear shadowing first and half right ear shadowing first; all subjects could shadow accurately with both ears before the experiment began.

Subjects were instructed that they were to concentrate on error free shadowing and not to attempt to rectify errors once they were committed. They were required to repeat out loud each word immediately it occurred, with sufficient clarity as to enable 'E' to monitor their performance. After the completion of all four lists which were presented in a random order, the subject was questioned as to whether or not he/she had made any observations as to the nature of the materials on the secondary channel or the relationship if any between the two messages.

Subjects were tested individually, and in equal numbers between 09.00 and 13.00 and 14.00 and 16.00 hours, as a control for effects due to time of testing.

4.3 Results

The results are divided into an analysis of reaction times associated with target locations, and the analysis of reaction times associated with all serial positions. The verbal reaction time for target work was analysed in an ANOVA (2x2x4:split plot deisgn) where ear of arrival (right of left), serial position (3 or 9), and type of target relationship (Synonym, Antonyn, Homophone were the Unrelated) factors. Both target position and type of target were repeated measures in this design.

The analysis revealed no main effects or interaction effect of ear of arrival and serial position, upon the shadowing latencies of target items. The main effect of the type of target was significant ($F=12.32$, df 3,66; $P < .001$) as was the interaction effect between type of target and ear of arrival ($F=3.91$, df 3,66; $P < .025$) (See Table 4.1). None of the other interactions, including the three-way interaction, proved to be significant. This analysis revealed no effect of serial position whatsoever, which superficially at least, affords a direct contrast with the work of Treisman et al (1974).

Simple main effects analysis revealed that the interaction effect was due to significantly longer latencies for synonym targets shadowed by right ear when compared with the left. The main effect of targets was analysed using Tukey's multiple comparison of means test (Kirk, 1968) which revealed that the shadowing latencies associated

Table 4.1 Reaction times to target positions 3 and 9

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	49503	1	49503	1.75	ns
SUBJECT (within groups)	620653	22	28211		
B (SERIAL POSITION)	43590	1	43590	3.25	ns
A x B	30966	1	30966	2.31	ns
B x SWG	294889	22	13404		
C (TARGETS)	145575	3	48525	12.32	< 0.001
A x C	46234	3	15411	3.91	< 0.025
C x SWG	260007	66	3940		
B x C	26442	3	8814	0.58	ns
A x B x C	120135	3	40045	2.65	ns
B x C x SWG	998481	66	15129		

Simple effects of the 2-way interaction:

A at C1 (synonym)	60634	1	60634	6.06	<0.025
A at C2 (unrelated)	8775	1	8775	0.88	ns
A at C3 (homophone)	23986	1	23986	2.40	ns
A at C4 (antonym)	2338	1	2338	0.23	ns
Error Term		88	10007		
C at A1 (right)	106520	3	35507	9.01	<0.001
C at A2 (left)	65154	3	21718	5.51	<0.005
Error Term		66	3940		

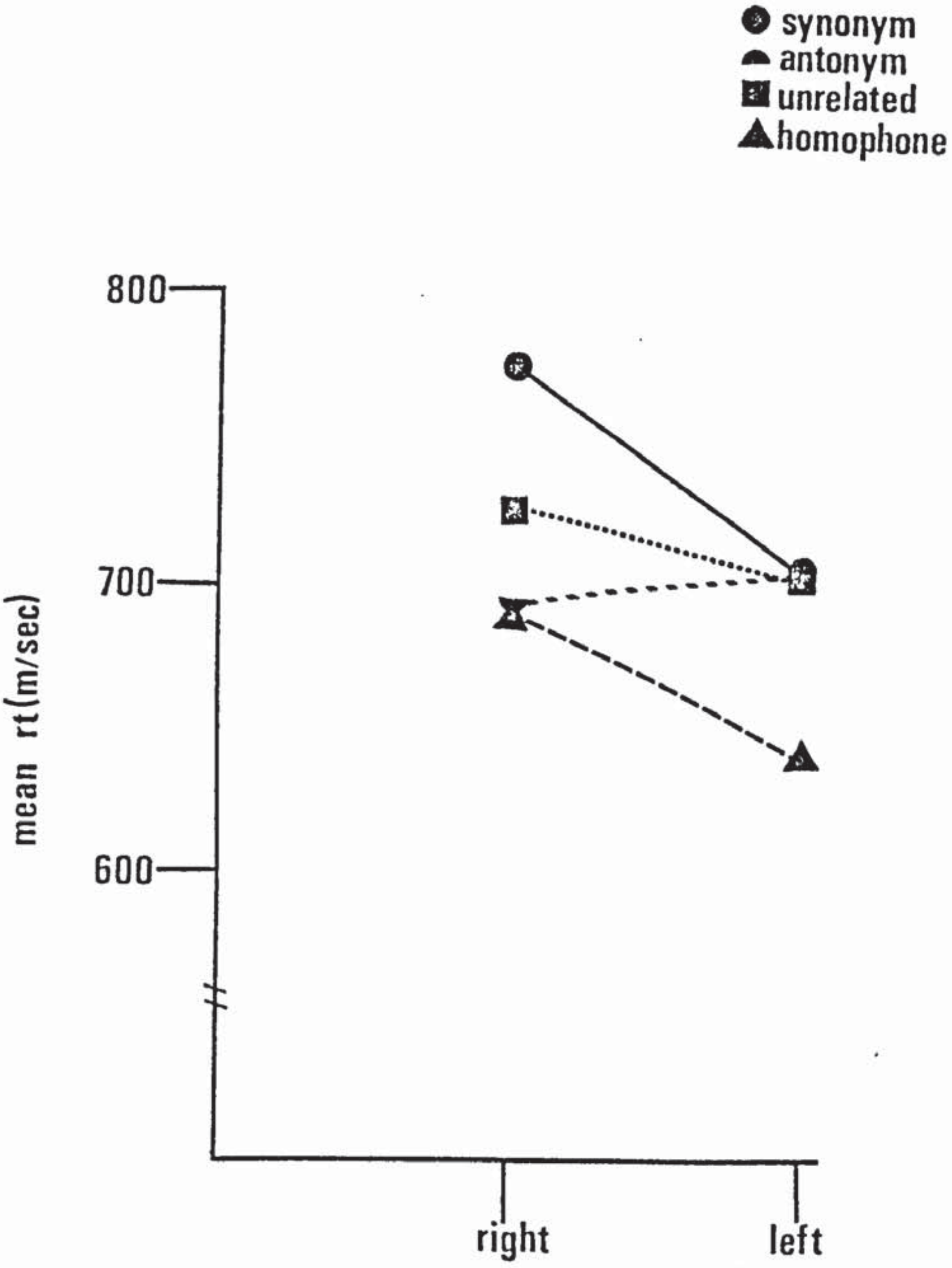

Figure 4.1 Shadowing latency as a function of ear of arrival for each type of target (pair).

Table 4.2 Reaction times to all serial positions

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	827273	1	827273	5.71	<0.05
SUBJECTS (within groups)	3187434	22	144883		
B (TARGETS)	119623	3	39888	0.94	ns
A x B	81747	3	27249	0.64	ns
B x SWG	2807591	66	42539		
C (SERIAL POSITION)	966291	11	87845	3.50	<0.001
A x C	96732	11	8794	0.35	ns
C x SWG	6074553	242	25101		
B x C	467348	33	14162	0.91	ns
A x B x C	396867	33	12026	0.77	ns
B x C x SWG	11344039	726	15625		

Table 4.2a Comparison between means (Tukey's HSD):

Comparison	q	p
A1 - A2	3.38	0.05

$q_{0.05}(2,22) = 2.95$

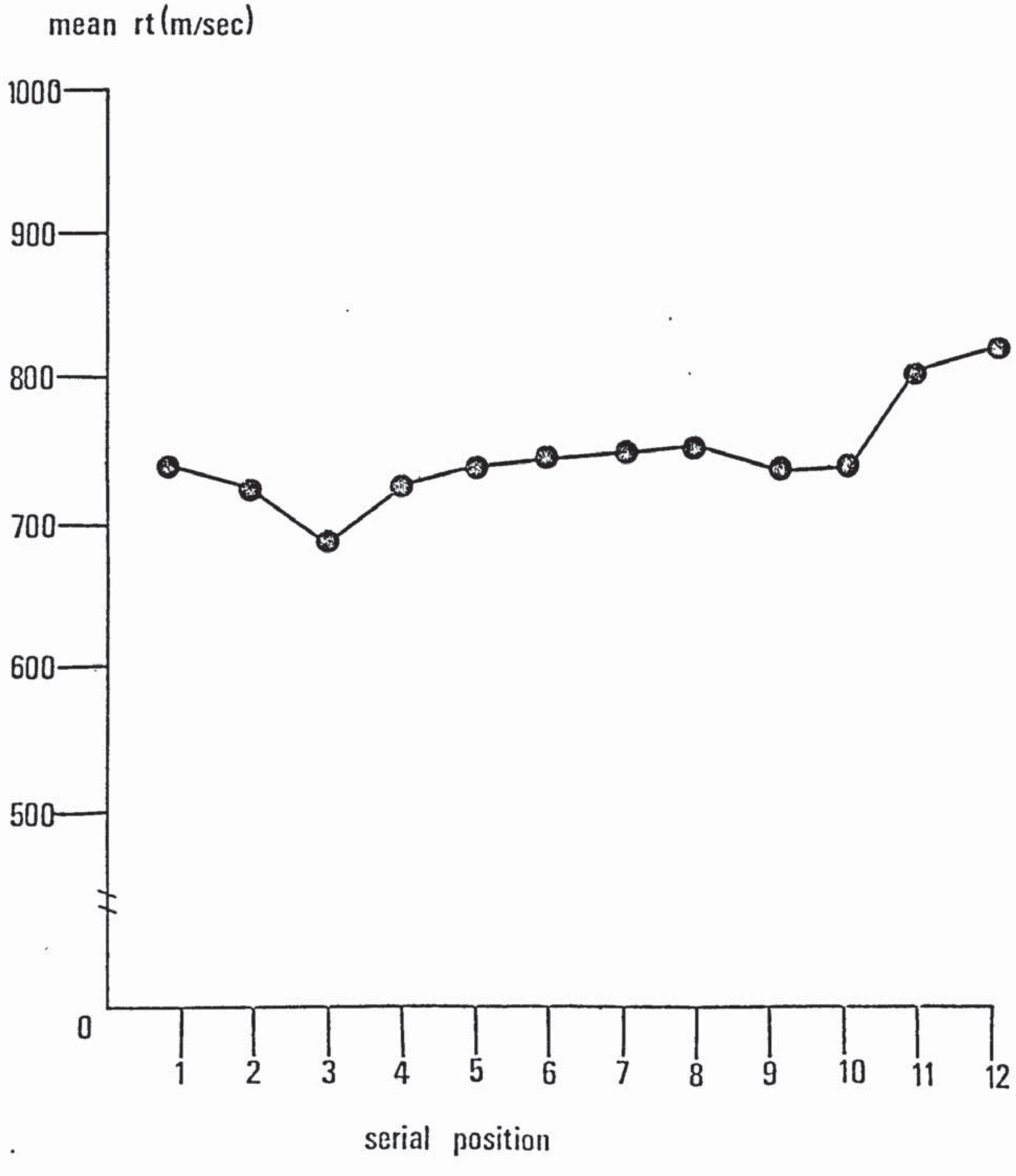

Figure 4.2 Mean shadowing latency as a function of serial position.

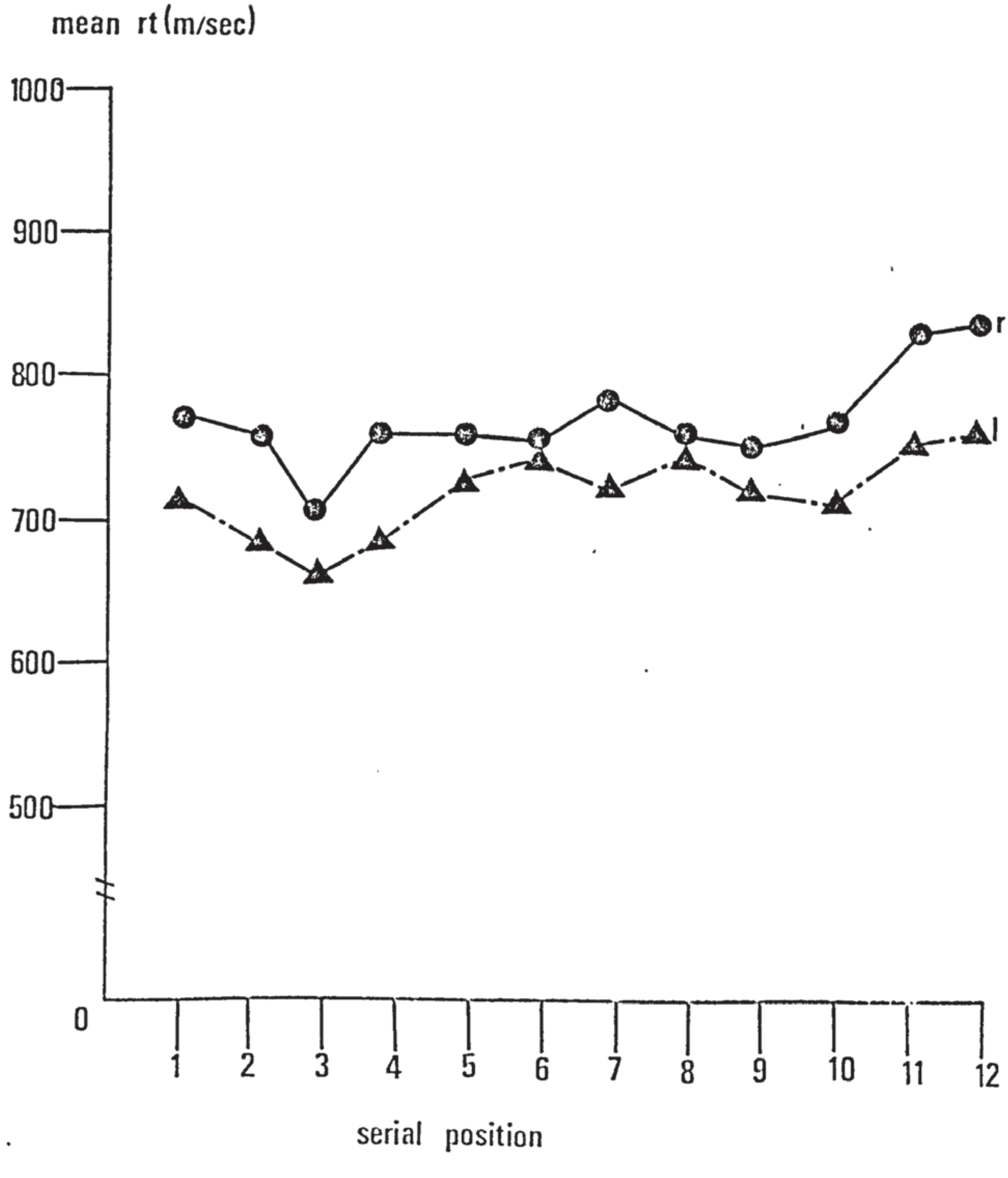

Figure 4.3 Mean shadowing latency for Left and Right ear presentations as a function of serial position.

Table 4.3 Right and left ear

	WORD TYPE	MEAN RT	SD
RIGHT	SYNONYM	772.79	103.15
	UNRELATED	724.62	115.66
	HOMOPHONE	686.79	107.75
	ANTONYM	692.25	110.72
LEFT	SYNONYM	701.70	116.73
	UNRELATED	697.88	90.92
	HOMOPHONE	642.08	128.88
	ANTONYM	706.21	116.25

Table 4.4

	WORD TYPE	RIGHT MEAN RT	SD	LEFT MEAN RT	SD
SERIAL POSITION 3 (EARLY)	SYNONYM	777.17	96.43	683.00	115.63
	UNRELATED	718.00	146.00	695.50	75.08
	HOMOPHONE	698.67	130.71	600.75	86.00
	ANTONYM	655.42	125.86	674.58	126.95
SERIAL POSITION 9 (LATE)	SYNONYM	768.42	117.79	720.42	124.80
	UNRELATED	731.25	91.65	699.67	111.31
	HOMOPHONE	674.08	95.71	683.42	158.46
	ANTONYM	729.08	89.14	737.83	104.90

with synonyms were longer than those for homophone or antonym word pairs ($P < .05$) but not unrelated targets. Homophones give rise to shorter shadowing latencies than unrelated or antonym target pairs ($P < .05$) and synonyms ($P < .01$) (See Table 4.3).

These results indicate that the 'Lewis effect', insofar as it is dependent upon the semantics of the relationship between dichotic word pairs, is confined to right ear shadowing. It is particularly interesting to note how the ear with which synonym targets are shadowed affects the variability of shadowing latencies (Table 4.3). It is obvious that unrelated word pairs exhibit far less variability as a consequence of changing the ear shadowed, thus overturning Treisman Squire and Green (1974) in their argument that variability is caused by errors in the construction of the dichotic tape. Rather we can argue that the changes in the shadowed deviation can be attributed to lateral differences in the performance of a dichotic shadowing task as they affect target shadowing latencies.

The differences between types of target, were all in the same direction as those reported by Lewis (1970) (Table 4.3). That the differences between early and late serial positions was not significant with respect to the increased latencies due to synonym pairs, is perhaps the most important finding. It is also interesting to note that homophones gave rise to shorter shadowing latencies on the left ear presentation than on the right

(See Fig. 4.1). This effect although statistically non-significant, has implications in the light of the following analysis.

The second ANOVA (a 2x12x4 split plot design) employed the same factors as before, but included the Rt data from all serial positions. In this analysis each list was classified according to the kind of target pair placed at positions 3 and 9.

In contrast with the analysis restricted to the Rt's associated with target pairs alone, there proved to be a significant main effect of ear of arrival ($F=5.71$, df 1,22; $P< .05$). (See Table 4.2). This was shown to be due to a significantly shorter shadowing latency for left ear inputs compared with the right ear, ($P< .01$, Tukey's HSD test). This superiority of left over right ear shadowing is perhaps surprising in view of the evidence from other studies that the simple reaction time for verbal stimuli is lower for right ear presentation than left (Springer, 1971).

The main effect of the type of list, that is lists classified by the targets contained therein, was not significant. This result disconfirms the finding reported by Treisman et al (1974), that the long Rts of early position synonyms gave rise to longer Rts for subsequent items. This perserveration effect would have revealed itself as a main effect of type of list, or an interaction between list type and serial position which effect also failed to reach significance. Further support for this result can be derived from the fact that there was no interaction between ear of arrival and type of list. Which of course adds to the conclusion that there was no perseveration of an effect due to synonyms, which ought really to have been the cause of a significant ear of arrival list type interaction.

There was a significant effect of serial position ($F=3.50$, df 11,242; $P< .001$), but no interaction effect of ear of arrival and serial position. Tukey's test was employed for the comparison of means at all serial positions. It was revealed that the shadowing latency at position twelve was significantly longer than at positions 2,3 and 4 ($P<.05$) (See Fig.4.2). The mean Rt at position 11 was also longer than at position 3 ($P<.05$).

Although there does appear to be some small overall increase in Rt across the list, this can probably be explained without reference to attention theory. In the first place the Rts at positions 3 and 4 are clearly reduced, presumably this is one of the effects of the target items. The other point is that the Rt for the final item(s) will be increased by the fact that there is no subsequent item to shadow. The subject can therefore take longer over forming a response, without the prospect of obscuring the next item and therefore failing in the performance of the task. It is useful to note that the other long shadowing latency, that associated with position 11, was significant only in comparison with the lower shadowing latencies of target items at position 3.

It would seem then, that these data do not support the changes in processing strategies that are hypothesised to occur during the shadowing of a dichotic list (Treisman et al, 1974). For such is the basis of the interpretation placed by Treisman et al (1974) on both their own data and that of Lewis (1970). It would appear that some close scrutiny of the design and execution of the experiments carried out using the Lewis paradigm, must provide a solution to the contradictions noted here.

4.4 Discussion

This experiment largely supports thefindings of Lewis (1970), the effects of both synonyms and antonyms are replicated and furthermore there would appear to be no effect of serial position upon these results. The lack of serial position effects is at first sight incompatible with the finding reported by Treisman et al (1974) that synonyms only increased shadowing latency when presented early in the list (position 3). Due to the theoretical implications of this issue the difference between the results of the two studies demands an explanation.

There are two main differences between the design of the present study, and that of Treisman et al (1974). The nature of these differences, the reasons for them and their consequences will be discussed separately. The first difference lies in the construction of the experimental materials, whereas in the present study there was only one type of target in each list, one at position 3 and the other at position 9. In the earlier study Treisman et al (1974) had paired an early control item (position 3) with a late target item (position 7) and compared these with lists were their positions were reversed.

The reason for preparing lists containing only one kind of target, derived from a close study of the results reported by Treisman et al (1974). In their study synonyms at late list positions gave rise to longer Rts than the words either immediately preceeding or succeding in the same list. They were not significantly longer however, in relation to the Rts from control items at position seven in the other list where control items were paired with earlier synonyms. The reason being that early position synonyms had a knock-on effect whereby they increased the latencies for shadowing subsequent items in the same list, including the control pairs.

The design of the present study allowed for this effect in two ways, firstly perseveration effects could only influence one type of target as each list contained only one type of target. Thus a perseveration effect could be tested for by examining the effect of each list as categorised by the target type it contained. No overall effect of list type occurred thus we assume that perseveration played no part in these results. Furthermore the intra-list distance between targets was increased from three to five items in an effort to reduce such effects.

The second major difference between the present study and that of Treisman _et al_ (1974) and Lewis (1970) is that the ear of shadowing was here used as an independent variable, thus laterality effects were tested for, rather than controlled. This would reduce the error variance associated with the synonym effect as noticed by Treisman _et al_. Because as suggested in the introduction synonym effects were constrained to right ear shadowing. Thus the present design would be more sensitive to such effects than would the design employed by Treisman _et al_.

The consequences of the increased sensitivity are so important that their source must be elaborated upon. In the study conducted by Treisman _et al_ there was a steady lengthening of shadowing latencies throughout the list. If the consequences of a synonym target pair, an increase in the shadowing latencies, are not purely additive under these circumstances, and there is no reason to assume that they need be, then the synonym effect would be reduced in significance at later list positions. Although shadowing latencies lengthened during the course of the present study, the error variance associated with the synonym effect was reduced by partitioning out the effect of shadowing with the left and right ears. Thus the design of the present experiment could well accommodate the finding of significant aspects of synonym targets at later list positions without involving any contradiction of the findings reported by Treisman _et al_.

In their conclusion Treisman _et al_ suggested that the synonym effect arose before the single channel 'filled-up', a process which required the presentation of up to three dichotic pairs. Indeed, there is some evidence in support of the contention that shadowing difficulty increased during the presentation of a dichotic list (Ambler, Fisicaro, and Procter, 1976). However, the results of the present study reveal that such an explanation is neither required nor tenable. Firstly, the single channel would appear not to 'fill-up', as the synonym effect continues to occur at later list positions. Second, the single channel model of selective attention is itself difficult to support in view of effects that arise from the ear of arrival of inputs. Effects that cannot be attributed to a perceptual level of analysis.

The question of interpreting the results of the studies employing the Lewis' paradigm; (Lewis (1970), Treisman, Squire and Green (1974) and the present study is not entirely resolved however. Treisman *et al* (1974) have suggested a number of reasons which suggest that parallel processing might not be the source of the Lewis effect. Furthermore, these arguments are to a certain extent independent of the validity of the serial position constraint upon the Lewis effect.

As the intention behind this technique was to devise a methodology for resolving the early-late selection controversy by demonstrating parallel processing in a selective attention task, these arguments forwarded by Treisman *et al* (1974) will be discussed in some detail.

3.4.1

The first argument of any importance is the suggestion that the shadowing latencies recorded in both the earlier experiments (Lewis 1970; Treisman et al 1974) and those of the present study insofar as they are directly comparable, are so long as to allow for the serial processing of inputs. Treisman *et al* (1974) cited a study by Marslen-Wilson (1973) in which subjects could successfully shadow prose at much higher rates of presentation than those reported in any of the studies employing the Lewis paradigm.

Marslen-Wilson (1973) employed highly practised subjects on a prose shadowing task, Holloway (1972) however, has shown that it is very much harder to shadow individual words matched for onset times than continuous prose. There remains some doubt nonetheless that a mean shadowing latency in excess of 600 m/sec does provide an opportunity for serial processing, and this is within the range reported by Lewis (1970), Treisman et al (1974) and in the present study.

3.4.2

In order to resolve this issue we must turn to the detailed nature of the effects arising from the Lewis paradigm. The effect of a synonym in increasing shadowing latencies has been noted elsewhere; (Underwood, 1976; Philpot and Wilding, 1979). These studies demonstrated, it has been argued (Philpot and Wilding (1979) an increase in interference caused by competition between inputs for common analysing mechanisms. An explanation that is entirely at odds with a serial processing explanation; no such competition would occur in a single channel serial processing device.

A further line of argument would suggest that the increase in shadowing latency caused by synonyms is difficult to accommodate with a serial processing model.

Meyer, Schvaneveldt and Ruddy (1972) showed that a semantically similar word facilitates the recognition of a second word thus a lengthening of the shadowing latency can only occur when the unattended word is processed after the attended word, otherwise the shadowing latency would decrease.

It is highly unlikely that a subject having processed the unshadowed word second, would delay the shadowing of an attended word which was processed first.

However the argument that unattended items are processed after the attended item, is incapable of explaining the antonym effect. Although Treisman et al (1974) did not replicate this part of Lewis's original (1974) study, it is vital to an explanation of the Lewis effect. The present study did not show a statistically significant effect due to antonym pairs, nonetheless the results were in the same direction as those reported by Lewis (1970). That is that antonym pairs reduced shadowing latencies below that of synonym and unrelated target pairs.

The analysis of an unattended item cannot be argued to reduce the shadowing latency of a shadowed item that has previously been processed. Otherwise the single channel hypothesis is reduced to a logical nonsense. Thus we are drawn to conclude that our results arise from the parallel processing of dichotic inputs. If the production of shadowed inputs had to wait upon the processing of the unshadowed input there would be little purpose to the single channel and its filter mechanism. The consequences of this conclusion, will be discussed after some attempt has been made to incorporate the implications of the ear of arrival effects in the present study.

3.4.3

The major finding of the present study was the main effect of ear of arrival upon the shadowing latencies of synonym targets. That the left hemispheres capacity with regard to the semantic content of verbal material is entirely superior to that of the right hemisphere and has long been known (Bryden, 1971, Haggard, 1971).

The main effect of early of arrival upon overall shadowing latencies was contrary to expectations in that Springer (1971) had shown a right ear advantage (REA) for reaction time to speech stimuli. The finding of an left ear advantage (LEA) at every position in the list, with no cross-over whatsoever therefore requires an explanation.

An explanation of the LEA for shadowing latency derives from two levels of argument, which are to a ceratin extent, interdependent. Experiments carried out by Heilman, Bowers, Rasbury and Ray (1977) showed that the shadowed ear has difficulty in rejecting inputs for which the contralateral hemisphere is specialized. For example when shadowing with the left ear the subject would have difficulty in rejecting a right ear input of music. At similar study was that of Kirstein and Shankweiler (1969), who showed that right ear shadowing was less efficiently carried out when the material to be rejected consisted of consonants for which the type of stimulus the left hemisphere is a specialised processor.

This type of analysis might suggest why the right ear inputs took longer to shadow, in that the rejection of left ear unattended inputs was more difficult because they consisted of meaningful speech. The difficulty in rejecting inputs for which the shadowed ear hemisphere is specialized, is therefore translated into longer shadowing latencies.

The second level of explanation which might encompass the reported LEA with respect to shadowing latencies, depends upon the assumption that the speech output is largely produced in the left hemisphere (Sperry, Gazzaniga and Bogen, 1969). Given that such is the case, then in dichotic shadowing we have a task which differentially loads the left hemisphere when the right ear is shadowing. Not only does the left hemisphere have to perform the analysis which provides the to-be-repeated items, but also it must organise the verbal output. The reverse case in which inputs are directed to the left hemisphere for analysis and a response organised by the right hemisphere, does not similarly load the left ear-right hemisphere. This would of course indicate sufficient cause for the longer shadowing Rts associated with right ear shadowing.

Support for this argument comes from a number of recent studies where lateralized stimuli are used for the primary task over which a secondary task is superimposed. The secondary task is known to tap the resources of one hemisphere, rather than the other. Thus Rizzolatti, Bertolini and Buchtel (1979) lateralized visual stimuli using tachistoscopic presentation, they then superimposed upon this simple reaction time task, a second task requirement, counting backwards. The secondary task was known to place its processing load upon the left hemisphere and so a differential task loading between the two hemispheres was achieved. When the visual stimuli were directed to the left hemisphere at the same time as the counting task was being undertaken, then Rts were significantly lengthened. Hellige and Cox (1979) have independently repeated and extended these findings in a series of experiments.

Finally, we can conclude that the present experiment allows for the assumption that the Lewis effect arises from the parallel processing of dichotic inputs. The direction of the synonym effects, and their dependence upon the ear of arrival inputs allow most arguments in favour of serial processing to be disposed of. Thus we can argue that the present study in its confirmation of the findings of Lewis (1970) is a satisfactory test of early selection models which it fails to confirm. For even if such models in their later form (Treisman, 1969), can accommodate parallel processing to a certain extent. There can be no value to a late selection model, if it includes among its assumptions the evidence that the post-perceptual processing of individual dichotic words, that is to the level of meaning, can proceed in parallel.

The evidence of this experiment does not confirm however, the predictions of a late selection model (Deutsch and Deutsch, 1963; Keele, 1973). It is obvious that all inputs are not completely processed prior to the selection of outputs. This much it is possible to conclude from the existence of laterality effects in the present study. The problem, however, is compounded by the fact that as the review of the literature in Chapter I has shown, many of the characteristics of the theories of selection are far from independent of the constraints of the dichotic shadowing task itself. It would be wrong to extend this process by now seeking to place laterality effects into a model of selective attention. Rather it would appear to be more appropriate to employ the task as a tool for the study of laterality effects in memory and attention.

It must be remembered therefore that insofar as the dichotic shadowing task employs lateralized stimuli, it is not an appropriate technique for the exploration of selective attention. However, the technique affords an adequate control of the attention of normal subjects, to the extent that it may be particularly valuable for studies which seek to explore the consequences of the two hemispheres in contributing to the normal function of auditory memory.

It is from within this framework the rest of the studies in this thesis were developed. Whilst acknowledging the lack of ecological validity and therefore the difficulty of generalising to 'real-world' problems from the results of dichotic shadowing, some empirical gains must be made in the direction of linking laterality effects and mainstream cognitive psychology. An attempt to move in this direction has already been suggested by Cohen (1977).

CHAPTER FIVE

THE RIGHT EAR ADVANTAGE AS A FUNCTION OF TYPE OF MATERIAL AND SERIAL POSITION IN SELECTIVE ATTENTION

5.1 Introduction

The previous experiment established the existence of laterality phenomena in connection with the dichotic listening task. It has already been argued (Chapter I) that the shadowing technique has been central to the construction and elaboration of theories of auditory selective attention. Obviously it would be valuable to extend our understanding of processing asymmetries as they effect selective attention experiments. In order to do so it would seem to be appropriate to explore a phenomenon common to both areas of research, namely short-term memory.

In attention research the level of recall of attended items has frequently been the source of interest (Lackner and Garret, 1972; Underwood, 1972; Mackay, 1973; Underwood, 1976b). Similarly, the recall of unattended inputs has been seen as the key to a number of theoretical controversies in attention research (Moray, 1959; Norman, 1969; Glucksberg and Cowan, 1970; Underwood, 1973).

With respect to the study of lateral differences in hemispheric function, particularly studies based upon the dichotic listening paradigm, recall has been one of the principal measures employed (Kimura 1961; Bryden, 1963; Kinsbourne, 1975). Indeed some writers have expressed the view that the short term memory component of tasks is crucial to the demonstration of laterality effects (Darwin and Baddeley, 1974; Yeni-Konshian and Garden, 1974). Although this view does not command universal support, it nonetheless serves to underline the importance of memory as a factor in laterality phenomena.

Having established the relevance of memory as a psychological construct of importance to both fields of study, we shall now consider an experiment in which both attention and ear of arrival were manipulated and their effect upon recall measured. Mainka and Hörmann (1971) sought to establish whether or not it was possible for a subject to compensate for ear asymmetry by focussing attention on one input of a dichotic pair. It was found when recall from the left and right ears as the shadowed ear was compared, that the R.E.A. for verbal material persisted.

There are however a number of procedural problems which cast doubt upon the generalizability of their earlier results (Mainka and Hörmann, 1971) and suggest that a study which included a partial replication of this work might be useful in resolving a number of issues. The lack of any adequate control over the focussing of attention such as shadowing and the considerable delay between presentation and recall of items, makes comparisons between the study carried out by Mainka and Hörmann (1971) and the large body of studies were control was exercised over these variables (Norman, 1969; Treisman, 1969), most difficult.

A second level upon which the work carried out by Mainka and Hörmann requires reconsideration is entirely concerned with its theoretical implications. Mainka and Hörmann (1971) concluded that they had demonstrated that structural constraints such as those assumed to underly lateral differences in performance, could not be compensated for by focussing attention. Bosshardt and Hörmann (1975) reanalysed the data from the earlier study and revealed a difference between the two ears in the relationship between order of recall and order of presentation that they exhibited. There was a significant tendency for more of the words presented to the right ear to be recalled in the correct order than was the case with the recall of items presented to the left ear.

Essentially, Bosshardt and Hörmann (1975) embraced a structuralist conception of laterality effects (Kimura, 1961b). They assumed a neurophysiological dominance for speech in the left hemisphere, which was attributed in part to the 'directness of neural connections' serving that hemisphere. However Bosshardt and Hörmann (1975) attempted to explain why this dominance relationship came to be expressed as a right ear superiority for the coding of item order information.

The theory forwarded by Bosshardt and Hörmann (1975) is based upon evidence that a left hemisphere superiority exists for the encoding of the temporal aspects of stimuli. The data in support of their precision of temporal coding hypothesis comes from two main sources. Studies of brain damage or trauma in the field of neuropsychology have indicated the importance of the left hemisphere in processing and retaining the sequential aspects of auditory stimuli(Efron 1963; Teuber, 1969; Albert, 1972; Swisher and Hirsh, 1972). Studies which have involved the presentation of dichotic stimuli to normal subjects, have provided converging evidence that the left hemisphere enjoys a marked superiority for the analysis of the temporal aspects of stimuli. A number of authors have now concluded that an R.E.A. exists for the processing of serially presented auditory stimuli (Zurif and Carson, 1970; Blakemore, Iverson and Zangwill,1972; Vroon, Timmers and Tempelaars, 1977).

It has been suggested that auditory linguistic capacity is entirely dependent upon the ability of the brain to make fine discriminations in the temporal domain (Hirsch, 1967). It follows from the temporal coding hypothesis that language lateralization or rather consequent laterality effects, arise because of the right ear advantage for temporal discrimination, which it is argued is a crucial sub-process in language behaviour (Hécaen and Albert, 1978). Conversely it can be argued that lists which are not dependent upon an accuracy in temporal coding will not exhibit an R.E.A. Once again there is experimental evidence in support of this view. In particular the finding of an L.E.A. for music and the recognition of melodies (Kimura, 1964) has been shown to be linked to the relative <u>independence</u> of this task from a requirement for precision in temporal coding (Bogen and Gordon, 1971; Gordon and Bogen, 1974).

Although there is every reason to expect differences in the location of psychological processes to give rise to laterality effects, it is clear from the discussion in Chapter II that it is unlikely that they arise in so direct a fashion as structural models would seem to imply. Consequently the present experiment will be concerned with the effects of such variables as the subject's psychological 'set', the way in which the subject attempts to meet the changing demands of the experiment; 'strategies'. Both these factors have been seen to influence the results of dichotic listening studies and they deserve consideration before the structuralist model proposed by Bosshardt and Hörmann (1975) is adopted.

There is a considerable body of evidence, largely reviewed by Bryden (1978), which suggests the importance of subject strategies in determining the outcome of experiments designed to explore laterality phenomena. One particular line of evidence that response strategies influence measures of dichotic listening (Rollins, Evanson and Schurman, 1972; Schurman, Evanson and Rollins, 1972; Freides, 1977) would seem to indicate that they are a major source of processing asymmetries. Freides (1977) concluded that studies of dichotic listening measure response strategies alone.

A subject's response strategy can be influenced by the output factors implicit in a particular study; the response 'set' established by the experimenter's instructions and the experimental design. Darwin (1974) provides a useful demonstration of response 'set'; subjects were misled into expecting an entirely non-verbal stimulus sequence (pitch contours), as a result a left ear superiority ensued even when meaningful words were presented.

In the present experiment attentional 'set' will be manipulated by the requirement to shadow the right or left ear. This requirement may well interact differently with the two input channels, and a theoretical framework is required from within which an explanation of possible effects might be sought. As the recall of shadowed items is to be the independent variable in the present study a comparison of results from dichotic listening and dichotic shadowing is required.

Research into hemispheric differences has already brought to light differences in the serial position of items recalled from the left and right channels of dichotically presented lists (Bartz, 1968; Bosshardt and Hörmann, 1975). It has also been shown that the typical serial position curve of short-term memory research, occurs in the recall of shadowed material (Underwood, 1972). However, few comparisons have been made of possible laterality differences in the serial position curves from the left and right ears as the shadowed ear.

The theoretical interpretation of memory phenomena such as the serial position effect, is both complex and controversial (Baddeley, 1976; Cermak and Craik, 1979). However, the most influential hypothesis at present, the levels of processing approach (Craik and Lockhart, 1972) would seem to provide a framework for analysing laterality differences in the serial positions of items recalled from a focused attention experiment.

The levels of processing model of memory differentiates between the early and late positions of a list in terms of the levels of processing they exhibit; primacy effects arising from a relatively deep or elaborated encoding strategy, whereas later list positions are subject to a relatively 'shallow' mode of processing.

The manner in which levels of processing theory differentiates between primacy and recency, suggests that they would interact in quite different ways with the known characteristics of the left and right hemispheres. A related concept, that of encoding specificity (Tulving and Thompson, 1973), predicts an interaction between the manner in which the initial encoding of inputs occurs and the subsequent demands of the recall task.

Thus we can expect there to be some difference in the asymmetries in performance recorded when the encoding 'set' and scoring criterion are incompatible. This was of course the case when Bosshardt and Hörmann (1975) rescored the original free recall data of Mainka and Hörmann (1971) for ordered recall. When the experimental 'set' established by instruction and the subsequent recall task are complementary,a smaller effect of ear of arrival can be expected. The differences between the ears of the relationship between the encoding of intial inputs and the recall requirements, should be a sensitive index of laterality differences in selective attention.

The present experiment thus attempts to provide evidence of the relationship between (the) task requirements, the nature of the material presented and the use of lateralized stimuli. There is strong evidence that these factors interact and that a structural analysis such as that proposed by Bosshardt and Hörmann (1975) as an explanation of laterality effects in selective attention would prove to be an incomplete picture.

5.2 Method

5.2.1 Subjects

Forty-five undergraduates, 18 males and 27 females aged between 18 and 25 years participated in the experiment and were paid for their services. All subjects were self reported as being right-handed on a sub-test of 19 questions derived from the Edinburgh Handedness Inventory, see Appendix (B) for the full questionnaire. Three groups, designated left or right ear or monophonic shadowing were each assigned 15 subjects on a random basis. Before the experiment began each subject was trained in dichotic listening, the criterion employed being two successive shadowing trials with no errors. Subjects were tested individually in sessions lasting approximately one hour.

5.2.2 Apparatus

Fifteen lists consisting of five words drawn from the A or AA frequencies of the Thorndike-Lorge word count (Thorndike-Lorge, 1944) were compiled (see Appendix A for the complete list of words.) Each word employed in these lists were of either four of five letters in length, and all were monosyllabic. The words were presented in dichotic pairs, the error rate in matching was within the range of + or - 5 milliseconds as determined by visually comparing the two channels with an oscilloscope. The word pairs were placed at one second intervals.

Five lists were composed of words sharing the same meaning class; high, tall, etc. Five lists were of words having a common phonemic structure, cap, cad, can etc. The final five lists consist of words that bore no relationship to one another in terms of phonemic structure or semantic content.

These lists were recorded in parallel with fifteen lists consisting entirely of dissimilar words, of the same length, and drawn from the same source. The recording was made on the equipment maintained by the Psychology Department of the University of Edinburgh; D.I.T.M.A. (see photograph, Appendix C).

The stimuli were recorded ona Teac A-23405X tape recorder and presented through a pair of Pioneer SE-50cc headphones. The sound intensity at the ear was adjusted so that the sound level was 75dbA at the subject's head, as measured by a Brüel and Kjaer model 2203 sound level meter.

Monophonic stimuli were created by presenting the to-be-shadowed material from the dichotic tapes, to both ears of subjects in the monophonic shadowing condition.

5.2.3 Procedure

The subject sat in a chair facing the tape recorder which separated him/her from the experimenter. The subject was instructed that each list would consist of five words and that each word was to be repeated aloud, as it occurred. Subjects in the ordered recall condition were instructed to write down the words in the response booklet provided, each page of which contained a row of five boxes. At the end of each list the tape recorder was immediately stopped, and this was the signal for the subject to begin writing. Similarly the signal for the start of the list was the turning on of the tape recorder followed by a three second gap before the list was presented.

After the experimenter had ensured that the instructions had been understood, the experiment began; each list was followed by a period of one and a half minutes for recall. Finally, in testing subjects control was exercised over possible time of day effects by testing approximately equal numbers of subjects between 09.00 and 11.00 and 11.00 and 14.00 and 16.00 hours.

5.3 Results

The statistical analysis of the ordered recall data, consisted of three analyses of variance (ANOVAs). The three types of recall performance measure were:- 1) Ordered recall, the total number of items recalled in the same order as they were presented; 2) Free recall, the total number of items recalled irrespective of their location; 3) A comparison of Ordered recall scores for each type of shadowing; right, left or monophonic shadowing.

The factors in each ANOVA (a 2 x 3 x 5 split-plot design) were type of shadowing, (right, left or monophonic), list type (semantic, phonemic or unrelated), and serial position (position one to five), with 'repeated measures' on the last two factors. The data used in each type of analysis, were the untransformed raw scores.

The analysis of the data scored for ordered recall revealed no significant effect of ear of arrival. There was no significant effect of the ear of arrival type of list interaction. The interaction between the ear of arrival and serial position of correctly recalled items proved to be significant ($F=4.13$; dF 4,112; $P < .005$). As can be seen from Table 5.1 a simple main effects analysis of this interaction, following Kirk (1968), revealed that the significant contribution of ear of arrival was restricted to list positions one and three. However, by examining the graph of the serial position ear of arrival interaction (Fig. 5.1), it can be seen

Table 5.1 Ordered Recall

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	6.72	1	6.72	2.16	ns
SUBJECTS (within groups)	87.30	28	3.11		
B (TYPE OF LIST)	60.76	2	30.38	18.52	< 0.001
A x B	2.48	2	1.24	1	
B x SWG	91.96	56	1.64		
C (SERIAL POSITION)	151.11	4	37.77	34.02	< 0.001
A x C	18.36	4	4.59	4.13	< 0.005
C x SWG	124.99	112	1.11		
B x C	23.68	8	2.96	3.08	< 0.01
A x B x C	5.51	8	0.68	1	
B x C x SWG	215.95	224	0.96		

Simple effects of the 2-way interactions:

A at C1	9.34	1	9.34	6.18	< 0.005
A at C2	2.50	1	2.50	1.65	ns
A at C3	8.10	1	8.10	5.36	< 0.025
A at C4	0.22	1	0.22	0.14	ns
A at C5	4.90	1	4.90	3.24	ns
Error Term		140	1.51		
B at C1	18.20	2	9.10	8.34	< 0.001
B at C2	13.49	2	6.74	6.18	< 0.005
B at C3	12.20	2	6.10	5.59	< 0.005
B at C4	12.80	2	6.40	5.87	< 0.005
B at C5	13.09	2	6.54	6.00	< 0.005
Error Term		280	1.09		

Table 5.1a Comparison between means (Tukey's HSD) for the effect of list type at each serial position (ordered recall).

Comparison	q	p
B1 - B2 at C1	5.50	0.01
B1 - B3 at C1	2.50	ns
B2 - B3 at C1	3.00	ns
B1 - B2 at C2	4.35	0.01
B1 - B3 at C2	3.85	0.01
B2 - B3 at C2	1	
B1 - B2 at C3	4.50	0.01
B1 - B3 at C3	2.85	ns
B2 - B3 at C3	1.65	ns
B1 - B2 at C4	4.00	0.01
B1 - B3 at C4	0.00	ns
B2 - B3 at C4	4.00	0.01
B1 - B2 at C5	4.65	0.01
B1 - B3 at C5	2.15	ns
B2 - B3 at C5	2.50	ns

$q'_{0.05} = 3.44$
$q'_{0.01} = 3.70$

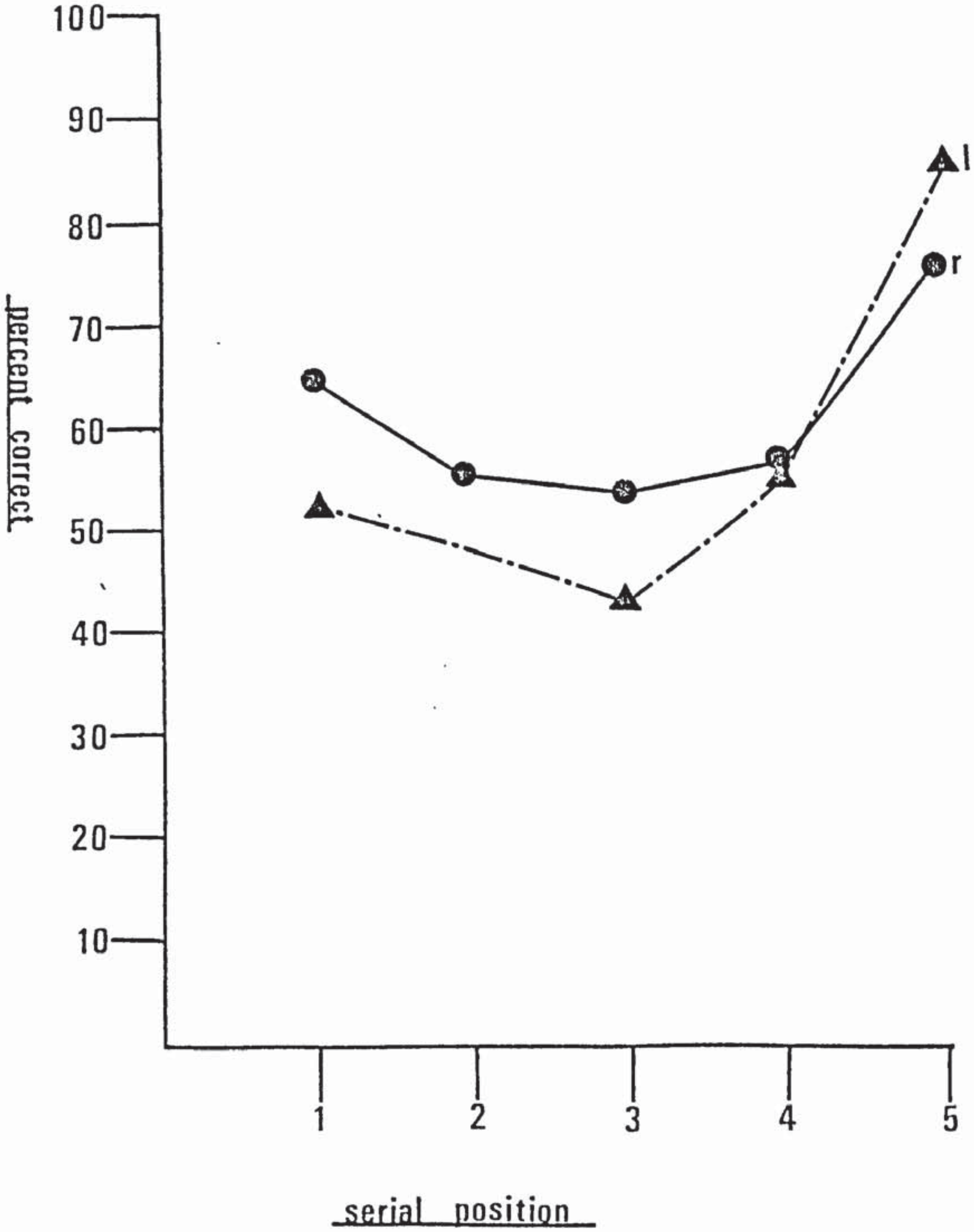

Figure 5.1 Ordered recall:- Percent correct as a function of serial position.

that the underlying trend is for a right ear superiority over the first half of the list to reverse at the final list position.

There was a significant main effect of the type of list shadowed ($F=18.52$; $dF2,56$; $P<0.001$), a significant main effect of serial position ($F=34.02$; $dF4,112$; $P<0.001$) and a significant effect of the interaction between the two factors, ($F:3.8$; $dF8,224$; $P<0.01$). The simple main effects analysis of this interaction (Table 5.1) showed that there had been a significant effect of list type at each serial position. Examination of the graph of this function (Fig. 5.2) reveals very similarly shaped recall curves for the semantically and acoustically related lists, which confirms previous findings in this area (Shulman, 1970). The recall efficiency of the various list types similarly corresponds to earlier work, (Baddeley, 1966), as can be seen from Table 5.2. Finally, it is important to note the very high frequency of successful recall of the last word in the list, (Figs. 5.1; 5.2). This effect which has been noted previously (Underwood, 1972), most probably arises because of the lack of verbal interference and the immediate freeing of analytical capacity that is directed to the terminal item(s) in a shadowed list. It should also be noted that three-way interaction proved to be non-significant.

The analysis of the ordered recall protocols when scored for free recall, revealed no main effect of

Table 5.2 Per cent correct for each type of list

Ordered Recall (see Table 5.4):

	SERIAL POSITION				
EAR OF ARRIVAL	1	2	3	4	5
A1 (right)	65.77	55.11	54.66	57.77	76.88
A2 (left)	52.88	48.44	42.66	55.55	86.22
A3 (mono)	88.00	73.33	62.22	68.88	90.22

Ordered Recall - rescored for free recall (see Table 5.3):

TYPE OF SHADOWING					
B1 (semantic)	75.33	81.33	79.33	84.66	94.00
B2 (phonemic)	65.33	80.00	70.66	71.33	82.66
B3 (unrelated)	64.00	56.00	68.00	78.00	83.33

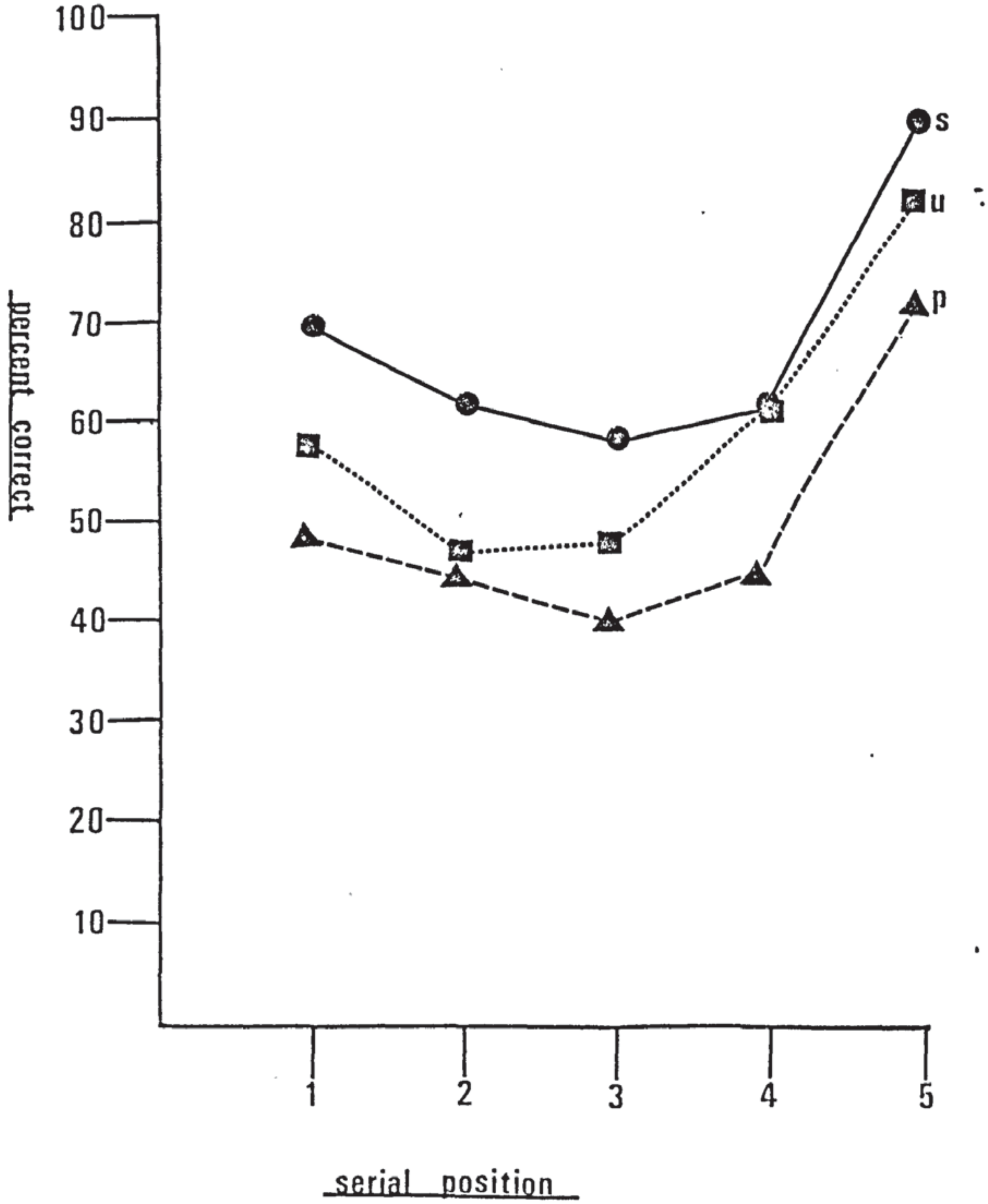

Figure 5.2 Ordered recall:- Percent correct for semantic, unrelated and phonemic lists as a function of serial position.

ear of arrival. Interestingly the interaction between ear of arrival and serial position approached significance (F:2.22; df4,114; $P < .10$). Whereas the interaction between ear of arrival and type of list, was not significant. The effect of serial position was significant (F=13.4; dF4,114; $P < 0.001$) as was the main effect of type of list (F=14.16; dF2,56; $P < .001$). The interaction between the last two factors was again significant, (F=2.33; dF8,224; $P < .001$), and the three-way interaction failed to approach significance. (Table 5.3).

The simple main effects analysis of the interaction between list type and serial position, is represented in Table 5.3; this shows that each factor was significant at every level of the other factor. In order to elaborate on these findings Tukey's HSD test for comparing means was employed (Kirk, 1968). The simple main effects analysis had shown that the main source of the significant effect of type of list occurred at position two. It was found that at this position recall of lists semantically related words was superior to recall of unrelated words (q=3.54; $P < 0.05$) but not phonemically related related words. Phonemically related words were better recalled than unrelated words however, (q=3.54; $P < 0.05$). The only other significant difference was that semantically related words were better recalled than phonemically related words at position 4, (q=3.54; $P < 0.05$).

This pattern of results contrasts quite markedly with those of the ordered recall protocols as can be

Table 5.3 Ordered Recall (rescored for free recall)

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	1.62	1	1.62	1	
SUBJECTS (within groups)	81.60	28	2.91		
B (TYPE OF LIST)	33.45	2	16.72	14.16	< 0.001
A x B	5.37	2	2.68	2.27	ns
B x SWG	66.38	56	1.18		
C (SERIAL POSITION)	45.27	4	11.31	13.15	< 0.001
A x C	7.66	4	1.91	2.22	ns
C x SWG	96.33	114	0.86		
B x C	20.80	8	2.60	3.33	< 0.001
A x B x C	5.35	8	0.66	1	
B x C x SWG	176.02	224	0.78		

Simple effects of the 2-way interaction:

C at B1 (semantic)	14.94	4	3.72	4.65	< 0.001
C at B2 (phonemic)	15.33	4	3.83	4.78	< 0.001
C at B3 (unrelated)	35.83	4	8.95	11.18	< 0.001
Error Term		338	0.80		
B at C1	5.71	2	2.87	3.33	< 0.05
B at C2	30.49	2	15.24	17.72	< 0.001
B at C3	5.26	2	2.63	3.05	< 0.05
B at C4	6.66	2	3.33	3.87	< 0.025
B at C5	6.06	2	3.03	3.52	< 0.05
Error Term		280	0.86		

Table 5.3a Comparison between means (Tukey's HSD), ordered recall rescored for free recall.

Comparison	q	p
B1 - B2 at C1	2.94	ns
B1 - B3 at C1	3.29	ns
B2 - B3 at C1	1	
B1 - B2 at C2	1	
B1 - B3 at C2	7.41	0.01
B2 - B3 at C2	7.05	0.01
B1 - B2 at C3	2.52	ns
B1 - B3 at C3	3.29	ns
B2 - B3 at C3	1	
B1 - B2 at C4	3.94	ns
B1 - B3 at C4	1.94	ns
B2 - B3 at C4	2.00	ns
B1 - B2 at C5	3.35	ns
B1 - B3 at C5	3.17	ns
B2 - B3 at C5	1	

$q'0.05 = 4.90$
$q'0.01 = 6.11$

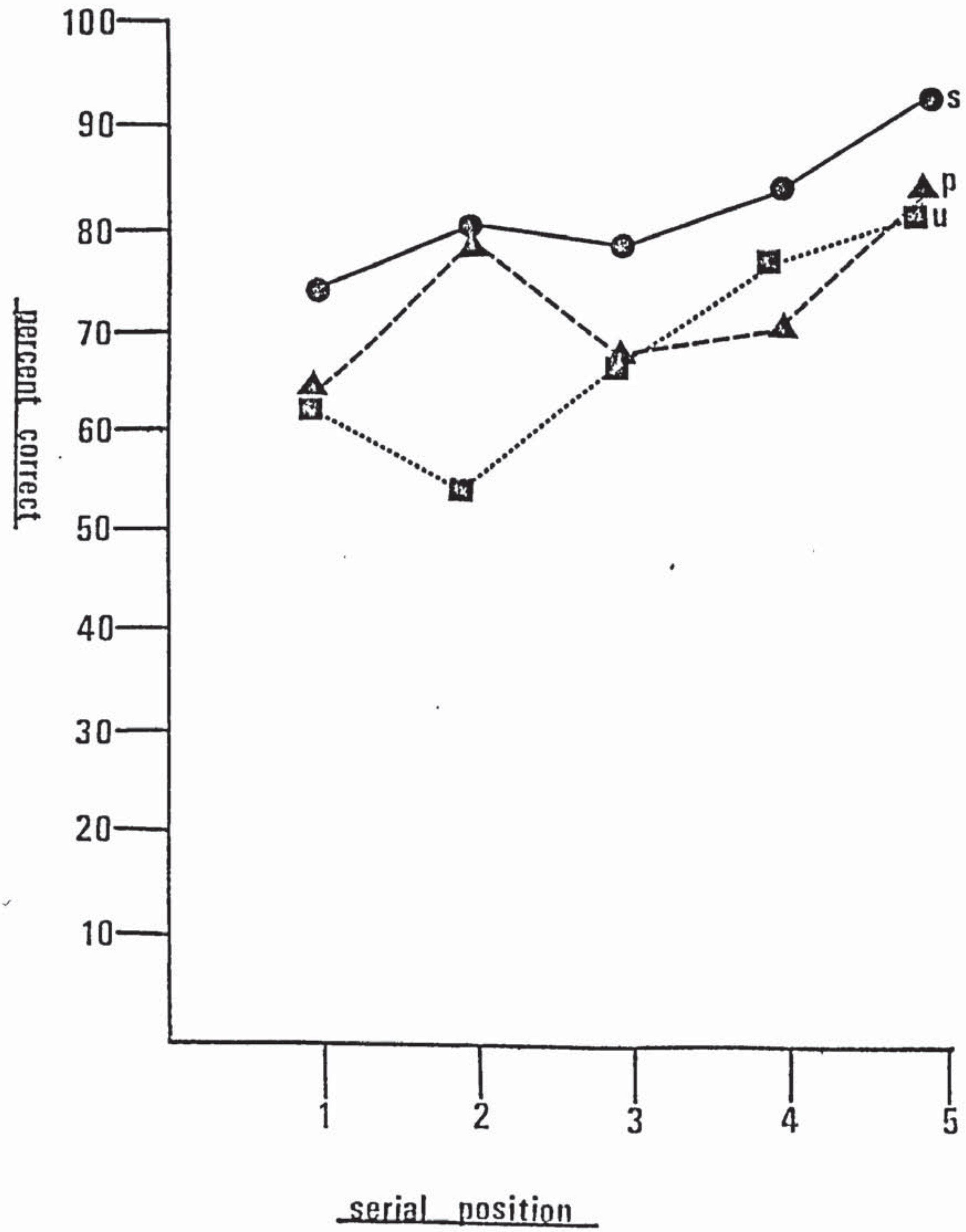

Figure 5.3 Ordered recall reanalysed for free recall:- Percent correct for semantic and phonemic lists as a function of serial position.

seen from a comparison of the two graphs (Fig. 5.2 and 5.3 respectively). Basically in ordered recall, semantically related words are better recalled than acoustically related words at every position (Table 5.1a). The superiority of semantically related material over unrelated occurs again at position 2 ($q=3.44$; $P< 0.05$). But unrelated material so diverges from acoustically related material as to be significantly superior at position 4, ($q=3.44$; $P< 0.05$), whereas no such divergence occurs in the ordered recall scored for free recall material. So the relationship between acoustic and unrelated material reverses; in ordered recall they converge at position two and diverge at position 4 (Fig. 5.2). The reverse situation holds true when they diverge at position two, and there is significant difference between the two at position 4, for ordered recall scores re-scored for free recall scores (Fig. 5.3).

The comparison between the two types of analysis thus reveals an interaction between the overall demands of the task, the material recalled, and the serial position of items recalled. The detailed nature of the relationship between these factors, will be more apparent when a comparison is made between the results of correct or ordered recall and free recall instructions.

The comparison between the effects of monophonic shadowing, and right and left ear dichotic shadowing, revealed a main effect of shadowing type ($F=15.46$; $dF2,42$; $P< .001$). The main effects of type of list ($F=46.04$; $dF4,168$; $P <.001$) and serial position ($F=46.04$; $dF4,168$; $P <.001$) were

Table 5.4 Ordered Recall - right, left and monophonic shadowing

SOURCE	SS	DF	MS	F	P
A (TYPE OF SHADOWING)	116.37	2	58.18	15.46	< 0.001
SUBJECTS (within groups)	158.05	42	3.76		
B (TYPE OF LIST)	112.36	2	56.18	31.92	< 0.001
A x B	8.61	4	2.15	1.20	ns
B x SWG	147.81	84	1.75		
C (SERIAL POSITION)	197.43	4	49.35	46.04	< 0.0001
A x C	37.68	8	4.71	4.39	< 0.001
C x SWG	180.08	168	1.07		
B x C	5.73	8	0.71	1	
A x B x C	11.27	16	0.70	1	
B x C x SWG	252.18	336	0.75		

Simple effects of the 2-way interaction:

C at A1 (monophonic)	66.64	4	16.66	15.57	< 0.001
C at A2 (right)	39.93	4	9.98	9.32	< 0.001
C at A3 (left)	129.53	4	32.38	30.26	< 0.0001

Table 5.4a Comparison between means (Tukey's HSD), right, left and monophonic presentation at positions 1 to 5.

Comparison	q	p
A1 - A2 at C1	3.16	ns
A1 - A3 at C1	7.25	0.01
A2 - A3 at C1	9.26	0.01
A1 - A2 at C2	1.74	ns
A1 - A3 at C2	4.79	0.01
A2 - A3 at C2	6.53	0.01
A1 - A2 at C3	3.16	ns
A1 - A3 at C3	2.00	ns
A2 - A3 at C3	5.16	0.01
A1 - A2 at C4	1	
A1 - A3 at C4	3.16	ns
A2 - A3 at C4	3.63	0.05
A1 - A2 at C5	2.47	ns
A1 - A3 at C5	3.52	ns
A2 - A3 at C5	1.05	ns

q'0.05 = 3.62
q'0.01 = 4.44

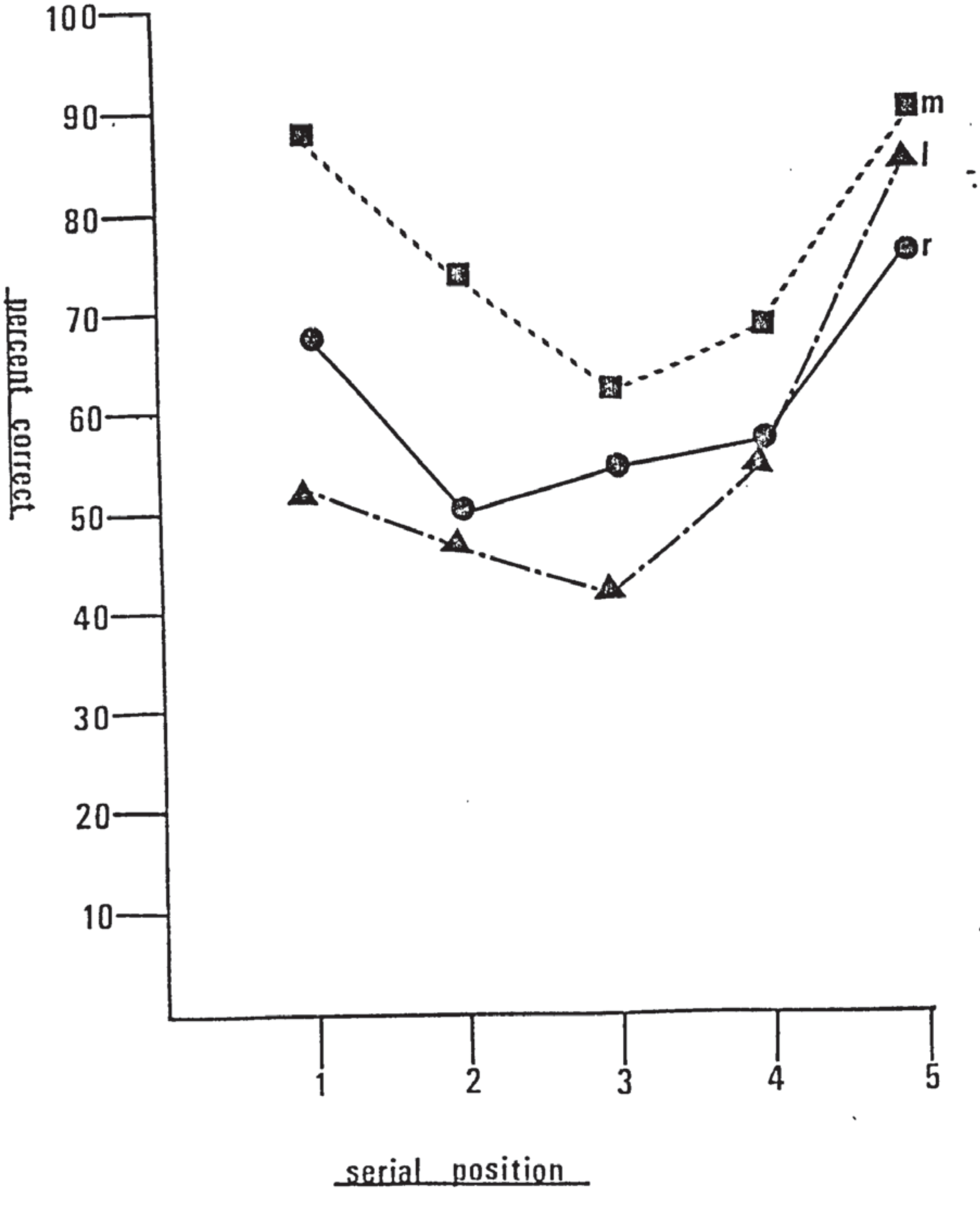

Figure 5.4 Ordered recall:- Percent correct for each type of presentation; monophonic, left and right as a function of serial position.

also significant. Only one interaction, that of type of shadowing and serial position, proved to be significant ($F=4.39$; $dF 8,168$; $P < .001$) (Table 5.4).

The simple main effects analysis of the interaction between type of recall and serial position revealed a significant contribution of serial position in all three types of shadowing. Multiple comparisons of complex means (Tukey's HSD Test after Kirk (1968) showed that recall of monophonically shadowed items was superior to the recall of both left and right ear shadowing at positions one and two (Table 5.4a). Significantly, the monophonic recall is superior to phonemic recall alone at positions three and four ($q=5.16$; $P \leq .01$) and ($q=3.63$, $P < .05$) respectively. There was no significant difference between the three types of shadowing, in terms of recall, at the final list position.

This comparison demonstrates the attentional effort expanded in separating the two channels of the dichotic inputs. The outstanding effect being that the consequences of having to reject a secondary input diminish as the list proceeds. This finding is in close accord with studies using such diverse techniques as pupil size and E.E.G. as measures of shadowing difficulty (Rabat, 1979).

5.4 Discussion

There are two main areas of consideration in discussing the results of experiment two; the consequences of the differential level of recall exhibited by the three kinds of material that were presented, and the implications of a laterality effect in the ordered recall of shadowed words. In the present work the laterality effect is of prime interest and this will be dealt with first.

5.4.1 Perhaps the most noteworthy aspect of these results is the fact that selective attention to a particular channel failed to eradicate the consequences of hemispheric differences. In the present case, the known superiority of the left hemisphere for the analysis of order of information (Bosshart and Hörmann, 1975) was manifest. The left hemisphere dominance for the processing of sequential inputs has been linked to the superior representation of time at the left hemisphere (Vroon, Timmers and Tempelaars 1977). It has recently been suggested (Vroon et al, 1977) that a basic, structural asymmetry underlies the frequently reported superior discriminating capacities of the left hemisphere in encoding information in time.

Bosshardt and Hörmann (1975) also argued that the differential perceptual efficiency of the two hemispheres with respect to time, must have a neurophysiological basis, as the asymmetry was evident in the comparison between left and right ears even when attention was focussed. The results of the present experiment do not allow any test to be made of hypotheses as to the fundamental basis of the lateral asymmetry in encoding or representing brief periods of time. However the evidence that this asymmetry is not consistent in its effect, but dependent for its magnitude upon the order in which the items were presented, indicates that the effect is a complex one.

In order to model the effect of the left hemisphere superiority with respect to the recall order information, it will be necessary to employ concepts which developed as an explanation of short-term or 'working memory' phenomena (Baddeley and Hitch, 1974). Previous work (Underwood, 1972) employing the same paradigm, indicates that the serial position effects found in this study are common to experiments employing serial recall in a focussed attention task. The serial position curve in the present study can therefore be described in a similar fashion. Thus the primacy effect can be attributed to an elaborated form of encoding, whereas the recency component reflects a relatively 'shallow' level of encoding where recall efficiency is attributed to the temporal proximity of recall rather than the effective storage of inputs.

It would follow from this levels of processing model (Craik and Lockhart, 1972) that the instructional requirement for the encoding of item order information interacted with the different levels of processing undergone by items at the primacy and recency locations.

A model of the storage of item order and item information proposed by McNicol (1971, 1975) is appropriate here. McNicol suggested that later list items are placed in a buffer store in which item and order information are linked. At the primacy portion of the list this is not the case, a random address system applies and item and order information are stored separately.

Having established a model of the relationship between serial position, concommitant changes in the level of processing of items and the requirement to recall items in the order in which they were presented, an explanation of the present results can be offered.

At later list positions order information is stored in some kind of buffer, effectively in the form of a complete representation of the input. Recent research has that the echoic trace persists for considerably longer than was previously supposed, and perhaps for as long as 15-29 seconds (Watkins and Watkins, 1979; Engle, 1980). Under these circumstances the experimental requirement for the retention of order information does not necessarily increase the processing load. Indeed, items recalled from recency positions are passively stored. There can be no grounds therefore upon which to expect any laterality differences to arise as a function of processing behaviour at later list positions.

At the primacy portion of the list order information becomes an explicit processing requirement, one which the left hemisphere is known to meet more readily than the right (Albert, 1972; Bosshardt and Hörmann, 1975). Consequently the superiority of the right ear is restricted to the primacy effect.

The overall advantage of right over left ear recall noted by Mainka and Hörmann (1971), where the R.E.A. persisted despite the focussing of attention, could well have arisen because of the delay before recall included in their experimental procedure. In fact such a delay would reduce the level of recall from the recency locations in the list, and thereby over-emphasise recall from the early list positions where the laterality effect would appear to arise. Thus giving rise to an overall R.E.A. which does not occur in the present study because of the reduced delay between presentation and recall.

5.4.2 The effect of the different types of material that made up the dichotic messages can be explained with reference to the levels of processing framework. The benefit in terms of efficient recall, of semantically similar items would, of course, flow from the deeper processing of items from the primacy portion of the list.

Unrelated lists composed of words which enjoy no attributes in common, present the most difficulty in recall as a consequence. Phonemically similar word lists are particularly disadvantaged at the recency position which would tend to confirm the suggestion that recall from these positions represents an echoic store (Baddeley, 1966).

An interesting effect revealed by the reanalysis of ordered recall is that lists composed of phonemically similar items actually facilitated the recall of items but not of order information, to the point where phonemically related words were remembered more frequently than unrelated words at primacy positions. Thus phonemic similarity affected only the recall of an item's position in the list, and not of the item itself, which confirms McNicol's (1975) suggestion that recall of items presented early in a list is from a random address store.

The absence of any laterality differences in ordered recall rescored for free recall tends to support the conclusion that it is the processing of order information and not just language, that is asymmetrically represented between the cerebral hemispheres. It has been suggested for example that they are both, that is the facility for discriminating sequences and processing linguistic inputs, representations the same nuero-physiological asymmetry (Bosshardt and Hörmann 1975). It is clear from the evidence of the present study however, that they can be identified separately in terms of their consequences for behaviour.

5.4.3 The comparison between monophonic, right and left ear shadowing suggests some final conclusions as to the nature of the laterality effect noted in this study. However, discussion of this issue is complicated somewhat by the logical consequences of shadowing monophonic input. The primary aim of the monophonic condition is, of course, to examine any differences in the level of recall caused by the requirement to select and shadow one of two inputs.

There are two possible ways in which the monophonic condition can be interpreted. Firstly, it can be argued that such a condition controls for the impact that the presence of an unattended input, in terms of the effort expended in selecting between inputs, may have upon recall. Unfortunately this position cannot be maintained in view of the fact that monophonic shadowing can only act as a control condition in this manner; for a phonic experimental condition in which both ears received both attended and unattended channels. Because in this experiment in the dichotic shadowing condition the subject had to shadow one lateralized input and ignore another. This is a logically different requirement from shadowing one input channel which is not lateralized in the same manner.

In effect there is no control condition where a solitary input channel is lateralized because even if the structural theory that a second dichotic input is essential to lateralize inputs (e.g. Kimura 1961b) is rejected, and a more recent model accepted, lateralization cannot be guaranteed to occur. The more recent models of laterality include the assumption that it is by fully loading processing capacity, completely engaging a subject's attention, that dual tasks are lateralized (Hellige and Cox, 1979; Jonides, 1979). Single channel shadowing does not fully engage a subject's available shadowing capacity, indeed there is evidence that even dichotic shadowing cannot always fulfill such a role (Salter, 1973).

It is not possible, therefore, to draw any firm conclusion as to whether or not the absence of a second (unattended) channel of inputs reduced the level of recall of dichotically shadowed inputs below that of monophonic shadowing. The conclusion that there is no direct comparison to be drawn between monophonic and dichotic shadowing in terms of recall level, because dichotic inputs are lateralized whereas monophonic inputs are not, implies that monophonic shadowing _is_ a control condition, with reference to the implications of lateralizing inputs in dichotic shadowing.

In fact, bearing in mind one important caveat it is permissible to conclude that shadowed inputs when lateralized to one or the other hemisphere, are less liable to be recalled as a consequence. Words presented to the right or left hemisphere are with reference to the deeper level of processing performed upon items presented early in a list, recalled less well than monophonically presented items. The recency portion of the list however, revealed no significant differences between the three types of shadowing. It would seem, therefore, that the mnemonic capacities of the independent hemispheres are less than that of the 'whole', that is to say when inputs are represented at both ears as in monophonic shadowing.

The right ear advantage would seem therefore to arise not from a straight forward left hemisphere superiority for language, but rather from the relatively superior and possibly different processing carried out at the left hemisphere as opposed to the right.

This last observation is in keeping with recent research which has suggested that although the two hemispheres are characterized by very different capabilities in the processing of information particularly language, the extent of these differences has been somewhat over-emphasized. In particular there is increasing evidence that the right hemisphere possesses a considerable capacity for the representation of language especially when material is presented auditorily (Gazzaniga, 1970; Levy, Trevarthen and Sperry, 1972; Zaidel, 1976, 1978).

Finally, some mention must be made of the fact that although monophonic shadowing may be a useful comparison with dichotic shadowing with reference to laterality effects, it cannot be argued to be good model of 'ordinary' listening behaviour. Obviously two inputs are normally represented at both hemispheres in free field listening, the relationship between attentional and hemispheric difference effects under such conditions are by no means directly comparable with the results of the present experiment. In this respect therefore, the value of the monophonic, dichotic shadowing comparison is limited.

5.5 Experiment three

The materials and procedure for this study were the same as for experiment two. The exception was, of course, that subjects were not required to recall the lists in any particular order. The age and sex of subjects and other details of this study are covered in Chapter Three (Table 3.1).

5.6 Results

The statistical analysis of the free recall data followed the same pattern as that for the ordered recall data. There were three main analyses of variance (ANOVAs) employing the same factors; type of shadowing (right, left or monophonic), list type (semantic, phonemic or unrelated) and serial position (position one to five), with 'repeated measures' on the last two factors. The analyses were:- the free recall protocols marked for free recall, that is the total number of items correctly recalled irrespective of position. The same protocols marked for ordered recall; total number of items recalled in the same order as they were presented, and finally a comparison was made between right, left and monophonic shadowing free recall scores.

5.6.1. The data from the free recall analysis (Table 5.5) showed that there had been no significant main effect of ear of arrival; right or left upon the number of items recalled. This does not correspond with the reported persistance of the R.E.A. noted by Mainka and Hörmann (1971) even when attention is focussed. Two features of the earlier study suggests where this difference may have arisen, and will be dealt with in the next section.

The main effect of serial position was significant ($F= 18.18$; df 4,112; $P< .001$), as was the main effect of list type ($F= 14.09$; df 2,5; $P< .001$) and the interaction between serial position and list type ($F= 14.00$; df 8,224; $P< 1001$). None of the two-way interactions including ear of arrival were found to be significant. The three-way interaction effect was found to be significant ($F = 2.25$; df 8,224; $P < .05$). The simple main effects analysis of the three-way interaction (Kirk, 1968), showed that the significant contribution of ear of arrival differences to the interaction occurred when comparing the recall of unrelated material at list position two (Table 5.5).

The sharp decline in the recall of unrelated words at list position two, already noted in the free recall analysis of ordered recall protocols (Fig. 5.3) was apparent in the recall of items presented to the left ear (Fig. 5.5). This result suggests that in the previous experiment the difference between the left and right ears in terms of the efficiency with which they processed order information was largely compensated for by focussing attention upon order information. The disparity becomes far more significant when attention is diverted away from order information. The benefit in terms of mnemonic efficiency conferred by items sharing phonemic or semantic attributes would appear to overcome the disparity between the hemispheres at least in the primacy portion of the list where the effect is apparent. Both semantic ($q = 7.64$; $P < .05$) and phonemically similar items ($q = 7.05$, $P < .05$) are recalled more efficiently than unrelated words at list position two.

At the recency portion of the list, significantly at position five, semantic and unrelated items are

Table 5.5 Free Recall

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	5.33	1	5.33	2.03	ns
SUBJECTS (within groups)	73.49	28	2.62		
B (TYPE OF LIST)	30.45	2	15.22	14.09	< 0.001
A x B	1.09	2	0.54	1	
B x SWG	60.86	56	1.08		
C (SERIAL POSITION)	62.57	4	15.64	18.18	< 0.001
A x C	2.34	4	0.58	1	
C x SWG	96.89	112	0.86		
B x C	32.50	8	8.12	14.00	< 0.001
A x B x C	10.54	8	1.31	2.25	< 0.05
B x C x SWG	131.46	224	0.58		

Simple simple effects of the 3-way interaction:

A at BC11	0.83	1	0.83	1	
A at BC12	0.03	1	0.03	1	
A at BC13	2.70	1	2.70	3.13	ns
A at BC14	0.13	1	0.13	1	
A at BC15	2.13	1	2.13	2.47	ns
A at BC21	0.13	1	0.13	1	
A at BC22	0.53	1	0.53	1	
A at BC23	0.13	1	0.13	1	
A at BC24	0.73	1	0.73	1	
A at BC25	0.53	1	0.53	1	
A at BC31	0.03	1	0.03	1	
A at BC32	8.53	1	8.53	9.91	< 0.005
A at BC33	2.70	1	2.70	3.13	ns
A at BC34	0.03	1	0.03	1	
A at BC35	0.00	1	0.00	1	
Error Term		420	0.86		
BC at A1	13.19	8	1.64	2.82	< 0.01
BC at A2	29.85	8	3.69	6.36	< 0.001
Error Term		224	0.58		
B at AC11	9.25	2	4.62	6.79	< 0.005
B at AC12	6.40	2	3.20	4.70	< 0.01
B at AC13	0.93	2	0.46	1	
B at AC14	3.33	2	1.66	2.44	ns
B at AC15	4.13	2	2.06	3.02	< 0.05
B at AC21	4.05	2	2.02	2.97	ns
B at AC22	29.20	2	14.60	21.47	< 0.001
B at AC23	9.92	2	4.96	7.29	< 0.001
B at AC24	4.05	2	2.02	2.97	ns
B at AC25	4.13	2	2.06	3.02	< 0.05
Error Term		280	0.68		

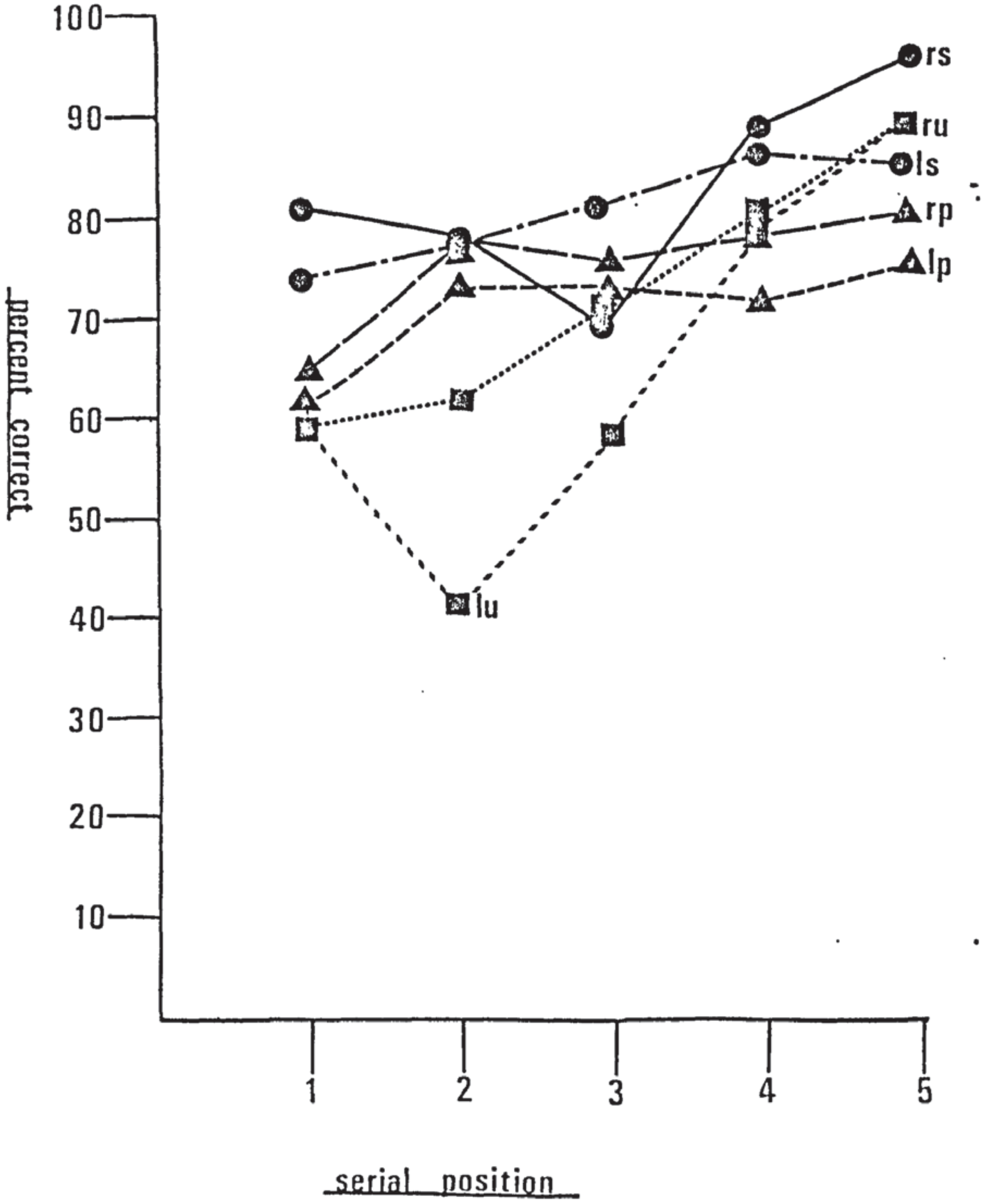

Figure 5.5 Free recall:- Percent correct as a function of type of list, ear of arrival and serial position.

more frequently recalled than phonemically similar items ($q= 3.52$; $P< .05$) whereas semantic and unrelated items are recalled with equal efficiency at that position. Evidence once again that phonemically similar items can be confused and recall reduced, in the recency 'buffer' store. This must be contrasted with the superior recall of phonemically similar items in comparison with unrelated items at position two. Whereas ordered recall reduced the level of recall of phonemically similar items, free recall encouraged a higher level of recall at position two. Because the characteristic held in common, phonemic structure, can help recall the item, but apparently reduces recall of its location within the list. This does suggest that whereas the meaning of an item can help recall, for example in semantically similar lists, this is independent of any requirement for the recall of item order, which is not the case with phonemically similar items, where the requirement for item and order information are to an extent, mutually incompatible requirements.

5.6.2. The analysis of free recall protocols scored for ordered recall confirmed the finding of Bosshardt and Hörmann (1975) in showing a main effect of ear of arrival (Table 5.6) ($F= 8.08$; df 1,28; $P< .01$). The recall of items presented to the right ear was

Table 5.6 Free Recall (rescored for ordered recall)

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	116.02	1	116.02	8.08	< 0.01
SUBJECTS (within groups)	402.05	28	14.36		
B (TYPE OF LIST)	50.93	2	25.47	11.58	< 0.001
A x B	4.88	2	2.44	1.11	ns
B x SWG	123.12	56	2.20		
C (SERIAL POSITION)	29.27	4	7.32	5.86	< 0.001
A x C	1.71	4	0.43	1	
C x SWG	139.62	112	1.25		
B x C	8.40	8	1.05	2.39	< 0.025
A x B x C	2.32	8	0.29	1	
B x C x SWG	98.68	224	0.44		

Simple effects of the 2-way interaction:

B at C1	13.61	2	6.80	8.60	< 0.001
B at C2	10.75	2	5.37	6.79	< 0.001
B at C3	8.62	2	4.31	5.45	< 0.001
B at C4	14.86	2	7.43	9.40	< 0.001
B at C5	18.60	2	9.30	11.77	< 0.001
Error Term		280	0.79		
C at B1 (semantic)	13.34	4	3.33	4.69	< 0.001
C at B2 (phonemic)	15.84	4	3.96	5.57	< 0.001
C at B3 (unrelated)	8.49	4	2.12	4.09	< 0.005
Error Term		336	0.71		

Table 5.6a Comparison between means (Tukey's HSD), type of list at each serial postion

Comparison	q	p
B1 - B2 at C1	3.00	< 0.05
B1 - B3 at C1	2.65	< 0.05
B2 - B3 at C1	1	
B1 - B2 at C2	3.70	< 0.05
B1 - B3 at C2	3.70	< 0.05
B2 - B3 at C2	1	
B1 - B2 at C3	3.65	< 0.05
B1 - B3 at C3	1	
B2 - B3 at C3	2.65	< 0.05
B1 - B2 at C4	4.65	< 0.01
B1 - B3 at C4	1	
B2 - B3 at C4	3.80	< 0.05
B1 - B2 at C5	5.50	< 0.01
B1 - B3 at C5	2.00	ns
B2 - B3 at C5	3.50	< 0.05

$q'0.05 = 2.43$
$q'0.01 = 4.31$

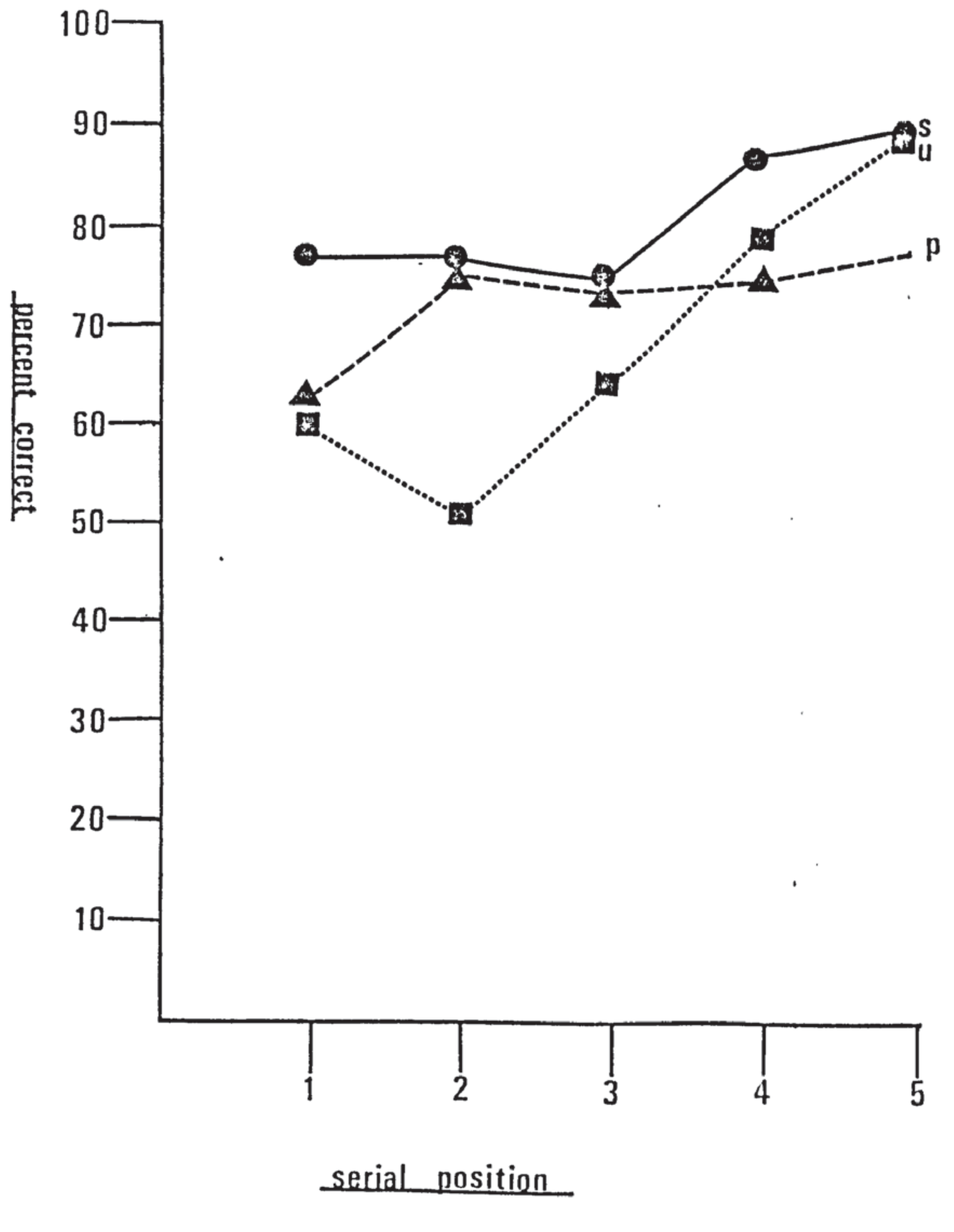

Figure 5.6 Free recall:- Percent correct for each type of list, semantic, unrelated and phonemic as a function of serial position.

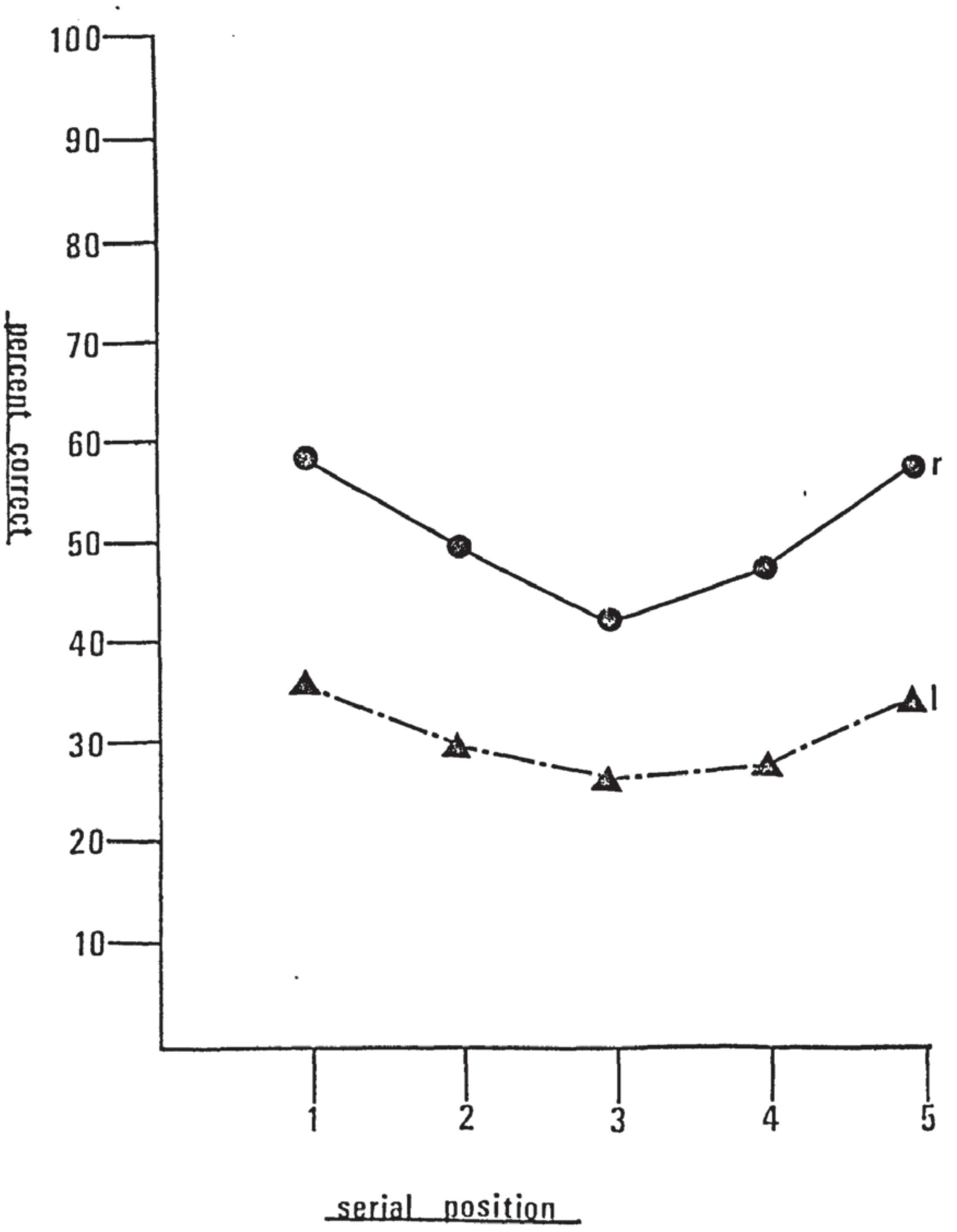

Figure 5.7 Free recall reanalysed for ordered recall:- Percent correct, for right and left ear presentation as a function of serial position.

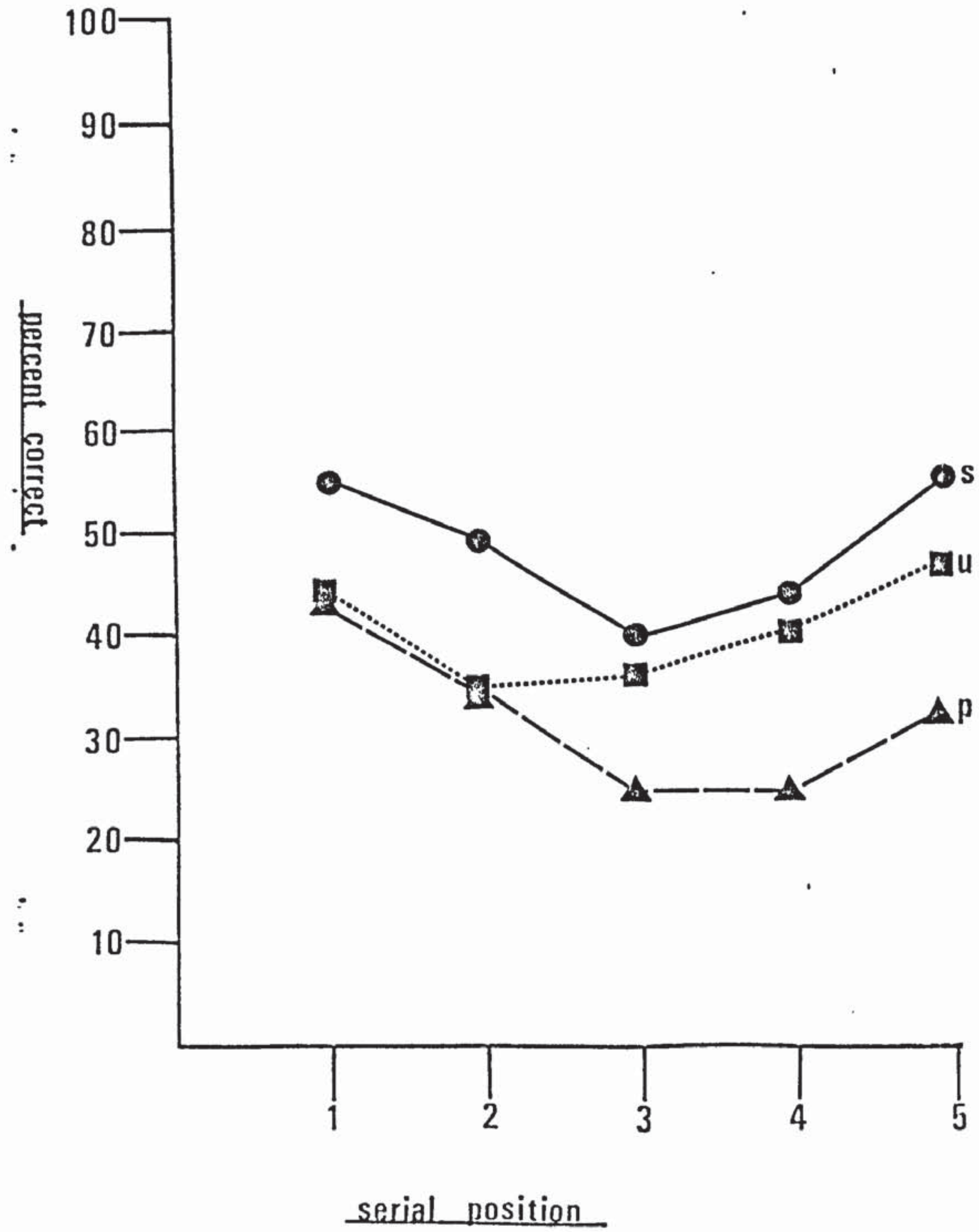

Figure 5.8 Free recall analysed for ordered recall:- Percent correct for each type of list semantic, unrelated and phonemic as a function of serial position.

superior to that of the left ear ($q= 4.16$; df 2,28; $P < .01$) and was a uniform effect in so far as the interactions between ear of arrival and list type, and ear of arrival and serial position were not significant (Fig. 5.7). This lack of interaction effects reflects the level at which the functional asymmetry for the processing of order information is manifest when order information is an incidental characteristic of an item to be recalled. It is a basic indicator of success in recall, and this does not depend upon any explicit requirement to memorize serial position, a feature of the recall of serial position information that has been confirmed (Toglia and Kimble, 1976).

The main effect of list type was significant ($F= 11.58$; df 2,56; $P < .001$) as was that of serial position ($F= 5.88$; df 4,112; $P < .001$) and the interaction between the two factors ($F= 2.39$; df 8,224; $P < 025$). The serial position curve of the interaction (Fig. 5.8), bears close resemblance to the recall curve for the recall of serial position information in the previous experiment (Fig. 5.2). The serial position curve for the reanalysis of free recall is less steeply bowed than that for ordered recall reanalysed for free recall. This simply reflects the much lower level of recall for items in the correct position under free recall conditions.

Another similarity between these two interactions of serial position and type of list is in the relationship between the different types of list. The reanalysis of free recall scores revealed that whereas there had been no difference between the recall of unrelated and phonemically similar items at positions one and two where both were less well recalled than semantically similar items, unrelated items were recalled more frequently than phonemically similar words at position three ($q = 2.65$; $P < .05$), 4 ($q = 3.80$; $P < .05$) and 5 ($q = 3.50$; $P < .05$). Semantically related material was recalled more efficiently than phonemically related words at all list positions, but only at positions one and two in relation to unrelated words (Table 5.6a).

This 'cross-over' effect is exhibited by unrelated material when both free and ordered recall are scored for free recall. At the primacy portion of the list unrelated material is at a disadvantage in comparison with lists of semantically similar words, because like phonemically similar word lists, they exhibit none of the semantic attributes in common, which facilitate recall of items presented at the beginning of a list. At the recency portion of the list however, unrelated and semantically similar words both afforded a distinctive phonetic/phonemic structure, a basis for recall. Phonemically similar items promoted confusion in the echoic store and so were poorly recalled. In effect they are unrelated words at early list positions and phonemically similar at the recency position, thereby reducing recall throughout the list.

The fact that the recall curves for free and ordered recall scored for ordered recall are so similar, suggests that order information is an attribute of an item which is encoded independently of other item attributes such as its meaning or sound. This would indicate in line with experiment II, that order information is an independent sub-process in memory for linguistic inputs and not a dominant feature of language behaviour as has been suggested (Bosshardt and Hörmann, 1975).

The comparison of monophonic, left and right ear shadowing revealed a main effect of type of shadowing ($F= 32.46$; df 2,42; $P< .001$) (Table 5.7). There were also significant main effects of type of list ($F= 20.79$; df 2,84; $P< .001$) and serial position (17.32; df 4,168; $P< .001$). The interaction effect between serial position and type of list was not significant, however, the interaction effect of type of shadowing and serial position of items recalled did reach significance ($F= 4.46$; df 8,168; $P< .001$). The three interaction effect was not significant therefore the two-way interaction was further subject to a simple main effects analysis (Kirk, 1968).

There was no significant effect of serial position of presentation upon the recall of items presented monophonically (Table 5.7) presumably because a list of five items is considerably less than the memory span of normal subjects (Millar, 1956). The simple

Table 5.7 Free Recall - right, left and monophonic shadowing

SOURCE	SS	DF	MS	F	P
A (TYPE OF SHADOWING)	122.09	2	61.04	32.46	< 0.001
SUBJECTS (within groups)	79.06	42	1.88		
B (TYPE OF LIST)	32.02	2	16.01	20.79	< 0.001
A x B	3.50	4	0.87	1.12	ns
B x SWG	64.82	84	0.77		
C (SERIAL POSITION)	46.44	4	11.65	17.32	< 0.001
A x C	23.96	8	2.99	4.46	< 0.001
C x SWG	112.60	168	0.67		
B x C	30.96	8	3.87	1	
A x B x C	17.25	16	1.07	1	
B x C x SWG	1434.79	336	4.27		
Simple effects of the 2-way interaction:					
C at A1 (monophonic)	5.49	4	1.37	2.04	ns
C at A2 (right)	32.41	4	8.10	12.08	< 0.001
C at A3 (left)	32.49	4	8.12	12.11	< 0.001
Error Term		168	0.67		
A at C1	53.71	2	26.87	29.52	< 0.001
A at C2	57.34	2	28.67	31.50	< 0.001
A at C3	18.19	2	9.09	9.98	< 0.001
A at C4	9.25	2	4.62	5.07	< 0.01
A at C5	7.53	2	3.76	4.13	< 0.025
Error Term		280	0.91		

Table 5.7a Comparison between means (Tukey's HSD), right, left and monophonic shadowing

Comparison	q	p
A1 - A2 at C1	10.00	>0.01
A1 - A3 at C1	9.07	>0.01
A2 - A3 at C1	1	
A1 - A2 at C2	11.07	>0.01
A1 - A3 at C2	7.78	>0.01
A2 - A3 at C2	3.28	>0.05
A1 - A2 at C3	5.70	>0.01
A1 - A3 at C3	5.33	>0.01
A2 - A3 at C3	1	
A1 - A2 at C4	4.14	>0.01
A1 - A3 at C4	3.14	>0.05
A2 - A3 at C4	1.28	ns
A1 - A2 at C5	4.07	>0.01
A1 - A3 at C5	2.21	>ns
A2 - A3 at C5	1.85	>ns

q'0.05 = 2.80
q'0.01 = 3.71

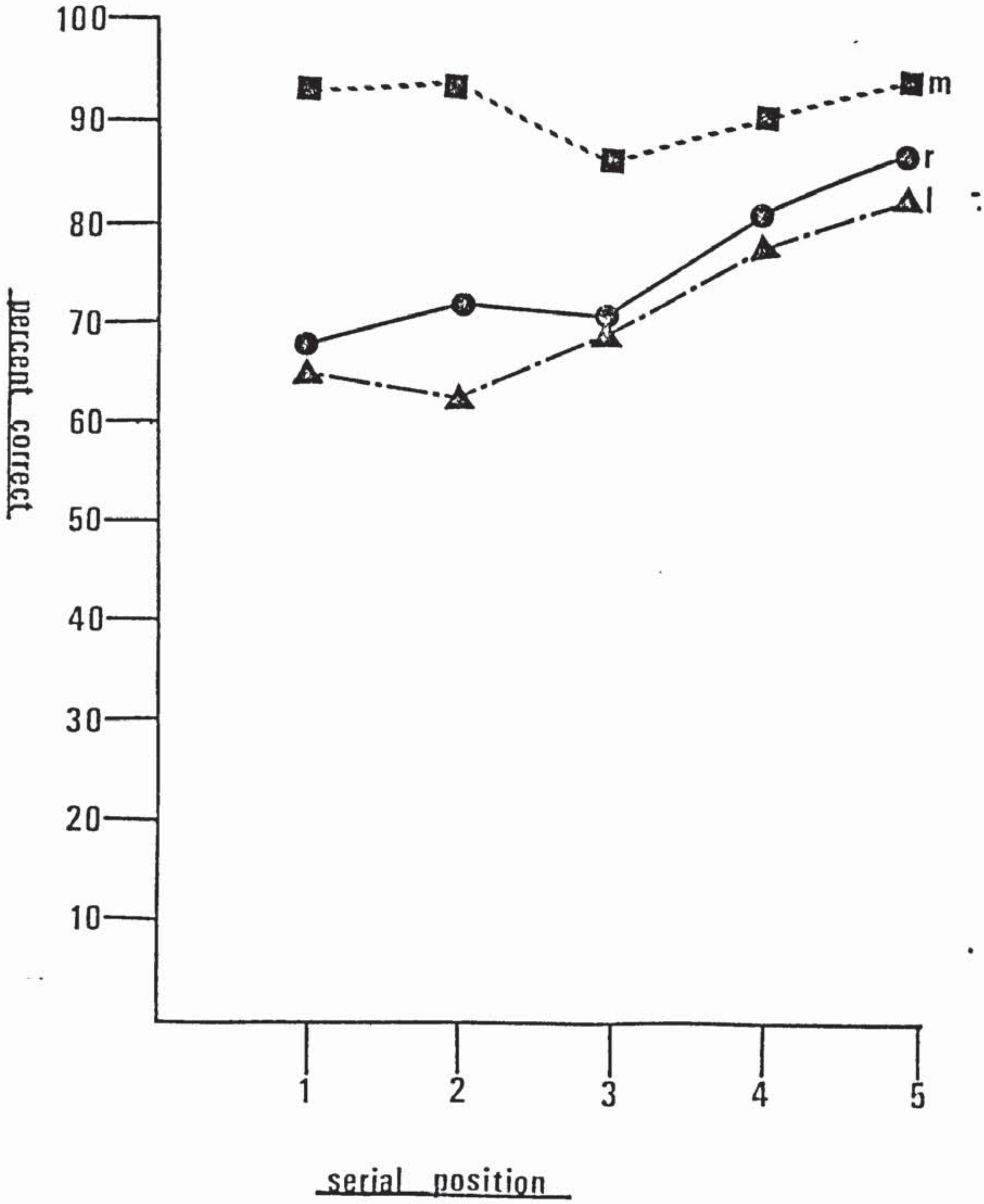

Figure 5.9 Free recall:- Percent correct for each type of presentation; monophonic, left and right as a function of serial position.

main effect of type of shadowing was significant at every position in the list (Table 5.7) and therefore Tukey's HSD was employed to compare complex means (Kirk, 1968).

The results of the multiple comparison means analysis, contained in Table 5.7b, reveal differences in the recall of material shadowed under the three different conditions. At positions one to four, recall of words shadowed monophonically was superior to recall of right or left ear shadowed inputs. At position five monophonically presented items were only recalled more frequently than items shadowed at the left ear ($P < .01$). Also at position two right ear recall was superior to left ear recall ($P < .05$). This result reinforces the earlier observations that the effect of ear of arrival is constrained by serial position, and that the R.E.A. is particularly concentrated at the primacy position of the list.

5.7 Discussion

Discussion of results from the free recall task is considerably facilitated by the fact that there are no significant departures from the framework already established. The laterality effect, a significant interaction between the order of presentation of an item, type of list and ear of arrival, was confined to an R.E.A. for unrelated material. Once again the R.E.A. originated at the primacy portion of the list where items are encoded to a deeper level.

It is interesting to note that this only applied to unrelated material, semantically similar items, did not give rise to any asymmetries in recall. This might suggest that the difference between the ears is to a certain extent decided by a resource limitation upon the right hemisphere in processing language, rather than a complete inability to do so, as some research has suggested (Gazzaniga and Sperry, 1967). Thus in the present case the unattended words which lacked distinctiveness (Eysenck, 1978; Cermak and Craik, 1979) and were therefore less likely to be recalled from the primacy portion of the list exhibited a laterality effect, whereas the semantically similar items were more easily encoded in the context of a list.

The absence of any significant main effect of ear of arrival in a focussed attention task would seem to contradict the findings reported by Mainka and Hörmann (1971). Two procedural differences between the two studies might form the basis of an explanation of this discrepancy. First, there was a considerable delay before recall in the earlier study and second, there was no operational control of attention such as shadowing; in the previous study subjects were simply required to concentrate on the attended inputs. It can be argued therefore that the rate of decay of right and left ear traces may be different and that the controlled focussing of attention reduced potential laterality differences in recall.

The analysis of free recall in terms of the number of items remembered in their correct location, confirms the findings of Bosshardt and Hörmann (1975). However, details of the present experiment place the previous interpretations of this effect in a new light. Although the spontaneous level of items recalled in their order of presentation is considerably lower for left than right ear inputs, there is no interaction with the type of list or serial position. Thus it can be concluded that order information is not essential for item recall, but that it is an attribute of an item which itself exhibits a serial position curve.

It the above interpretation is correct then the thesis proposed by Bosshardt and Hörmann (1975) as to the central role of an asymmetry for order information in determining an R.E.A. for language can be rejected. The independent nature of position information at once denies such a role and underlines the flexibility of the attended system. When attention is paid to an asymmetrically represented capacity for determining the sequence of inputs, that asymmetry is not obvious in performance. When attention is not paid to order information, the asymmetry becomes clear on analysis, but once again because attention was focussed, there is no overall behavioural asymmetry, i.e. an R.E.A. for the recall of lists. Thus focussing attention can reduce the overt behavioural consequences of an order information asymmetry, if that is what is required of the subject.

It must be noted, however, that any departure from the relationship between the various attributes of an item in terms of the encoding that obtains in free recall, reduces recall. Thus ordered recall can be achieved, but is necessarily less successful than free recall in terms of the number of items recalled. This suggests that when item order changes from an implicit to an explicit cue for recall the processing effort involved is only achieved at the expense of the encoding of other attributes which could more successfully promote recall.

5.7.1 The comparison between monophonic and lateralized inputs confirmed the superiority of monophonic shadowing over primacy and middle portions of the list. That this effect occurred in both free and correct recall, underlines the fact that there is a lack of information about lateralized inputs, which reduces recall. This in turn suggests the likelihood of co-operation and integration of the hemispheres as characteristics of normal mnemonic efficiency.

5.8 Conclusions

The first conclusion to be drawn from these two experiments, is that the selective attention task can be used as an effective tool for analysing the differences between left and right hemispheres. Even though the present experiments revealed no overall effects of laterality as it is usually measured, that is with a global superiority in the recall of items presented to one ear as opposed to the other. There is substantial evidence that hemispheric differences exert an effect upon human performance involving focussed attention.

5.8.1 Experimental evidence drawn from the study of commissurotimized and normal subjects, indicates that the cerebral commissures unify the left and right hemispheres into a single attentional system (Ellenberg and Sperry, 1980). The studies reported here further suggest that the system by which there is a bilateral integration of attention involves a shifting pattern of dominance relationships in the face of instructional set and varying stimulus characteristics. In the present case the dominant hemisphere was indicated by the experimenter when nominating the ear to be shadowed. The processing characteristics of the hemisphere processing the attended input, interacted with the mnemonic requirements of particular types of stimulus attribute; the type of material shadowed and the requirement to emphasize order information. In both cases, whether the relevant stimulus dimensions were established by the context of the material or task requirements concerning the nature of recall, a laterality effect resulted.

This pattern of results does not in fact lend itself to a complete interpretation within the framework of structural models (Kimura, 1961b, 1967) attentional models (Kinsbourne, 1973, 1975) or process-oriented models (Cohen, 1975) of laterality. The present study would seem to suggest that overall dominance is determined by the task at hand, and that any laterality effects, observed asymmetries in performance upon specific features of the task, are dependent upon the interaction of a number of situational constraints.

The flexibility in the locus of processing has already been noted in relation to a number of studies employing lateralized stimuli (Geffen, Bradshaw and Nettleton, 1973; Kinsbourne, 1973; Patterson and Bradshaw, 1975; Levy and Trevarthen, 1976. The present study suggests that when attention is focussed upon lateralized stimuli, the differences between the hemispheres are similarly complex in their expression. It would appear that the study of selective attention and hemispheric differences reveal phenomena and explanatory concepts which are common to both.

5.8.2 In respect of selective attention, the principal conclusion to be drawn is that human beings need not always exhibit behaviour consistent with the assumption of a single channel processing device (Broadbent, 1958, 1971). The argument to be developed here is that whereas the brain as a whole is integrated to function as such a processing device, functional sub-assemblies are engaged by lateralizing stimuli, and that under certain circumstances the consequences of de-coupling, functionally isolating components of the cortex, can be made explicit.

This viewpoint receives some support from neuropsychology; current models of hemispheric differences suggest:-

> "That hemispheric specialization falls on a continuum; it is a matter of degree rather than on all or non concept. Thus each hemisphere has a wide range of cognitive competencies that is sufficient to support diverse behaviours, including some that would be better performed by the other hemisphere." (Zaidel, 1978, p.281)

In the present case it has become clear that although the right hemisphere can process lists of unrelated words and order information, neither of these tasks can it perform as well as the left hemisphere.

It would seem, then, that the dominant hemisphere in a focussed attention task with dichotic stimuli is that which assumes the responsibility for carrying out the majority of processing, as has been suggested by other workers (more generally concerned with laterality effects, Cherry and Trevarthen, 1976; Jonides, 1979).

The relative difficulty with which the two input channels carry out the task of recalling the attended items, indicates underlying hemispheric differences but not an overall dominance of one hemisphere in shadowing dichotic inputs. It is interesting to speculate that where inter-hemispheric partition of competence is complete, for example in language production (Zaidel, 1976), then perhaps as in the present case, there can be no straight forward behavioural indication of this superiority. Instead the hemisphere specialized for speech production would seem to operate regardless of the ear of arrival of the items to be shadowed.

To return to the issue of the relative difficulty with which the left and right ear inputs are recalled. In both free and ordered recall, there was an interaction between type of shadowing and serial position. Recall of monophonic stimuli was uniformly superior to the recall of items presented to the right or left ear at early positions. It can be concluded, therefore, that under the processing conditions which obtain in the primacy portion of the list, those attributes which are separately encoded by the two channels promote a higher level of recall when they are encoded in common by the integrated processing system, which is how the brain as a single channel operates when inputs are not lateralized by external circumstances.

The conclusion must be drawn that although the dichotic shadowing task has been argued to fully engage a subject's attention (Treisman, 1969; Norman, 1969) it cannot be said to do so. Linguistic stimuli are clearly different in their implications for attention when presented to the left and right hemispheres, as in a dichotic shadowing task. Not only does this reflect upon dichotic shadowing as a technique for exploring selective attention, it also suggests some interesting features of attention as a concept.

It is possible to argue for example that attention not be considered as a mechanism whereby inputs are allowed varying degrees of access to a central, limited capacity, processing device. But instead as a system by which the processing device can be differentially engaged in representing external events. The engagement or coupling of processing capacity to inputs can take the form of devoting particular structures, for example the right or left hemisphere, or even functionally determined structures which are represented in both hemispheres, to particular tasks. It can also consist at the same time of engaging a number of functionally independent structures to a greater or lesser extent.

It has been argued this can be due to situational determinants, for example when order information becomes an explicit rather than an implicit processing requirement. Or perhaps because of an interaction between situational and structural characteristics of a task, as for example when a subject is required to remember order information with regard to items presented to the left ear. This latter case clearly requires more processing capacity than does the similar requirement when shadowing a list at the right ear. As purely neurophysiological evidence regarding to the capacity of the right hemisphere to process order information would indicate (Teuber, 1969; Albert, 1972).

It is clear from the evidence of the first three studies that ear of arrival can strongly influence the consequences of a focussed attention task such as dichotic shadowing. The effect of instructional set, type of material and length of the list has been seen to influence the nature of recall. The evidence would suggest that further examination of the situational variables in the dichotic listening test would reveal further inconsistencies in the assumption of a straightforward R.E.A. for verbal stimuli.

CHAPTER SIX

LATERALITY EFFECTS AND THE SERIAL POSITION CURVE : THE IMPORTANCE OF LIST LENGTH

6.1 Introduction

This experiment is designed to explore some of the implications of increasing list length for the laterality differences that occur in the ordered recall of verbally shadowed dichotic lists. Experimental evidence indicates that as list length increases, then the serial position curve reveals a declining contribution to total recall of the primacy portion of the list (Postman and Phillips, 1965; Baddeley and Hitch, 1977). Experiment II has already revealed that the primacy portion of the list, is the site of a significant difference between the ordered recall of words presented to the left and right ears.

A change in the recall superiority of the right ear as the primacy effect declines, would constitute a contradiction of structural models of lateral asymmetries with regard to speech stimuli (Kimura, 1966, 1973). Similarly a change in the laterality effects reported in experiment II, simply as a result of increasing the length of the list, would not be in accord with Kinsbourne's attentional model (Kinsbourne, 1975). In the case of structural models when there is no change in the location of the input or its content, then no change in the pattern of the R.E.A. is expected. The attentional model would require for there to be some change in the nature of the stimulus or the environment to alter the subjects 'priming' for speech (Kinsbourne, 1975).

Following the proposition that structural invariances are expressed in functional terms as the subject actively seeks to meet the demands of an experiment, then an increase in the memory load might be expected to affect the R.E.A. especially when consideration is given to the known limitations of right-hemisphere short-term memory (Zaidel, 1978). This would suggest that there might be a disproportionate dependency of the right-hemisphere, on the form of memory storage which characterizes the recency portion of a recalled list of items.

In Experiments II and III, the finding of Mainka and Hörmann (1971) was replicated; incidental recall of order information revealed a main effect of ear of arrival unconstrained by serial position. This can be interpreted as a clear expression of structural differences between the two hemispheres. The situation with regard to the overt requirement for item order information is far more complex. It is in this area that we see the interplay between structural invariants, attentional factors such as the partial failure to compensate for ear differences which gives rise to the interaction effects and finally the widely examined features of cognitive behaviour, the constraints of human short-term memory.

In order to increase our understanding of the first two aspects of laterality and it is assumed here that they hold a complementary relationship rather than a mutually exclusive one.

Then further insight into the effect of the last constraint, that of memory, must be sought. In the present case the importance of the primacy effect to the issue of laterality effects,necessitates some discussion of its theoretical background. Rdcent work on the primacy effect has resulted in a model which discounts factors such asproactive interference. Instead the notion of a perceptual or pre-storage basis for the primary effect has been developed (Underwood, 1975; Hockey and Hamilton, 1977). The emphasis here is upon the efficiency of perceptual analysis and encoding during the early part of the list.

It has already been noted that the experimental study of laterality effects has indicated that there is a perceptual basis to such effects, both in terms of the consequences for the recall of, and the reaction of time to, lateralized verbal input (Bryden 1967, Springer, 1971). There is good reason to suppose that those contraints known to influence the character of the primacy effect will also reflect the relative efficiency of the right and left channels for the recall of shadowed dichotic lists.

It has been suggested that the primacy effect influences the recency portion of the list since there is a corresponding decrease in the recall of later list items, as the primary effect increases. Thus a longer list would give more opportunity for this "rebound effect" to occur than was the case in Experiment Two. Similarly, we would expect this feature of the primacy model to be reflected in the present experiment, as a source of differences in the recall of left and right ear inputs.

A study reported by Underwood (1977) reinforces this last suggestion and indicates that the cross-over effect noted in Experiment II might have some significance for the present experiment. The above mentioned effect took the form of a change from an R.E.A. at the primacy portion of the list to a non significant L.E.A. at the latter half of the list, the primacy effect. Employing a list of ten items Underwood (1977) reported a 'curious' finding, namely that whereas the right ear message was recalled on 66.25% of all occasions, the left ear message was accurately recalled 77.5% of the time. Although this tendency towards an L.E.A. was not statistically significant, it serves to underline the possibility that the L.E.A. observed at the recency position in Experiment II may become significant as list length increases.

The purpose of this experiment, then, is to seek a closer understanding of the relationship between memory and the relative efficiency of recall exhibited by the right and left channels. By analysing the areas in which our knowledge of short-term memory might illuminate the expression of laterality effects, a clearer understanding of the relationship between structural and functional (attentional) laterality constraints can be gained.

6.2 Method

6.2.1 Subjects

Twenty undergraduates, 11 males and 9 females aged between 18 and 22 years participated in the experiment and were paid for their services. All subjects were self-reported as being right-handed on a sub-test of 19 questions derived from the Edinburgh handedness inventory; see Appendix (B) for the full questionnaire. Ten subjects were assigned on a random basis, to each of two groups designated left and right ear shadowing. Before the experiment began each subject was trained in dichotic listening, the criterion employed being two successive error free shadowing trials. Subjects were tested individually in sessions lasting approximately fifty minutes.

6.2.2 Apparatus

Twelve lists consisting of nine words drawn from the A and AA frequencies of the Thorndike-Lorge word count (Thorndike-Lorge, 1944) were compiled; see Appendix A for the complete list of words. Each word employed in these lists was of either four of five letters in length, and all were monosyllabic. Four lists were composed of words sharing the same meaning class; high, tall etc. (semantically similar lists). Four lists were of words with a common phonemic structure; war, law, door etc. (phonemically similar lists). The final lists were made up of words that bore no resemblance to one another in terms of semantic or phonemic content (unrelated word lists).

These lists were recorded in parallel with white noise recorded at a slightly higher level of intensity than the words. The recording was made using white noise prepared by means of a Campden Electronics Model 530 white noise generator on channel one and a sequence of words recorded at the rate of one per second on channel two of a Teac A-23405X stereo tape recorder.

The recording was relayed from the Teac A-23402X and presented through a pair of SE-50cc headphones. The sound intensity at the ear was adjusted so that the level was 75dbA at the subject's head as measured by a Brüel and Kjaer model 2203 sound-level meter.

6.2.3 Procedure

The subject sat in a chair facing the rear of the tape recorder which separated him/her from the experimenter. The subject was instructed that each list would consist of nine words and that each word was to be repeated aloud as it occurred. Subjects were further instructed that immediately after the end of a list, they were to write down the shadowed words in the order in which they had been presented in the response booklets provided. Each page of the booklet contained a row of nine boxes. At the end of each list the tape recorder was stopped immediately. The signal for the start of the list was the turning on of the tape recorder followed by a three-second gap before the list was presented.

After the experimenter had ensured that the instructions had been understood, the experiment began. The period allocated for recall was one and a half minutes, after which the subject was instructed to stop writing and turn the page. Finally, control was exercised over possible time-of-day effects by testing equal numbers of subjects between 09.00 and 13.00 and 14.00 and 16.00 hours.

6.3. Results

In the statistical treatment of the data analyses of variance ANOVA were performed upon the results of the ordered recall protocols and upon the same protocols rescored for free recall. The factors in each ANOVA (a 2x3x9 split-plot design) were ear of arrival (Right or Left), list type (Semantic, Phonemic or Unrelated) and serial position (Positions one to nine), with 'repeated measures' on the last two factors. The data employed in the analysis of variance were the untransformed raw scores.

The analysis of the ordered recall scores revealed no significant main effect of ear of arrival. There was a significant effect of the type of list (F=20.45; dF2,36; $P < .001$), but the interaction of list type and ear of arrival failed to approach significance. The main effect of serial position was significant (F:102.56; dF:8,144; $P < .001$), and the interaction between list position and ear of arrival also proved to be significant (F=2.32; dF8,144; $P < .025$). This interaction was of course significant in Experiment II, but the graph of the interaction (Fig.6.1) reveals a very interesting development of the earlier effect. Whereas in Experiments II and III there had been an REA for the items recalled from the primacy portion of the list, in the present study this situation is entirely reversed and a significant LEA was obtained for items recalled from the recency portion of the list.

Table 6.1 Ordered Recall

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	1.78	1	1.78	1	
SUBJECTS (within groups)	36.21	18	2.01		
B (TYPE OF LIST)	24.14	2	12.07	20.45	< 0.001
A x B	0.89	2	0.45	1	
B x SWG	21.27	36	0.59		
C (SERIAL POSITION)	525.17	8	65.64	102.56	< 0.001
A x C	11.97	8	1.49	2.32	< 0.025
C x SWG	93.27	144	0.64		
B x C	50.60	16	3.16	4.51	< 0.001
A x B x C	4.71	16	0.29	1	
B x C x SWG	202.73	288	0.70		

Simple effects of the 2-way interactions:

A at C1	1.31	1	1.31	1.70	ns
A at C2	0.41	1	0.41	1	
A at C3	0.27	1	0.27	1	
A at C4	0.27	1	0.27	1	
A at C5	0.42	1	0.42	1	
A at C6	3.27	1	3.27	4.13	< 0.05
A at C7	3.75	1	3.75	4.74	< 0.05
A at C8	3.75	1	3.75	4.74	0.05
A at C9	0.27	1	0.27	1	
Error Term		162	0.79		
B at C1	37.64	2	18.82	27.67	< 0.001
B at C2	5.70	2	2.85	4.19	< 0.05
B at C3	5.64	2	2.82	4.14	< 0.05
B at C4	2.44	2	1.22	1.79	ns
B at C5	2.24	2	1.12	1.64	ns
B at C6	0.20	2	0.10	1	
B at C7	3.05	2	1.52	2.24	ns
B at C8	13.90	2	6.95	10.22	< 0.001
B at C9	4.04	2	2.02	2.97	ns
Error Term		324	0.68		

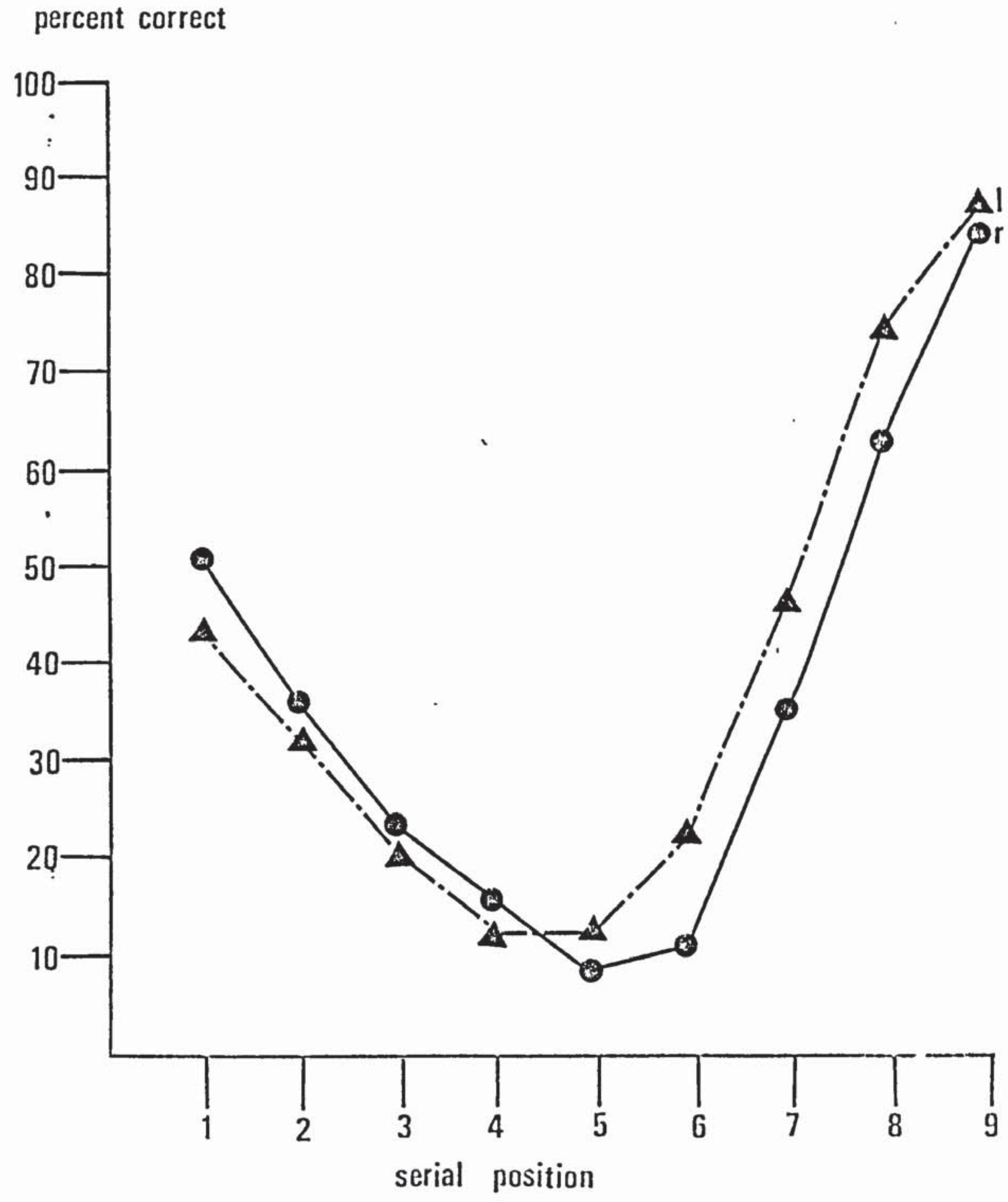

Figure 6.1 Percent correct for right and left ear presentations as a function of ear of arrival.

The simple main effects analysis (Kirk, 1968) of this result underlined the reversal, the significant contribution of ear of arrival to the interaction with serial position, occurred only at positions 6,7 and 8. At these positions the recall of material presented to the left ear was superior to the recall of those words presented to the right ear ($P < .05$). At the same time the expected reduction in the number of items recalled from the primacy portion of the list, gave rise to a non-significant trend towards an R.E.A. This contrasts heavily with Experiment II where the R.E.A. occurred only at the primacy portion of the list.

Of greater interest is the non-significant trend towards an overall L.E.A. for verbal material, with 36.29% of the items presented to the right ear and 39.16% correctly recalled from the left. Although ear of arrival was non-significant as an overall effect, the ear of arrival serial position interaction was entirely dominated by the L.E.A. at positions 6,7 and 8. This finding bears close comparison with the results of Underwood (1977), as they were discussed earlier.

The type of material serial position interaction proved to be significant ($F=4.51$; dF16,288; $P < .001$) and this was also analysed for simple main effects. The results of this test (Table 6.1) showed that the source of the interaction was a significant effect of list type at positions 1,2,3 and 8. This of course confirms the pattern of Experiment II, where the main effect of type of material was similarly restricted to the early portion of the list (Fig.6.2). Tukey's H.S.D. test revealed that the difference between semantic and acoustic material was only significant at position one (q =7.47, $P < .05$). The superior recall of semantically related over unrelated items was also significant only at position one (q =7.47, $P < .05$), no other pairwise comparison proved to be significant.

The analysis of the ordered recall protocols when rescored for free recall, showed no significant main effect of ear of arrival. Nor did any of the interactions involving ear of arrival approach significance. The main effect of list type was significant (F=36.82; dF2,36; $P < .001$), as was that of serial position (F=40.64; dF8,144; $P < .001$). The interaction between type of list and serial position was significant, (F=3.12; dF16,288; $P < .001$), and was further subject to a simple main effects analysis.

The only significant simple effect of type of list occurred at list position one, Tukey's H.S.D. test revealing that although semantically related words were recalled more frequently than either acoustically related (q = 4.09, $P < .05$), or unrelated words (q =4.09, $P < .05$) there was no significant difference in the level of recall of acoustically related and unrelated words. An overall comparison of recall from the three categories showed that whereas the difference between the recall from semantically related and acoustically related lists only approached significance the semantic and acoustically related lists

Table 6.2 Free Recall

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	1.56	1	1.56	1	
SUBJECTS (within groups)	78.33	18	4.35		
B (TYPE OF LIST)	54.43	2	26.71	56.82	< 0.001
A x B	0.94	2	0.47	1	
B x SWG	35.17	36	0.97		
C (SERIAL POSITION)	237.34	8	29.66	40.64	< 0.001
A x C	4.36	8	0.54	1	
C x SWG	105.97	144	0.73		
B x C	49.94	16	3.12	4.65	< 0.001
A x B x C	7.28	16	0.45	1	
B x C x SWG	195.23	288	0.67		

Simple effects of the 2-way interaction:

B at C1	34.90	2	17.45	4.90	< 0.05
B at C2	8.40	2	4.20	1.17	ns
B at C3	16.90	2	8.45	2.37	ns
B at C4	9.70	2	4.85	1.36	ns
B at C5	17.64	2	8.82	2.47	ns
B at C6	2.54	2	1.27	1	
B at C7	10.04	2	5.02	1.41	ns
B at C8	1.64	2	0.82	1	
B at C9	1.64	2	0.82	1	
Error Term		324	3.56		
C at B1 (semantic)	77.30	8	9.66	14.00	< 0.01
C at B2 (phonemic)	43.28	8	5.41	7.84	< 0.01
C at B3 (unrelated)	166.70	8	20.83	30.18	< 0.01
Error Term		432	0.69		

Table 6.3 Percent correct for ordered recall by ear of arrival and list type

Type of List	Right	Left	Total
Semantic	84.44	93.33	88.9
Phonemic	63.06	58.88	67.22
Unrelated	74.44	74.44	74.44
Total	72.59	78.33	

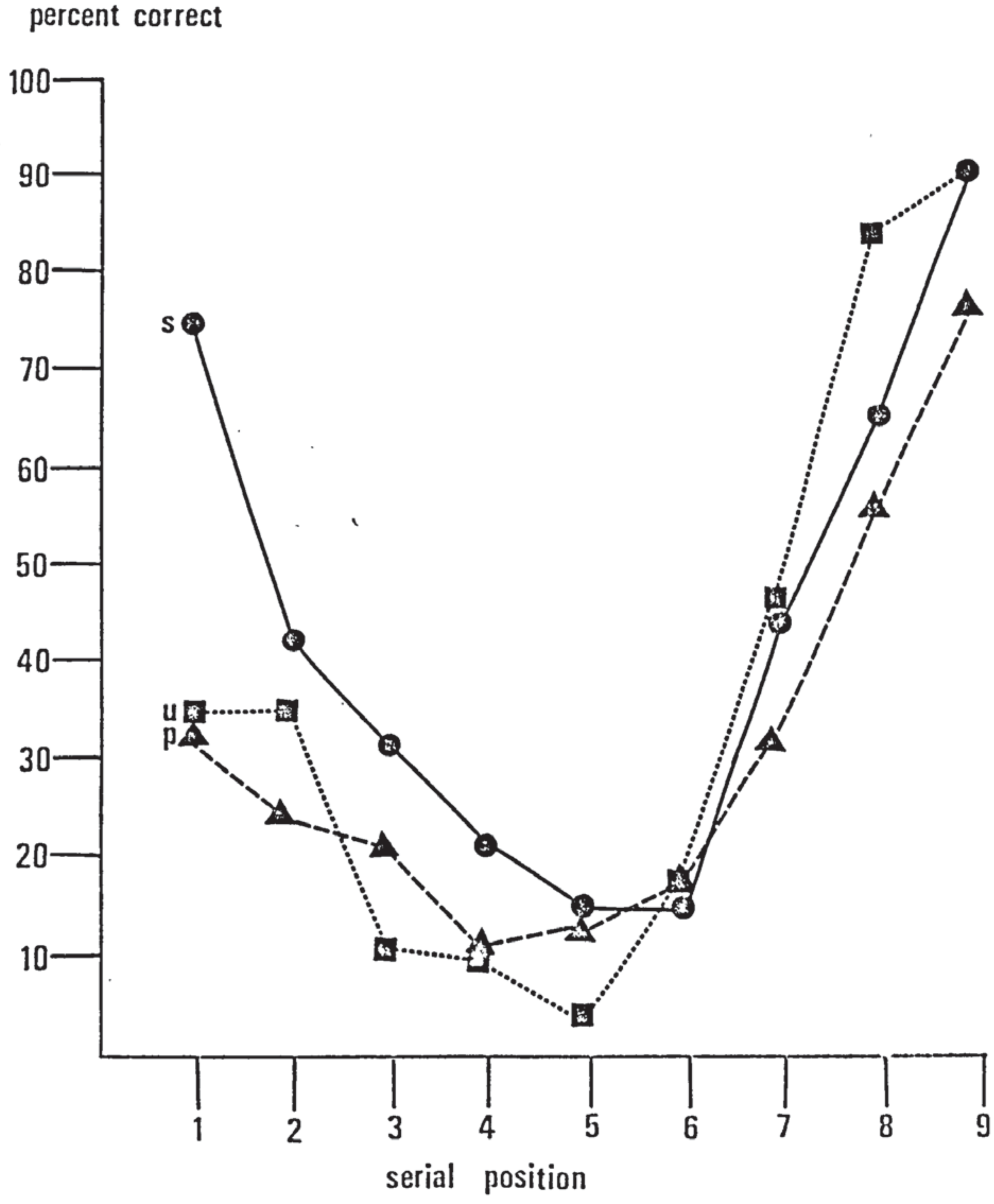

Figure 6.2 Percent correct for each type of list; semantic, unrelated or phonemic, as a function of serial position.

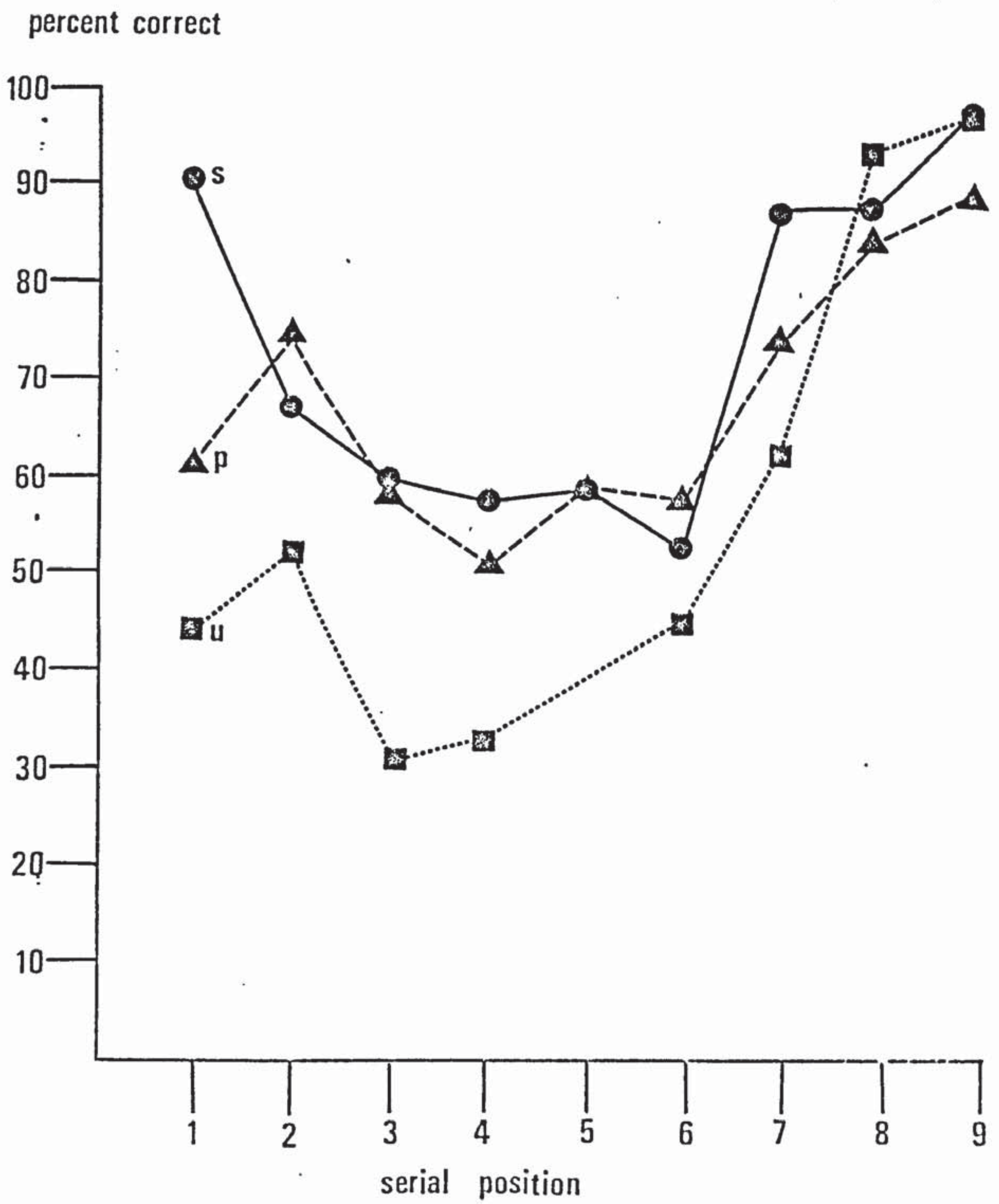

Figure 6.3 Ordered recall reanalysed for free recall:- Percent correct for each type of list, semantic, unrelated or phonemic, as a function of serial position.

both exhibited a higher level of recall than unrelated lists ($q = 10.71$, $P < .05$) and ($q = 7.57$, $P < 0.05$) respectively.

An analysis of intrusion errors (words recalled that were not presented) revealed no significant differences between the number of errors occurring in the recall of right and left ear presentations. Table 6.3 shows the percentage contributions of each type of list and ear of arrival. The variation between individuals was so considerable as to nullify the trends outlined in Table 6.3. The relative contribution of each type of list does however indicate the effect of list context on the accuracy of recall.

6.4 Discussion & Conclusions

The importance of these results lies in the replication and extension of the findings of Experiment II. The present study successfully demonstrated that although the serial recall curve exhibited the same form as previously, the significance of the result was determined by the number of items presented. The shorter list had provided a significant R.E.A. at the primacy portion of the list, and a non-significant trend towards an L.E.A. at the end of the list. The longer message gave a non-significant tendency for an R.E.A. at the beginning of the list, and a significant trend towards an L.E.A. over the latter half of the list.

Having elaborated upon this difference in the performance of the right and left channels, some attempt will be made to divine its source. The first step in this attempt is to model the circumstances of the effects already noted. In order to do so this the concepts of memory research will be employed and by comparing the relative success of such theories with respect to the left and right channels, some conclusions as to their source may be drawn.

The argument thatprimacy is based upon perceptual processing, the efficient registration of inputs, has much general support, (Underwood, 1975; Hockey and Hamilton, 1977). Although they argue that primacy itself is not dependent upon such secondary processing behaviour as rehearsal, the storage of subsequent items may well be. It has also been argued (Hockey and Hamilton, 1977), that 'ongoing and secondary processing activity' will reduce the likelihood of efficient perceptual registration. Therefore in a task such as dichotic shadowing, the benefits of efficient perceptual registration will be largely confined to the first item in a list.

It has already been argued that the primacy effect, as opposed to the particular efficiency of registration of very early items, is mediated to a certain extent by rehearsal strategies. Although it has been sufficiently well demonstrated that secondary processing such as shadowing is not essential for primacy to occur (Hockey and Hamilton, 1977), it is clear that the extent of the effect can be influenced by such rehearsal (Rundus, 1971). Furthermore, research has shown that an initially strong trace is more frequently rehearsed (Rundus, 1971).

6.4.1 At this point some dicscussion of how these constraints affect right and left channel performance would be appropriate. There are two areas in which laterality effects identified outside of this paradigm could influence the results of the present experiment. Springer (1971) has shown a superior perceptual accuracy of right over left ears in the recognition of C.V. syllables, at the same time it was demonstrated that the response to right ear stimuli was considerably faster (by 50 msec) than the response to left ear stimuli.

More efficient perceptual registration, for whatever reasons, would indicate that the trace strength of initial word or 'anchor' of a primacy effect, would be reduced in left ear presentations. Secondly the greater speed with which Right ear items are identified obviously increases the capacity for rehearsal. Thus we can at least partially model the underlying causes of an R.E.A. in the primacy region.

6.4.2 In order to attempt an explanation of the reverse circumstances as they obtain in the latter half of the list, several lines of argument will be drawn together. It has already been shown that the first one or two items of a list enjoy a relatively more efficient perceptual registration. The effect of this is carried further into the list by rehearsal and the interdependency of recall. This last suggestion is supported by evidence that rehearsal is cumulative, and that it fails when the list is so advanced that there is no longer sufficient time to rehearse the accumulated list between items (Rundus, 1971).

There is detailed evidence of the right hemisphere's limited short-term memory for verbal stimuli (Zaidel, 1978). From this we can conclude that the capacity to maintain items by rehearsal in a short-term store is lower for items presented to the left ear than for the right. Therefore there is every reason to expect an R.E.A. for the primacy position of the list.

Successful recall of items presented early in the list has its consequences, characterized by Hamilton and Hockey (1977) as the "rebound effect" the terminal items are recalled with reduced efficiency. Hamilton and

Hockey (1970) showed an increase in this effect was associated with lists that were increased in length to 9 digits. In the present case therefore we have two possible suggestions to make as to the source of the L.E.A. at the recency position.

Firstly, it can be argued that due to the left hemispheres engaging in a superior registration and rehearsal strategy early items are more effectively recalled. There is therefore a relatively lower level of recall from later list positions as a consequence of the "rebound effect." As material presented to the left ear does not exhibit this effect, an L.E.A. develops for items recalled from the recency portion of the list.

The difference between Experiment II and the present study can therefore be understood in the light of the relative efficiency of emphasizing early list items with short and (relatively) long lists. In lists containing only 5 items as in Experiment II, the trade-off between the recall of primacy and recency items clearly favours the primacy stragegy. The reverse situation obtains, when the length of the list exceeds the number of items that can be successfully maintained by a primacy strategy.

The second suggestion as to the nature of the L.E.A. at the recency portion of the list, is based on the notion that the right hemisphere processes verbal material in such a fashion as to maintain items more effectively under a passive strategy. Therefore when the recency portion of the list, the recall of which is commonly characterized as a passive process (McNicol, 1975), is recalled, this favours the manner of coding employed by the right hemisphere.

The problem of comparing the relative merits of these two suggestions can be approached by considering the recall of item and item order information. The argument as to whether or not item and order information are independently recalled (Conrad, 1965) or whether they are necessarily associated in recall (McNicol, 1971), has been partially resolved by the suggestion that fixed and random address models need not be mutually exclusive (McNicol, 1975). Instead later list items are held to be drawn from a buffer store where item and order are linked, or a longer term store where a random address system applies and item and order information are stored separately.

The implication of this model for the present experiment are clear, the comparison between free and correct recall should reveal an improvement, for free recall, only at the early portion of the list. At the primacy portion of the list a separate representation of item and order exist, thereby facilitating recall if only one attribute remains, whereas in ordered recall one attribute would be insufficient for accurate recall. At the later portion of the list, item and order are stored together, the absence of one attribute therefore implies the loss of the other. Consequently no improvement in recall can be expected from a comparison of free and ordered recall over the recency portion of the list. The superiority of free recall at the primacy portion of the list, is confirmed by a comparison of Figures 5.1 and 5.2., thus McNicol's (1975) model applies to the present results.

In relation to the laterality differences the above argument would involve no effect of ear of arrival in the free recall reanalysis. The effect of free recall rescoring would only be apparent at the early list positions and this portion of the list only exhibited a non-significant tendency toward an R.E.A. in ordered recall.

In conclusion it must be noted that we cannot unequivocally accept either of the two models proposed here as an explanation of an L.E.A. for items recalled from recency positions. However, as there is evidence to support Hockey and Hamiltons' (1977) perceptual hypothesis we can assess the contribution of this factor.

The recall of list type as we can see from Table 5.1b is a significant effect at early list positions, in fact by far the largest contribution to this source of variance is made by the difference in the recall of list types at position one. This highlights the important contribution made by perceptual efficiency at this position and yet no significant effect of ear of arrival is noted in interaction with list type, either in this experiment or in the analysis of ordered recall in Experiment II.

6.4.4 Thus we can conclude that it is necessary to look towards the secondary processing which mediates the primacy effect, since it is here, in the mnemonic efficiency of the two hemispheres that we can see the consequences of functional lateralization. Laterality effects would appear therefore to rise indirectly, not directly from differences in the perceptual efficiency of the two hemispheres, but more probably linked to the control of rehearsal and the time available for rehearsal in the period between continuous items.

Conclusions such as these have only an indirect bearing upon current models of laterality effects. Although the increase in memory load that an extended dichotic list represents has been shown to increase task difficulty, (see Underwood, 1976, for a discussion of this point). Therefore current developments in attentional models (Hellige Cox and Litvac, 1979) which have employed dual task studies, a primacy task with a secondary task which loads memory, apply. Essentially they argue that the memory burden differentially loads the left hemisphere, thereby causing a switch to a L.E.A. As this is exactly what occurred in the present study, we have further evidence that the two hemispheres behave as parallel; if qualitatively different processors during dichotic shadowing (Hellige et al, 1979).

CHAPTER SEVEN

LATERALITY EFFECTS AND THE SIGNIFIANCE OF UNATTENDED INPUTS

7.1 Introduction

The present study was devised in order to explore the fate of unattended inputs in the context of the lateral differences in performance established by the preceding experiments. The recall of unattended information has been the subject of a considerable volume of experimental work, most recently reviewed by Underwood (1976), which has unfortunately not resulted in a generally agreed theoretical perspective. Problems of interpretation abound and are exacerbated by the large number of methodological modifications which hinder any effective comparative analysis.

A primary concern of research in the area of selective attention has been to establish whether or not any memory for unattended items can be said to occur. The most important development of recent years is the evidence of the storage of unattended material reported by Norman (1969). This finding was in contrast to the results of Cherry (1954) and Moray (1959) both of whom reported no memory whatsoever for unattended material.

Norman (1969) had predicted the storage of unattended items on the basis of a late selection model of attention. Consequently Norman interpreted the rapid decay of unattended inputs as signifying that although they gained access to primary memory there was no subsequent transfer to a long-term store. The time established by Norman (1969) for the decay of unattended information in the primary store was reaffirmed by Glucksberg and Cowen (1970); after from 3 to 5 seconds recall declined rapidly to zero over a period of some 20 seconds.

Subsequent work has raised a number of questions relating to the persistence of the memory trace established by unattended items. Bryden (1971) demonstrated that the memory for unattended items could be relatively long lasting but susceptible to subsequent auditory inputs. This finding was elaborated by Martin (1978) who interpreted her replication of Bryden's work as evidence not for a relatively durable echoic trace as Bryden had suggested, but as indicating that unattended items were held in a stable long-term store of considerable capacity.

This last result came at the end of almost a decade of results which suggest that unattended material is analysed to an extent incompatible with earlier models of selective attention (Treisman, 1969). Lewis (1970) identified the effect of the semantic content of unattended material, upon shadowing latencies; Corteen and Wood (1972) reinforced this finding with a further change of technique involving the use of the Galvanic Skin Response (G.S.R.) in conjunction with dichotic listening.

Smith and Groen (1974) employed recognition memory in a study which showed the effect of semantic relatedness between attended and unattended channels. More recent work including that of Underwood (1976, 1977 a) and Forster and Govier (1978) has led to the general conclusion that whilst the semantic content of individual items is apparently available and capable of influencing the subject's response to attended items, the wider contextual meaning of the unattended channel is not. This analysis gains support from the results of earlier studies (e.g. Treisman and Geffen, 1967; Glucksberg and Cowen, 1970).

Most studies revealing the influence of unattended channel inputs upon the processing of attended stimuli reported no, or very little recall of unattended items (Lewis, 1970; Corteen and Wood 1972; Lackner and Garret, 1972; Forster and Govier 1978) however they were usually concerned with measuring the influence of unattended stimuli during shadowing. In essence such techniques as those employed by the authors cited above involved some interruption or disruption of the 'normal shadowing' process. The presence of words conditioned by electro-shock (Forster and Govier, 1978), or items that provoke an increase in shadowing latency (Lewis, 1970) create circumstances which do not lend themselves to generalizations about 'normal' shadowing.

The evidence that unattended inputs persist beyond the period of shadowing opens up a new avenue for the examination of the effect of unattended information. If it is also the case that the semantic context of the unattended list is not apparent during shadowing, then any effect of such a context, as with the employment of list types such as those used in experiments II, III and IV, would have to be a result of processing that occurred after shadowing had finished. This would constitute evidence for the active translation of unattended inputs into a long-term store. Although it would perhaps be appropriate to withold from employing the concept of a store, where the phenomenon involved would appear to be one of continuous activity.

The earlier experiemnts in this thesis indicated an effect of ear of arrival upon the serial position of recalled attended items. This effect should be replicated, and if there is no interaction between the type of unshadowed list and ear of arrival then it might be concluded that the shadowing requirement selectively focusses attention in the manner described by the modified single channel theory (Treisman, 1969). If, however, there is an interaction between the type of unattended material and the level of recall of attended items, the position adopted by proponents of a modified single channel theory would require some reconsideration, particularly in the light of evidence that the recall of attended items could be influenced by the semantic context of the unattended list.

The position with regards to theories of laterality effects is slightly more complex. Although it has long been argued that demands made upon short-term memory are essential to demonstrations of an R.E.A. (Darwin and Baddeley, 1974; Yeni-Komshian and Garden,

1974) this feature of lateral differences in performances has not been directly incorporated into theories of laterality effects. The present experiment could provide evidence however that laterality effects are influenced by processing that occurs after the stimuli have been presented rather than during dichotic presentation. An essential characteristic of structural models of laterality differences (Kimura, 1967) is their assumption that laterality effects arise solely because of such an input technique.

The attentional theory of lateral differences in performance would not predict any change from the results of the recall from lists containing unrelated words in experiments II, III and IV. There are no changes in the antecedent circumstances of the experiment or in the nature of the stimuli employed that would bring about a change in the attentional 'set' of subjects.

However the modified attentional theory, based upon the concept of functional cerebral distance would predict some interference effects in the subsequent processing of dual inputs. Basically the competition for analysis or more accurately for translation into a stable form of storage would involve competition for analyser capacity of a limited nature. The attributes encoded by the two ears as input channels would differ according to the known propensities of the two hemispheres, and the subsequent interference between attended and unattended inputs would reflect those differences.

The level of recall of unattended items would be influenced by the interaction between hemispheric differences in the processing of particular attributes (e.g. 'phonological similarity Cohen and Freeman, 1976), and the attributes that are reduced in mnemonic usefulness by the use of stimulus lists composed of words matched on some attribute. Thus any reduction in the level of recall of certain types of unattended input would depend upon their ear of arrival, as would the subsequent effect of the various types of unattended item upon the recall of attended items.

The present experiment is designed to explore the consequences of hemispheric differences in processing verbal stimuli. Unattended stimuli it is argued, will interfere with the mnemonic strategies which are involved in the processing of attended stimuli that occurs after the dichotic list has been presented. The effects of the various list types should take the form of an interaction between serial position and ear of arrival. Such a finding would confirm the model of serial position effects proposed in the discussion of experiments II and III.

Results which included an interaction between the type of unattended list and the level of attended item recall, would provide further evidence that the shadowing requirement as a device for focusing attention cannot overcome intrinsic and hence structural asymmetries in the processing of verbal inputs in the left and right hemispheres. Similarly evidence along these lines would support the conclusion that mnemonic strategies are important in experiments which employ the dichotic listening technique to explore lateral differences in performance (Freides, 1977).

7.2 Method

7.2.1 Subjects

Twenty undergraduates, 10 males and 10 females aged between 18 and 24 years of age participated in the experiment and were paid for their services. All subjects were self-reported as being right handed on a sub-test of the Edinburgh Handedness Inventory; see Appendix B for the full questionnaire. Ten subjects were assigned on a random basis to each of two groups designated Left or Right ear shadowing. Before the start of the experiment every subject was trained in dichotic shadowing, the criterion employed being two successive error free trials. Any subjects who failed to meet this criterion were excluded from the main experiment. Subjects were tested on an individual basis in sessions lasting approximately 40 minutes.

7.2.2 Apparatus

Fifteen lists drawn from the Thorndike and Lorge word count (Thorndike and Lorge, 1944) were used as experimental materials; these lists were identical to those employed in experiments II and III (see Appendix for the complete list of words). Five lists were semantically similar; high, tall etc. and five lists were composed of phonenically similar words; war, law, door etc. Finally there were five lists of unrelated words.

These lists were recorded in parallel with unrelated monosyllabic words of the same frequency in the Thorndike-Lorge (1944) word count (A/AA). Dichotic matching was carried out with the DITMA equipment maintained by the Department of Psychology at the University of Edinburgh. Subjects were always required to shadow the channel containing unrelated words.

The recording was played on a Teac A-23405X tape-recorder and stimuli were presented through a pair of Pioneer SE-50 cc headphones. The sound intensity at the ear was adjusted so that the level was 75dbA, as measured by a Brüel and Kjaer model 2203 sound-level meter.

7.2.3 Procedure

The subject sat in a chair facing the rear of the tape recorder which separated him/her from the experimenter. The subject was informed that each list would consist of five words and that each word had to be repeated aloud immediately upon presentation. The subject was further instructed that items on the second channel were to be ignored and recall of shadowed items alone was required. At the end of each list subjects were given 90 seconds to write down the shadowed words in the order in which they were presented. The response booklets provided contained fifteen pages, with five boxes to each page. The signal for the start of each list was the switching-on of the tape recorder which was always followed by the three-second interval before the start of the test.

After the experimenter had ensured that the instructions had been understood, the experiment began, and following each list the subject was asked to stop writing and turn the page. Control was exercised over possible time-of-day effects by testing equal numbers of subjects between 09.00 and 13.00 and 14.00 and 16.00 hours.

7.3 Results

Analyses of variance (ANOVA) were performed upon the results of the ordered recall protocols and upon the same protocols rescored for free recall. The factors in each ANOVA (a 2 x 3 x 5 split-plot design) were ear of arrival (Right or Left), list type (Semantic or Phonemic similarity or Unrelated) and serial position (positions one to five), with repeated measures on the last two factors. The data employed in the analyses of variance were the untransformed raw scores.

The analysis of the ordered recall data revealed no significant effect of ear of arrival. There was no significant effect of the type of unshadowed list and no significant interaction between the type of list and ear of arrival. The effect of serial position was significant ($F= 58.09$, df 4,72; $P<0.001$), as was the interaction effect of serial position and ear of arrival ($F= 2.66$, df 4,72; $P<0.05$). The simple main effects analysis of this interaction (see Table 7.1) revealed a non-significant tendency towards an effect of ear of arrival at positions one and three. There was a larger effect of serial position upon the recall of items presented to the right than the left ear (Table 7.1).

There was a significant interaction of serial position and type of unattended list, ($F= 7.86$, df 8,144; $P<0.001$) This significant interaction was decomposed using simple main effects analysis (Kirk, 1968) which revealed that the effect of type of unattended list was

Table 7.1 Ordered Recall

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	0.00	1	0.00	1	
SUBJECTS (within groups)	59.85	18	3.32		
B (TYPE OF UNSHADOWED LIST)	2.78	2	1.39	1.15	ns
A x B	0.98	2	0.49	1	
B x SWG	43.39	36	1.20		
C (SERIAL POSTION)	153.38	4	38.34	58.09	< 0.001
A x C	7.06	4	1.76	2.66	< 0.05
C x SWG	47.62	72	0.66		
B x C	40.92	8	5.11	7.86	< 0.001
A x B x C	10.26	8	1.28	1.96	ns
B x C x SWG	94.34	144	0.65		

Simple effects of the 2-way interactions:

A at C1	3.75	1	3.75	3.20	ns
A at C2	0.01	1	0.01	1	
A at C3	3.27	1	3.27	2.79	ns
A at C4	0.02	1	0.02	1	
A at C5	0.02	1	0.02	1	
Error Term		10	1.17		
C at A1 (right ear)	97.33	4	24.33	36.86	< 0.001
C at A2 (left ear)	61.55	4	15.38	23.30	< 0.001
Error Term		72	0.66		
C at B1 (semantic)	74.86	4	18.71	28.78	< 0.001
C at B2 (phonemic)	86.86	4	21.71	33.40	< 0.001
C at B3 (unrelated)	33.00	4	8.25	12.69	< 0.001
Error Term		148	0.65		
B at C1	14.25	2	7.12	9.36	< 0.001
B at C2	10.00	2	5.00	6.57	< 0.01
B at C3	13.64	2	5.82	8.97	< 0.001
B at C4	2.14	2	1.07	1.41	ns
B at C5	3.70	2	1.85	2.43	ns
Error Term		180	0.76		

Table 7.1a Comparison between means (Tukey's HSD):

Comparison	q	p
B1 - B2 at C1	1.57	ns
B1 - B3 at C1	6.05	< 0.01
B2 - B3 at C1	4.47	< 0.01
B1 - B2 at C2	5.26	< 0.01
B1 - B3 at C2	2.63	ns
B2 - B3 at C2	2.63	ns
B1 - B2 at C3	2.10	ns
B1 - B3 at C3	3.94	< 0.05
B2 - B3 at C3	6.04	< 0.01

q' 0.05 = 3.62
q' 0.01 = 4.34

B1: semantic, B2: phonetic, B3: unrelated.
C: serial position.

confined to the first three serial positions (Table 7.1, Fig.7.2). At list position one both semantic and phonetically similar unattended lists improved recall in comparison with unrelated lists, (q= 6.05, $P < .01$) and (q= 4.47, $P < .01$) respectively (Tukey's HSD, see Table 7.1 a). There being no difference between the level of recall of semantically and phonetically similar lists at position one.

At serial position two, phonetically similar unattended lists facilitated recall in comparison with semantically similar lists (q= 5.26, $P < .01$). There was no other significant comparison at position two. At list position three unrelated unattended word lists were associated with a higher level of recall than either semantically (q= 3.94, $P < .05$) or phonetically similar unattended lists (q= 6.04, $P < .01$), there being no significant difference in the level of recall associated with semantically and phonetically similar lists at this position (Table 7.1 a).

The significance of these effects lies in their confirmation that unattended inputs are retained in such a form as to influence the recall of attended information. Even though in the present study subjects were not required to attend to or recall unattended inputs, unattended item similarity facilitated recall at early list positions and effectively reduced it, in the case of semantically similar lists, at the central position in the list (Fig. 7.2)

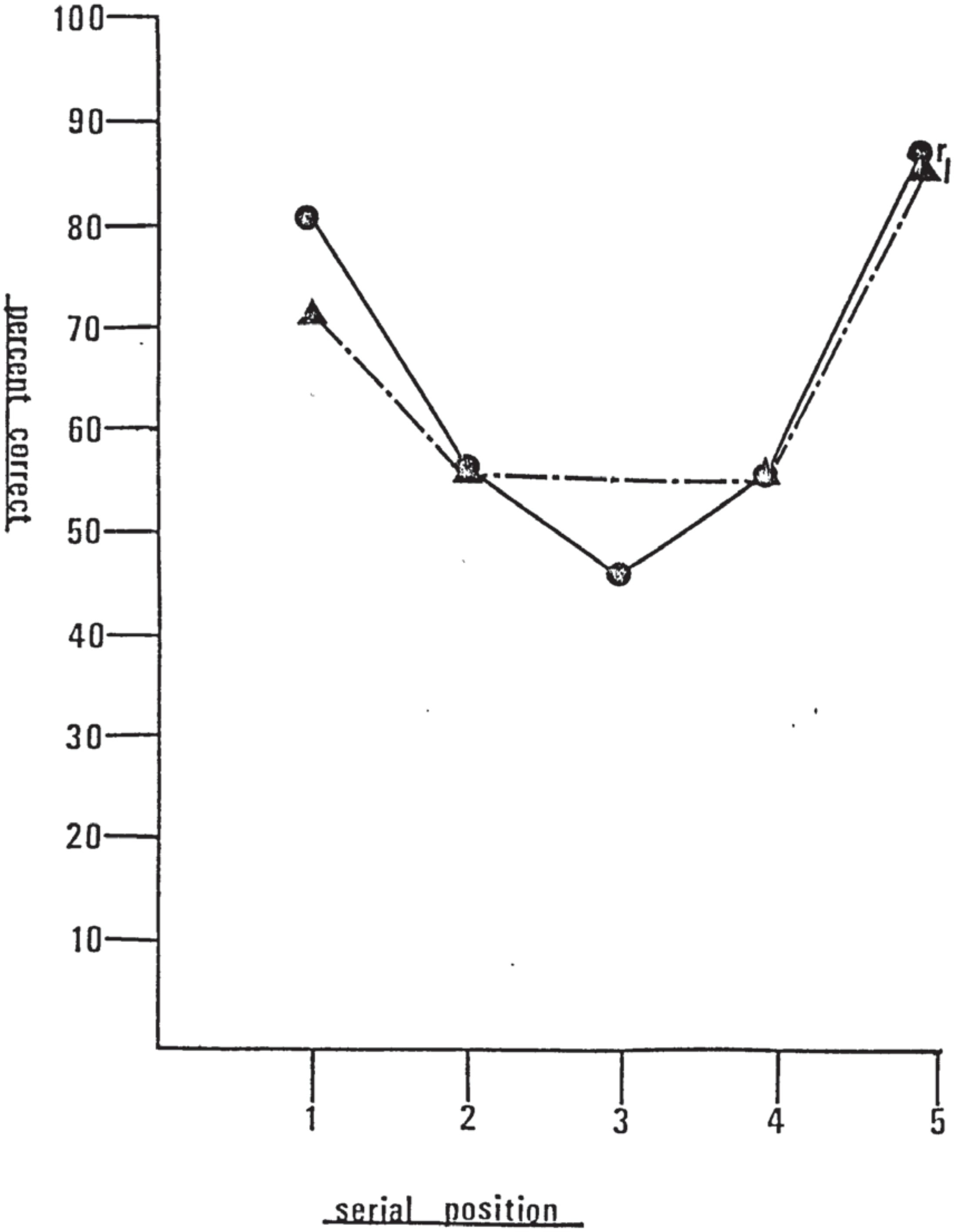

Figure 7.1 Ordered recall:- Percent correct for right and left ear presentations as a function of serial position.

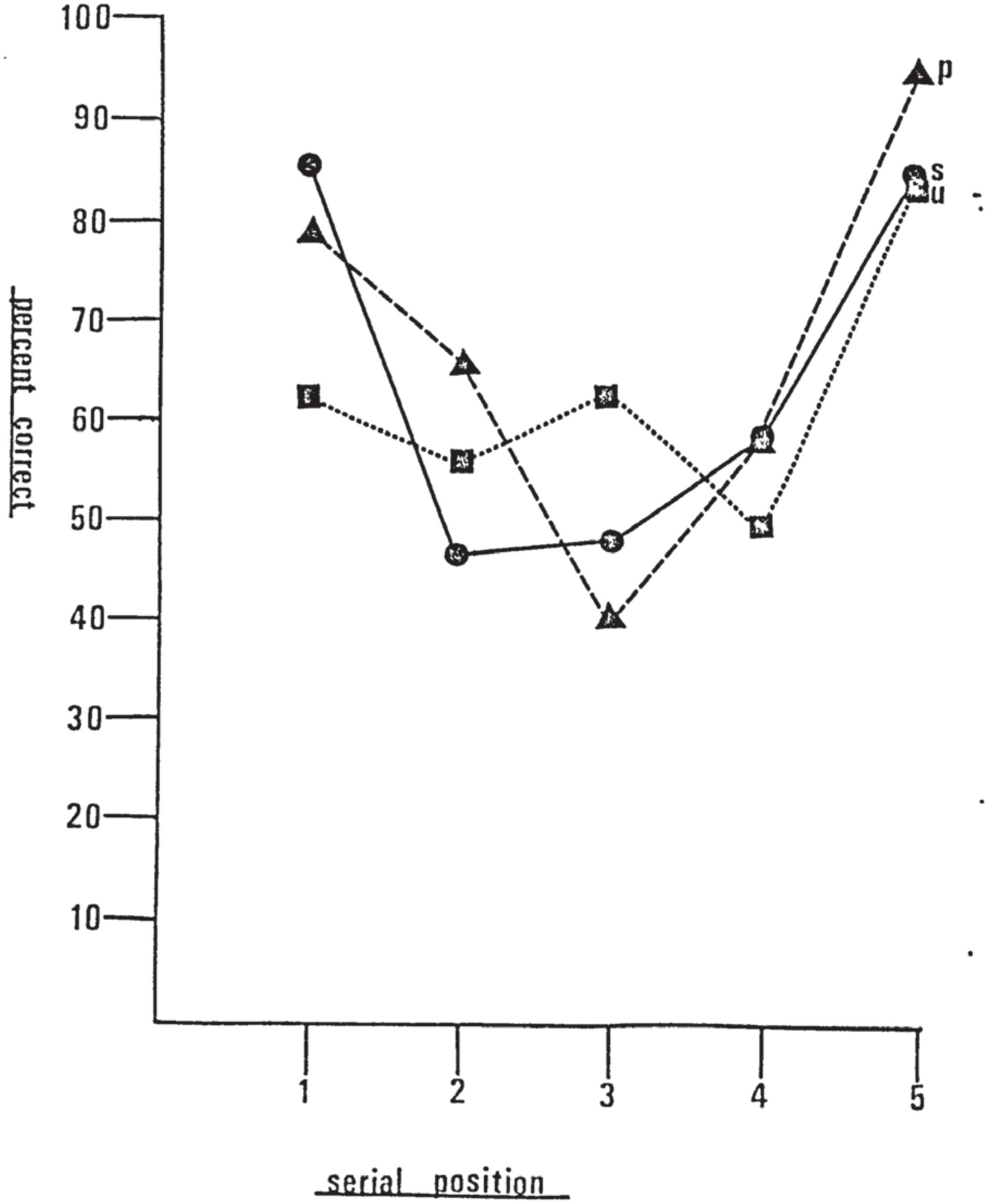

Figure 7.2 Ordered recall:- Percent correctly recalled for each type of list; semantic, unrelated or phonemic as a function of serial position.

The absence of a significant main effect of the type of unshadowed list replicates the results of experiment II, where list type was found to interact with changes in the level of processing of inputs as the list progressed. Once again this was the only statistically significant consequence of lists based upon semantic or phonemic similarity.

The direction of the effects of each type of list is slightly more complex, but the pattern of results follows closely from the results of experiment II. Evidence that type of material, although unattended, influenced recall at early list positions can be argued to arise as a result of processing that occurs after dichotic presentation. In support of this contention is the view that items from the primacy positions are more deeply processed (Craik and Lockhart, 1972) and the evidence that they are held in a stable, relatively long-term store (Baddeley, 1968).

Secondly there is the fact that the context of the unattended list, whether it is based upon semantic or phonemic similarity, cannot be apparent after only one item and yet inter item similarity had an effect at list position one. It follows therefore that we can attribute much of the effect of lists of semantically or phonemically related words to the consequences of processing which occurs after the initial presentation of the lists.

The analysis of ordered recall protocols rescored

Table 7.2 Free Recall

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	0.07	1	0.07	1	
SUBJECTS (within groups)	39.09	18	2.17		
B (TYPE OF UNSHADOWED LIST)	17.36	2	8.68	13.15	< 0.001
A x B	0.51	2	0.25	1	
B x SWG	23.87	36	0.66		
C (SERIAL POSITION)	34.93	4	8.73	14.31	< 0.001
A x C	0.96	4	0.24	1	
C x SWG	44.38	72	0.61		
B x C	37.69	8	4.71	10.23	< 0.001
A x B x C	8.38	8	1.04	2.27	< 0.05
B x C x SWG	66.86	144	0.46		

Simple main effects of the 3-way interaction:

AB at C1	0.94	2	0.47	1	
AB at C2	5.78	2	2.89	5.78	< 0.01
AB at C3	1.30	2	0.65	1	
AB at C4	0.70	2	0.35	1	
AB at C5	0.13	2	0.65	1	
Error Term		180	0.50		

Simple effects of the 2-way interaction:

B at C1	26.13	2	13.06	26.12	< 0.01
B at C2	14.29	2	7.14	14.28	< 0.01
B at C3	5.64	2	2.82	5.64	< 0.01
B at C4	2.50	2	1.25	2.50	ns
B at C5	6.54	2	3.27	6.54	< 0.01
Error Term		180	0.50		

Table 7.2a Comparison between means (Tukey's HSD):

Comparison	q	p
B1 - B2 at C1	1	
B1 - B3 at C1	3.50	< 0.01
B2 - B3 at C1	3.62	< 0.01
B1 - B2 at C2	2.87	< 0.05
B1 - B3 at C2	0.75	ns
B2 - B3 at C2	2.12	ns
B1 - B2 at C3	0.00	ns
B1 - B3 at C3	1.62	ns
B2 - B3 at C3	1.62	ns
B1 - B2 at C4	0.62	ns
B1 - B3 at C4	0.62	ns
B2 - B3 at C4	1.25	ns
B1 - B2 at C5	1.37	ns
B1 - B3 at C5	0.62	ns
B2 - B3 at C5	2.00	ns

$q'_{0.05} = 2.33$
$q'_{0.01} = 3.31$

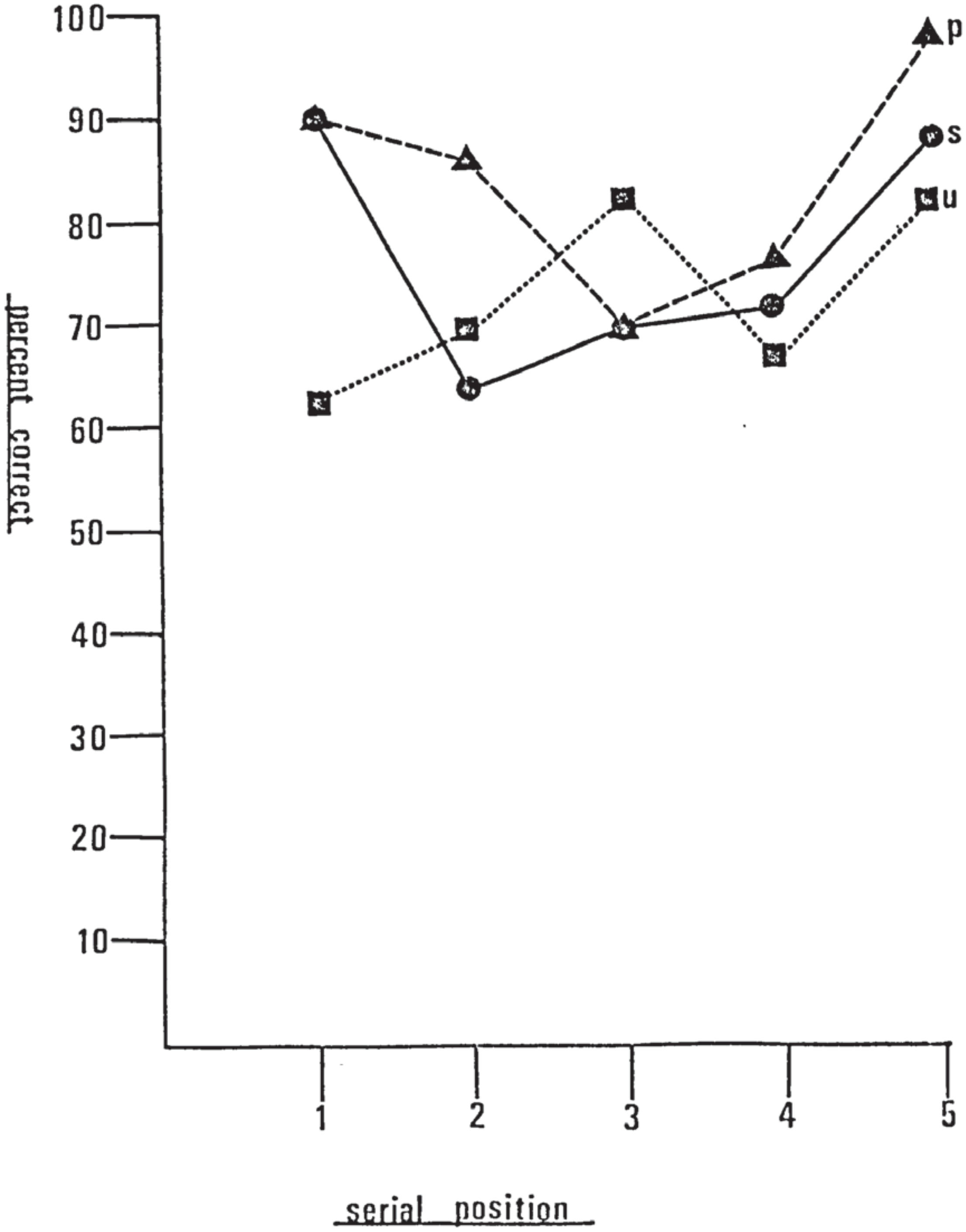

Figure 7.3 Ordered recall reanalysed for free recall:- Percent correct for each type of list; semantic unrelated and phonemic, as a function of serial position.

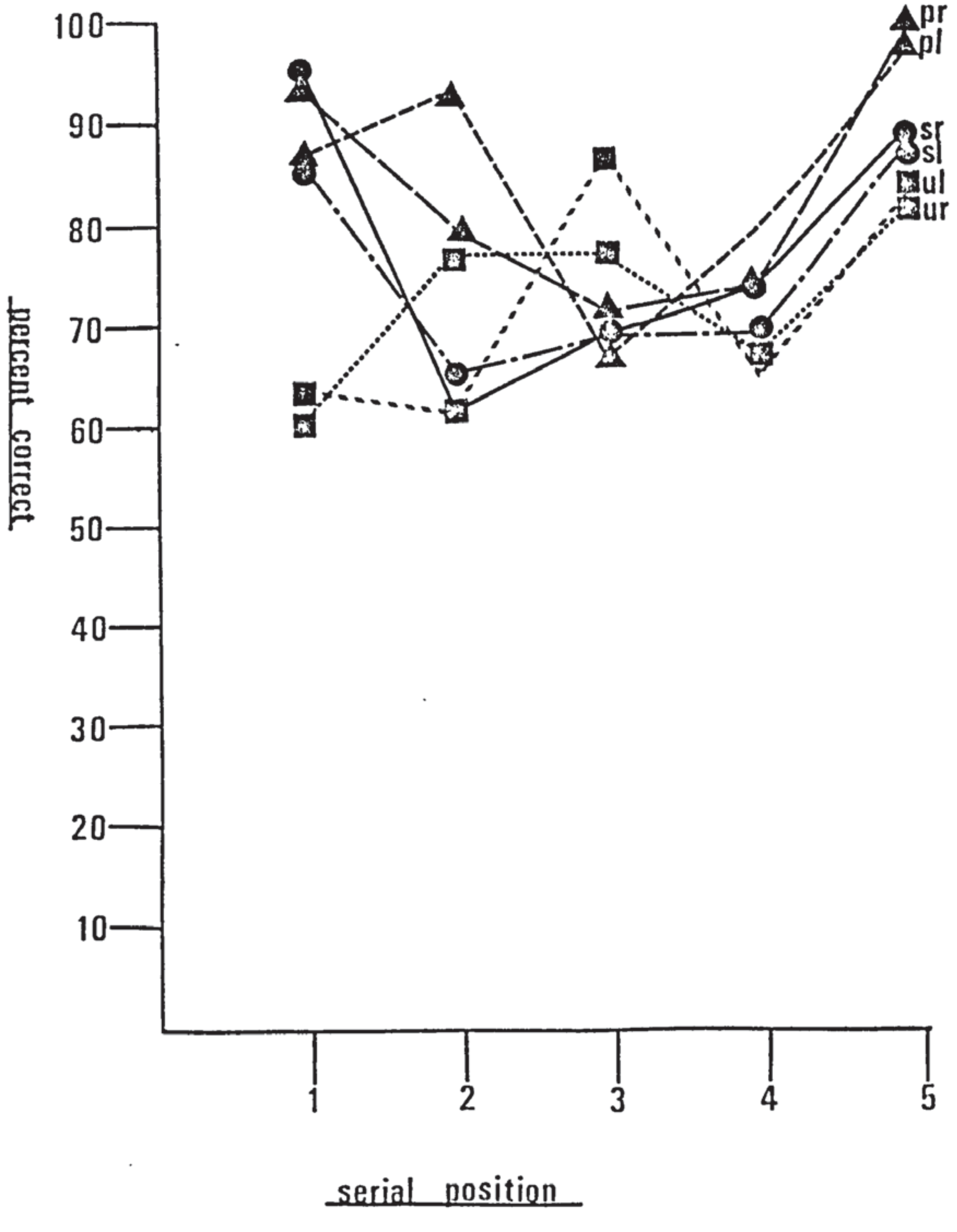

Figure 7.4 Ordered recall reanalysed for free recall:- Percent correct for each type of list presented to the left and right ears, as a function of serial position.

for free recall gave no significant effect of ear of arrival. However in contrast with ordered recall there was a significant main effect of type of unattended list ($F= 13.75$, df 2,36; $P< .001$). This result indicates that unattended item similarity influences the overall level of recall of attended items, independently of the requirement for the recall of item order information. If as was suggested in the discussion of experiments II, III and IV, the trace of item and item order information is independent at early list positions (McNicol, 1975), this present result would serve to emphasise the importance of the facilitative effect noted here, in influencing the recall of items presented early in the list.

There was no significant interaction between type of unattended material and ear of arrival. The main effect of serial position was highly significant ($F= 14.31$, df 4,72; $P< .001$). Ear of arrival did not significantly interact with serial position. There was a significant interaction of type of unattended list and serial position ($F= 10.23$, df 8,144; $P< .001$) the three way interaction was also significant ($F= 2.27$, df 8,144; $P< .05$). The three way interaction was decomposed using simple main effects analysis to reveal a significant interaction of type of unattended list and ear of arrival at list position two ($F= 5.78$, df 2,180; $P< .01$) (Table 7.2).

As can be seen from the graphical representation of this interaction (Fig. 7.4) this result reflects the superiority of right over left ear recall of unrelated material at position two and a superiority of left over right ear recall of lists matched with lists of phonemically similar material. A discussion of this result will follow, but it is necessary here to note that the left over right ear superiority for the recall of items from lists matched with sequences of phonemically similar material is simply the persistance of a facilitative effect which began at position one (see Fig. 7.4).

As a result of this observation and also because the graph of the type of unattended list serial position interaction (Fig. 7.3) suggested effects other than those at position two, the significant two way interaction was subjected to a simple main effects analysis. This analysis showed that there was a significant effect of list type at all serial positions except position four. A multiple comparison of means test (Tukey's HSD) (Table 7.2 a) revealed that at list position one, both semantically and phonemically similar material promoted more efficient recall than did unattended lists composed of unrelated items. At position two as with Ordered recall there was a significant superiority of phonemic over semantically similar unattended material in influencing recall. There were no more significant differences between individual means.

These results largely confirm the findings with respect to ordered recall and thereby reinforce the conclusion that whatever the role of laterality effects in selective attention there is abundant evidence that unattended items are processed. Furthermore, such processing has been demonstrated to have an impact upon the recall of attended items, an impact related to both semantic and phonemic characteristics of unattended stimuli.

7.4. Discussion and Conclusions

The results of the present experiment reinforce and expand the evidence for the view that in the case of dichotic shadowing paradigm the designation 'unattended' does not in fact imply a total disregard for secondary inputs. Instead, and in keeping with earlier research (Treisman, 1960; Forster and Govier, 1978), it would appear that although there may be some qualitative differences with respect to the outcome of processing, both unattended and attended inputs are processed.

7.4.1 The present experiment would also suggest that unlike earlier studies (Treisman and Geffen, 1967); Glucksberg and Cowan 1970; Underwood 1976, 1977; Forster and Govier 1978), it is possible to demonstrate consequences of a semantic analysis that includes the relationship between unattended items, rather than simply an awareness of the meaning of individual unattended words. For this has been the conclusion drawn from a number of studies which have examined the level of processing of unattended inputs during shadowing (Underwood, 1977; Forster and Govier 1978), where it was found that only one or two items and not sequences of words could be meaningfully associated during unattended processing.

The results of the present experiment replicated the finding that unattended items are analysed in terms of their semantic content. However the evidence for this contention is derived from the fact that the relationship between unattended items, the semantic context of the unattended list, influenced the recall of attended items. The effect of a list composed of semantically similar words is obviously not based solely upon an isolated awareness of the meaning of each item in turn. There is evidence therefore to suggest that the broader contextual meaning of a list, even an unattended list is available.

This finding does not contradict the results of earlier studies which demonstrated the semantic processing and awareness of only individual items during shadowing. Instead the evidence suggests that this coding is elaborated and extended between items subsequent to original registration of inputs.

7.4.2 The main goal of this discussion is to attempt some explanation of the differences between left and right ear shadowing, especially with regard to the differential consequences of the various types of unattended material. In the first place, however, we must establish exactly how unattended lists of similar words can influence the level of recall of attended word lists composed of unrelated items.

The first line of evidence to be considered is that which indicates that the influence of unattended inputs is confined to the primacy portion of the attended list. The primacy effect has been attributed to the greater saliency of initial items, which are also subject to less proactive interference (Hockey and Hamilton, 1977). There is evidence that early list items are rehearsed more frequently (Crowder, 1969) and in a different manner from later items (Rundus, 1971).

There is also experimental evidence which has a bearing upon the effect that unattended material has upon the processing and subsequent retrieval characteristics of attended inputs. Martin (1978) found that attended items were more efficiently recalled when they were reported before rather than after unattended inputs. There was a tendency for unattended items to be recalled more efficiently after rather than before the attended items are recalled.

Martin (1978) interpreted these results as evidence that unattended items entered a long-term store. The demonstration that a stimulus suffix effect can impair the recall of unattended items (Parkinson and Green, 1972) in a dichotic listening task, is held to reflect the slow rate at which unattended items are transferred from a precategorical acoustic store to the longer term store proposed by Martin (1978). This would suggest that the effect of unattended material is a function of the interference between the transference of unattended items to a long-term store and the recall of attended items from what would seem to be a relatively labile store. This view is supported by the reduction in efficiency with which attended items are recalled when unattended items are recalled first.

We must now proceed to the question of why the effects of related unattended items, expressed themselves as they did. Numerous workers have noted the reduction in the recency effect that is caused by acoustic similarity in items to be recalled (Levy and Murdoch, 1968; Kintsch and Buschke, 1969). Furthermore, in line with their theoretical and empirical challenge to a dual trace or twin store theory of memory, Craik and Levy (1970) have shown that semantic similarity can decrease the recency effect. Indeed, Glanzer, Koppenhal and Nelson (1972) found that both semantic and acoustic similarity reduced the recency effect.

It can be argued therefore that any persistance of unattended items beyond an echoic representation will exhibit the effects upon recall noted above. Namely that due to the nature of the processing afforded unattended rather than attended inputs, item similarity will depress the overall level of recall of unattended items. The two types of input which involve intralist similarity will therefore cause less interference with the rehearsal or encoding of attended items. Thus giving rise to superiority of recall for those attended lists matched with lists of similar items, at the recency position. As the shallow processing or registration of items from the redency portion of the list would not be influenced by such effects.

7.4.3 Finally, we can turn to the question of ear of arrival effects as they might be interpreted in terms of the explanatory framework proposed above. The significant three-way interaction effect, derived from the reanalysis of ordered recall protocols, involved attended lists matched with both unrelated and phonologically related lists. As well as a right ear superiority for the recall of attended lists paired with lists of unrelated material, there was a left ear superiority for the recall of items matched with phonologically related lists.

The finding of a right ear superiority for the recall of unrelated material is to be expected (Bryden, 1971).

Supporting evidence for the importance of the right ear advantage (R.E.A.) in selective attention comes from the work of Bosshardt and Hörmann (1975) and from the results of experiment II in the present study.

The left ear superiority for the recall of shadowed items matched with phonologically similar material is more difficult to explain. It has already been argued that the context of the unattended channel can have no effect until after presentation, this argument is derived in part from the evidence for the independance of input channels during shadowing (Martin, 1978). It would be reasonable to assume therefore that the interference caused by phonologically similar inputs depends upon the characteristics efficiency of the left ear right hemisphere, and right ear left hemisphere as they process the phonological attributes of an item.

There is clear evidence that the right ear left hemisphere is more sensitive to phonological similarity than the left ear right hemisphere. Cohen and Freeman (1976) used a lexical decision task in which subjects were required to decide whether letter strings were words or non-words i.e. homophones of real words, they found that homophones took longer to reject when presented to right ear left hemisphere. This they interpreted as right ear superiority for the processing of phonological attributes.

A study reported by Levy (1974) suggests that the right hemisphere, although perhaps capable of comprehending the meaning of short words such as 'ache' and 'lake' would not be capable of registering the fact that they rhyme. The studies reported by Cohen and Freeman (1976) and Levy (1974) both confirm a left hemisphere superiority for phonological analysis.

It follows therefore that a reduction in the level of interference caused by unattended phonologically similar inputs would only occur when they were presented to the right ear, which would give rise to a left ear superiority in the recall of the attended channel, as was the case in the present study. The three-way interaction effect arose because the effect of phonemic similarity occurred at position one and two, whereas the effect of semantic similarity disappeared at position two. It can be argued that this reflects the fact that whereas the right hemisphere does exhibit some limited ability to represent the meaning of dichotic inputs (Levy 1974, Zaidel, 1978), it is not at all sensitive to phonological similarity (Levy, 1974).

CHAPTER EIGHT

LATERALITY EFFECTS:- RECOGNITION MEMORY FOR ATTENDED AND UNATTENDED MATERIAL

8.1 Introduction

Although the present series of experiments has provided considerable evidence of hemispheric differences in selective attention, a number of problems arise in attempting to generalize from the results of the paradigm employed in experiments II, III, IV and V. The major difficulties are a consequence of the use that was made of lists comprised of items which were matched in terms of phonological or semantic characteristics.

It can be argued that when individual items in a list hold one attribute in common, then this serves to over-emphasize that characteristic when recall is required. For example the content of a list may well act as an orientating cue in the manner described by Craik and Lockhart (1972). It has long been realized that varying task requirements influences the level of processing of items to be remembered.

In the present case lists consisting of items with some characteristics in common may well serve to over-emphasize that characteristic, thus it could well prove to be the case that this technique led to an over-estimation of the importance and frequency of processing of semantic or phonological stimulus attributes in earlier studies. The problem arises therefore as to what level of processing is normally undertaken with respect to unrelated dichotic inputs. It must be remembered that whilst this requirement to process individual words without a context is uncharacteristic of the demands normally made of human subjects, it does represent the typical approach of most rigorous designs employed in the study of selective attention (e.g. Treisman, Squire and Green, 1974).

What is required therefore is a design which will allow for some analysis of the level of processing of both attended and unattended inputs independently of any effects which might arise from the use of list consisting of words which exhibit either semantic or phonological similarity. Unfortunately the data already collected with reference to the consequences of unrelated lists of items do not in themselves represent an answer to this problem.

So far in the present series of experiments unrelated lists have been employed as a control condition. The next step must be to gain some understanding of the processing afforded such unrelated inputs, where the context of list cannot be said to influence the level of processing of individual items. It is clear, therefore, that although unrelated stimulus words are essential, some technique is required which might indicate the level of processing of stimuli whether they are attended or not.

Evidence in support of this last contention that a measure of the level of processing of unattended inputs is required is provided by the results of Experiment I, which showed that unrelated items were processed in parallel, and that the shadowing latency of the attended item was very much influenced by the presence of an unattended item. This finding also suggests that items on both unattended and attended channels should bear no relationship with one another if some indication of their processing that they normally undergo is required.

8.1.1 In order to produce evidence as to the level of analysis characteristic of unrelated inputs, a technique is required which whilst maintaining an equivelance of stimulus features available for the encoding of individual items, allows for some conclusions to be drawn as to the nature of the memory trace for each item. An appropriate method would seem to be that employed by Davies and Cubbage (1976). The basis of their technique was the assumption that recognition errors represent the overlap between the discriminable features of distractor items involved and those of the stored traces (Tulving and Bower, 1974).

The results of the study reported by Davies and Cubbage (1976) showed that semantic and non-semantic orientating instructions in an incidental learning task gave rise to more false recognitions of distractors which were related to the critical item along the stimulus dimensions specified by the orientating instructions. An adaption of this technique for a selective attention task would simply require that the orientating instructions become the requirement to shadow or disregard a particular item.

An experiment reported by Wright, Ciccone and Brelsford (1977) showed that the recognition of target items could be influenced by the presentation of particular modifers; synonym, homonym or nonsense words. Distractors were synonyms, homonyms or unrelated control words; synonyms were more often incorrectly identified in the semantic conditions than homonyms or controls in the non-semantic condition subjects incorrectly recognized both synonym and homonym distractors more frequently than control distractors. There are a number of reasons for assuming therefore that lists of unrelated dichotic pairs, would give rise to the false recognition of different types of distractor as a function of whether or not inputs were shadowed or unshadowed and perhaps, of the ear at which they arrived.

There are also grounds upon which to expect differences in recognition to exhibit some effect of serial position. Drewnowski (1980) has proposed a feature model in which it is suggested that features or attributes of stimulus items are encoded during presentation and employed as cues during recall. Words are assumed to be represented in memory by their principal phonemic and non phonemic features as well as semantic information. The perfect recall of all items in short lists is expected to give way to acoustically related intrusion errors in longer lists. This effect should of course differentiate between the right and left ears in so far as it reflects their relative mnemonic capacities.

Empirical evidence in support of the position taken up by Drewnowski (1980) has been reported by Drewnowski and Murdock (1980). They showed by an elaborate analysis of errors of intrusion and omission in a conventional measure of memory span for words, that even errors of omission revealed some awareness of the most salient auditory features of the forgotten item. They concluded that their evidence indicated a range of potential recall between the perfect recall of some items and the absence of those that are completely forgotten. It was proposed therefore that their data supported attribute rather than unit models of short term memory, and that all-or-none recall was not characteristic of short term memory.

There are a number of lines of evidence which suggest the usefulness of an attribute model of memory performance in a task such as the recall of items in a dichotic shadowing experiment. Furthermore there is experimental evidence that the attributes encoded can be a function of the 'set' which is developed as a consequence of the experimenters instructions (Craik and Lockhart, 1972, Davies and Cubbage, 1976). It can reasonably be suggested therefore that the recognition level of presented items, whether attended or not, will be indicative of the type of attribute encoded as an attribute, when shared with a distractor item, reduces recognition.

A technique therefore exists, whereby the type of item attribute encoded can be measured as a function of the attention paid to that item. Similarly the opportunity arises for performing the same task, recognition, and assessing the impact of varying the ear of arrival of stimuli upon the type of item attribute encoded. This can be achieved without the use of intra-list similarity as an independent variable and thereby providing the opportunity to expand upon the findings of the earlier experiments in this series.

8.2 Method

8.2.1. Subjects

Sixty undergraduates, 38 females and 22 males aged between 18 and 29 years of age participated in the experiment and were paid for their services. All subjects were self reported as being right-handed on a sub-test of the Edinburgh handedness inventory; see Appendix B for the full questionnaire. Subjects were randomly allocated to either left or right ear shadowing groups. Each group consisted of three types of distractor, subjects were further allocated in-groups of ten, to one of these three conditions. Independent groups were required because of severe limits upon the number of words available for this experiment.

Before the start of the experiment every subject was trained in dichotic shadowing, the criteria employed was two successive error free trials after which a subject passed onto the experimental conditions. Subjects who failed to meet the performance criteria within the time allotted (30 minutes) were not allowed to continue to the main experiment. Subjects were tested on an individual basis in sessions lasting approximately thirty minutes.

8.2.2. Apparatus

Three lists of five pairs of words were drawn from the same frequency of occurrance category (A/AA) of the Thorndike-Lorge word count (Thorndike and Lorge 1944). These lists consisted of unrelated monosyllabic words which were dichotically matched on magnetic tape using the DITMA equipment maintained by the Department of Psychology at the University of Edinburgh.

The recording was played on a Teac A-23405X tape recorder and stimuli were presented through a pair of Pioneer SE-50cc headphones. The sound intensity at the ear was adjusted so that the level was 75dbA, as measured by a Brüel and Kjaer model 2203 sound-level meter.

Each word employed in the dichotic lists was paired on a 5 x 3 index card in a typewritten form (IBM Courier 12 typeface), with a single distractor item drawn from the same source (the A/AA category of the

Thorndike and Lorge word count). These distractor items were of three types; semantically similar, phonologically similar or entirely unrelated. Each type of distractor was paired in a pseudo-random fashion with a word from each serial position and attention condition. Thus there was one distractor of each type for all serial positions and attention (shadowed or unshadowed) conditions. Subjects shadowed all three lists, but were presented with distractors (10 for each list) of only one distractor type, during the recognition test for each list.

8.2.3 Procedure

The subject sat in a chair facing the rear of the tape recorder which separated him/her from the experimenter. The subject was informed that each list would consist of five words and that each word had to be repeated aloud immediately upon presentation. The subject was further instructed that items on the second channel were to be ignored and recognition of both shadowed and unshadowe words would be required. At the end of each list subjects were given three minutes to select one word from the pair on each of the ten cards presented which were presented in random order. Subjects wrote down their choice in a response booklet provided. Each booklet consisted of three pages and each page ten boxes. The signal for the start of each list was the switching on of the tape recorder which was always followed by a three second interval before the start of a list.

After the experimenter had ensured that the instructions had been understood, the experiment began, following each list the subject was asked to stop writing and turn the page. Control was exercised over possible time-of-day effects by testing equal numbers of subjects between 09.00 and 13.00 and 14.00 and 16.00 hours.

8.3. Results

The results were analysed in two ways; firstly the results from right ear shadowed, left ear unshadowed and left ear shadowed. Right ear unshadowed conditions were subjected to an analysis of variance (ANOVA). The factors in each ANOVA were distractor type (semantic, phonemic or unrelated), ear of arrival (right or left, effectively shadowed and unshadowed) and serial position (positions one to five), the first and last factors were repeated measures (a 3 x 2 x 5 split-plot design).

The second analysis was again based upon the use of analysis of variance (ANOVA), this time right and left ears are compared, firstly for shadowed ear performance and then for unshadowed ear performance. This ANOVA was in the form of a 2 x 5 x 3 split-plot design with the last factor as a within block treatment (Kirk, 1968). The factors are ear of arrival (right and left, shadowed or unshadowed), serial position (positions one to five) and type of distractor (semantic, phonemic or unrelated).

The analysis of the data from the right ear shadowed left ear unshadowed condition revealed as main effect of distractor type ($F= 9.35$; df 2,77; $P < .01$) (Table 8.1). Comparison of means using Tukey's HSD test showed that whereas unrelated distractors has less effect than either phonemic ($q= 6.25$, $P < 01$) or semantic distractors ($q= 4.62$; $P < .05$) there was no difference in the effects of semantic and phonemic distractors.

There was also a main effect of ear of arrival, that is right shadowed and left unshadowed ears where left ear recognition was superior to right ear recognition ($F= 6.80$; df.1,27; $P < .05$) (see Table 8.1 b). The interaction effect between ear of arrival and type of distractor was also significant ($F= 10.19$; df 2,27; $P < 01$), and was further subject to a multiple comparison of means test, the results of which are contained in Table 8.1 a).

In terms of an effect of the shadowing requirement the only significant difference is that whereas on the right (shadowed ear) both semantic and phonemic distractors reduced recognition significantly compared with unrelated distractors, ($q= 7.2$; $P < .01$) and ($q= 5.40$; $P<.01$) respectively, on the left (unshadowed ear), only phonemic distractors reduced the level of recognition below that of unrelated distractors ($q= 4.60$; $P<0.1$) (Table 8.1 a).

Table 8.1 Right Ear Shadowed

SOURCE	SS	DF	MS	F	P
A (TYPE OF DISTRACTOR)	13.46	2	6.73	9.35	< 0.01
SUBJECTS (within groups)	19.37	27	0.72		
B (EAR OF ARRIVAL)	2.45	1	2.45	6.80	< 0.05
A x B	7.34	2	3.67	10.19	< 0.01
B x SWG	9.73	27	0.36		
C (SERIAL POSTION)	2.01	4	0.50	1.01	ns
A x C	13.74	8	1.72	3.74	< 0.01
C x SWG	49.88	108	0.46		
B x C	0.35	4	0.09	1	
A x B x C	5.73	8	0.72	2.18	< 0.05
B x C x SWG	35.92	108	0.33		

Simple main effects of the 3-way interaction:

B at AC11	0.05	1	0.05	1	
B at AC12	6.05	1	6.05	17.79	< 0.001
B at AC13	1.80	1	1.80	5.29	< 0.05
B at AC14	1.25	1	1.25	3.68	< 0.05
B at AC15	3.20	1	3.20	9.41	< 0.01
B at AC21	0.45	1	0.45	1.32	ns
B at AC22	0.45	1	0.45	1.32	ns
B at AC23	0.45	1	0.45	1.32	ns
B at AC24	0.05	1	0.05	1	
B at AC25	0.80	1	0.80	2.35	ns
B at AC31	0.20	1	0.20	1	
B at AC32	0.20	1	0.20	1	
B at AC33	0.05	1	0.05	1	
B at AC34	0.05	1	0.05	1	
B at AC35	0.80	1	0.80	2.35	ns
Error Term		35	0.34		

Table 8.1a Comparison between means (Tukey's HSD):

	AB11	AB12	AB21	AB22	AB31	AB32
AB11		6.20**	1.80	1.80	7.20**	6.40**
AB12			4.40*	4.40*	0.10	0.02
AB21				0.00	5.40**	4.60*
AB22					5.40**	4.60*
AB31						0.80

q' 0.05 = 2.98 (*)
q' 0.01 = 4.65 (**)

Table 8.1b Total correct responses for each distractor type:

	B1 (right)	B2 (left)	SD (right)	SD (left)
A1 (semantic)	99	130	2.11	1.18
A2 (phonemic)	108	108	1.88	2.41
A3 (unrelated)	135	131	1.20	1.44

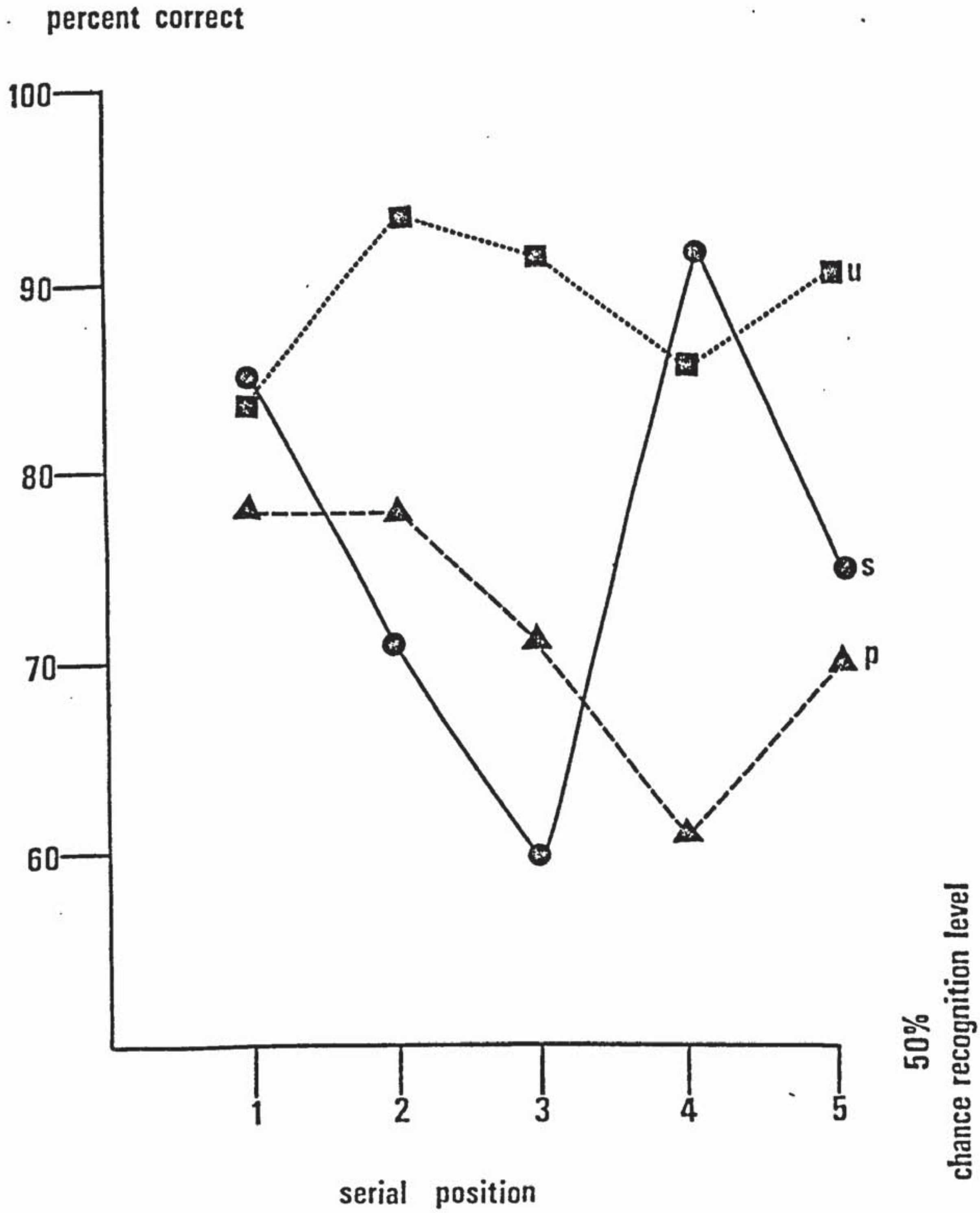

Figure 8.1 Right Ear Shadowing:- Percent correctly recognised as a function of distractor type and serial position.

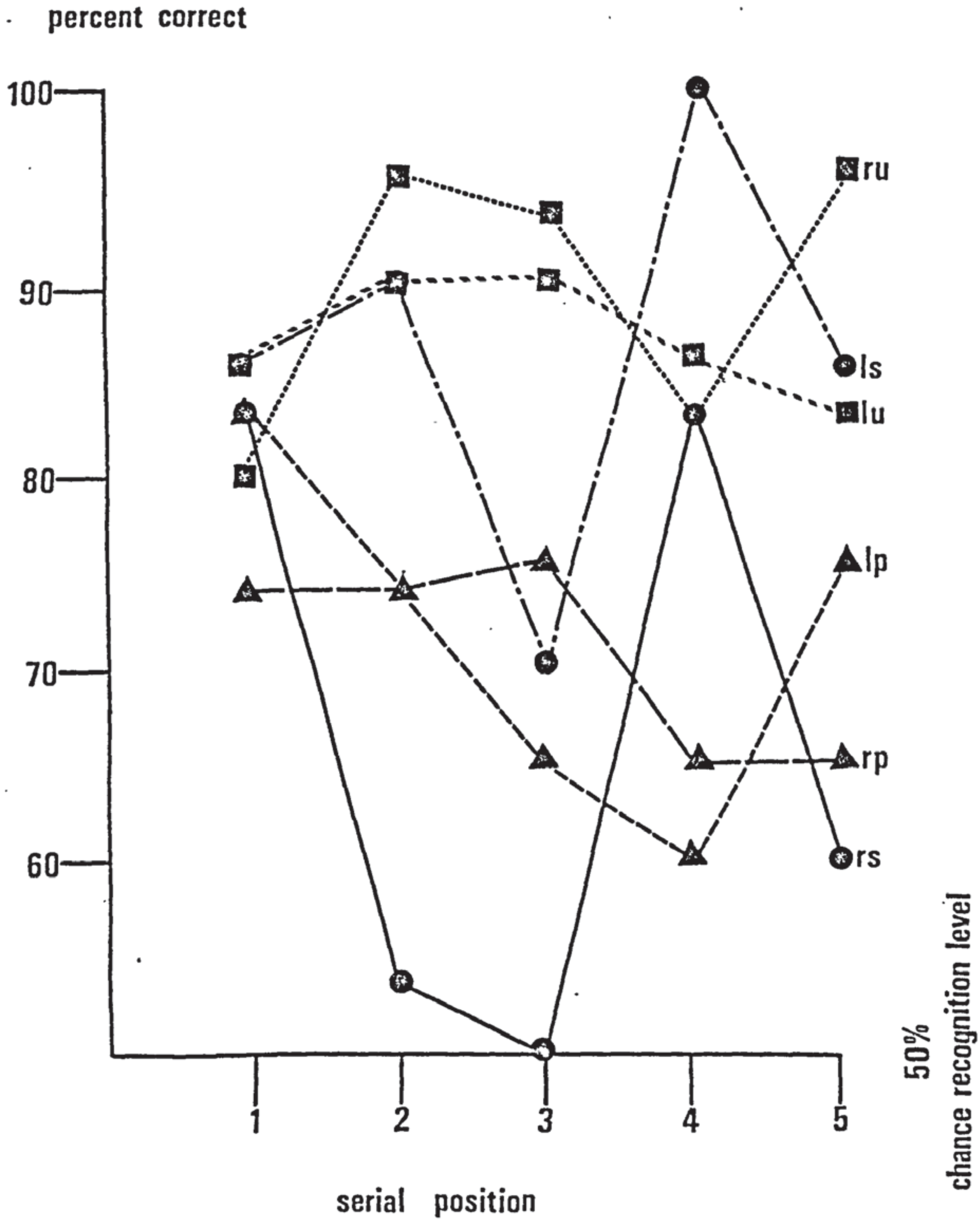

Figure 8.2 Right Ear Shadowing:- Percent correctly recognised as a function of serial position, type of distractor and whether shadowed or unshadowed.

Of course in the context of this analysis it is impossible to disentangle the consequences of ear of arrival and shadowing or not shadowing the stimuli. Therefore a discussion of this point is contained in the results of the analysis of the reverse condition; left shadowed right unshadowed.

There was no main effect of serial position, but the interaction between distractor type and serial position was significant (F= 3.74; df 8,108; $P < .05$). As can be seen from the graph of this interaction (fig. 8.2) the pattern of this result is somewhat confused, with the overall emphasis upon the difference between semantic, phonemic and unrelated distractors at the last position in the list. However, although the interaction between serial position and ear of arrival was not significant, the three-way interaction was (F= 2.18; df 8,108; $P < .05$) as a result further analysis was confined to this interaction.

The simple main effects analysis of the three way interaction (Table 8.1, Fig. 8.2) revealed a very interesting effect in that the interaction between type of distractor and serial position at positions 2-5, was dependent upon ear of arrival for items matched with semantic distractors only. This interaction is graphically represented in figure 8.2, from which it can be seen that whereas the difference between the levels of recognition is significant, the form of the recognition curve is very similar at the recency positions.

On the other hand the shapes of the recognition function on the right is very different from the left for the primacy portion of the curve. This would suggest that whereas ear of arrival effects predominate at the primacy portion of the list as suggested by the results of the previous experiments in this study, the recency portion of the list reveals the effect in terms of recognition efficiency of focussing attention alone.

This result would also suggest that focussing attention by shadowing has no differential effect upon the recognition efficiency of unrelated items, this is only a short list of items, and as there is no known study using a comparable methodology which might suggest a more complex reason for such a result, it might be suggested that an upper limit upon recognition efficiency had been reached, recognition accuracy being 90% on the right ear and 87.33% on the left.

This line of argument can be applied to the recognition of items paired with phonologically similar distractor items, in that there is no difference in the efficiency of recognition between the ears. The characteristic negative effect of this distractor type would not appear to betray my influence of ear of arrival although this may be because it is only apparent in the comparison between the two right or left shadowing regimes. Any final comment upon this is thus reserved until the results of the second analysis of the left shadowed right unshadowed condition have been outlined.

In the analysis of the left ear shadowed condition, the main effect of distractor type was again significant, ($F= 20.48$; df 2,27; $P<.001$). The main effect of ear of arrival was also significant ($F= 20.69$; df 1,27; $P< .001$), as was the interaction between ear of arrival and distractor types ($F= 3.84$; df 2,27; $P< .05$). The interaction effect was subject to a simple main effects analysis which revealed that the significant effect of ear of arrival was confined to semantic and phonemic distractor types (Table 8.2)

The detailed analysis of this interaction using Tukey's multiple comparison of means test, bears close comparison with the analysis of data from the shadowed right ear. Once again there is no difference in the absence of any effect due to unrelated distractors, at either the left or right ear.

The effect of semantic distractors is interesting in that there is no significant difference in terms of recognition efficiency between the effects of semantic and unrelated distractors. The results are, however, in the same direction as those derived from right ear shadowing, there is a large but non-significant effect due to semantic distractors at the right, unshadowed ear. Thus there is an impairment of right ear recognition, whether the shadowed ear or not, where the items were paired with semantic distractors. The left ear on the other hand, shadowing or not, reveals no effect of semantic distractors whatsoever.

Table 8.2 Left Ear Shadowed

SOURCE	SS	DF	MS	F	P
A (TYPE OF DISTRACTOR)	20.49	2	10.24	20.48	< 0.001
SUBJECTS (within groups)	13.58	27	0.50		
B (EAR OF ARRIVAL)	12.00	1	12.00	20.69	<0.001
A x B	4.46	2	2.23	3.84	<0.05
B x SWG	15.74	27	0.58		
C (SERIAL POSITION)	4.87	4	1.22	2.97	<0.05
A x C	3.81	8	0.73	1.78	ns
C x SWG	43.92	108	0.41		
B x C	1.73	4	0.43	1	
A x B x C	4.11	8	0.51	1.02	ns
B x C x SWG	53.9	108	0.5		

Simple main effects of the A x B interaction:

B at A1 (semantic)	6.44	1	6.44	11.10	< 0.001
B at A2 (phonemic)	9.61	1	9.61	16.50	< 0.001
B at A3 (unrelated)	0.09	1	0.09	1	
Error Term		27	0.58		

Table 8.2a Comparison between means (Tukey's HSD):

	AB11	AB12	AB21	AB22	AB31	AB32
AB11		3.46	2.40	1.73	3.73	4.13
AB12			5.86*	1.86	0.26	0.66
AB21				4.13	6.13*	6.53*
AB22					2.00	1.20
AB31						0.40

q' 0.05 = 4.20 (*)

Table 8.2b Total correct response for each distractor type:

	B1 (right)	B2 (left)	SD (right)	SD (left)
A1 (semantic)	100	126	2.19	1.49
A2 (phonemic)	82	113	1.24	1.55
A3 (unrelated)	128	131	1.32	1.37

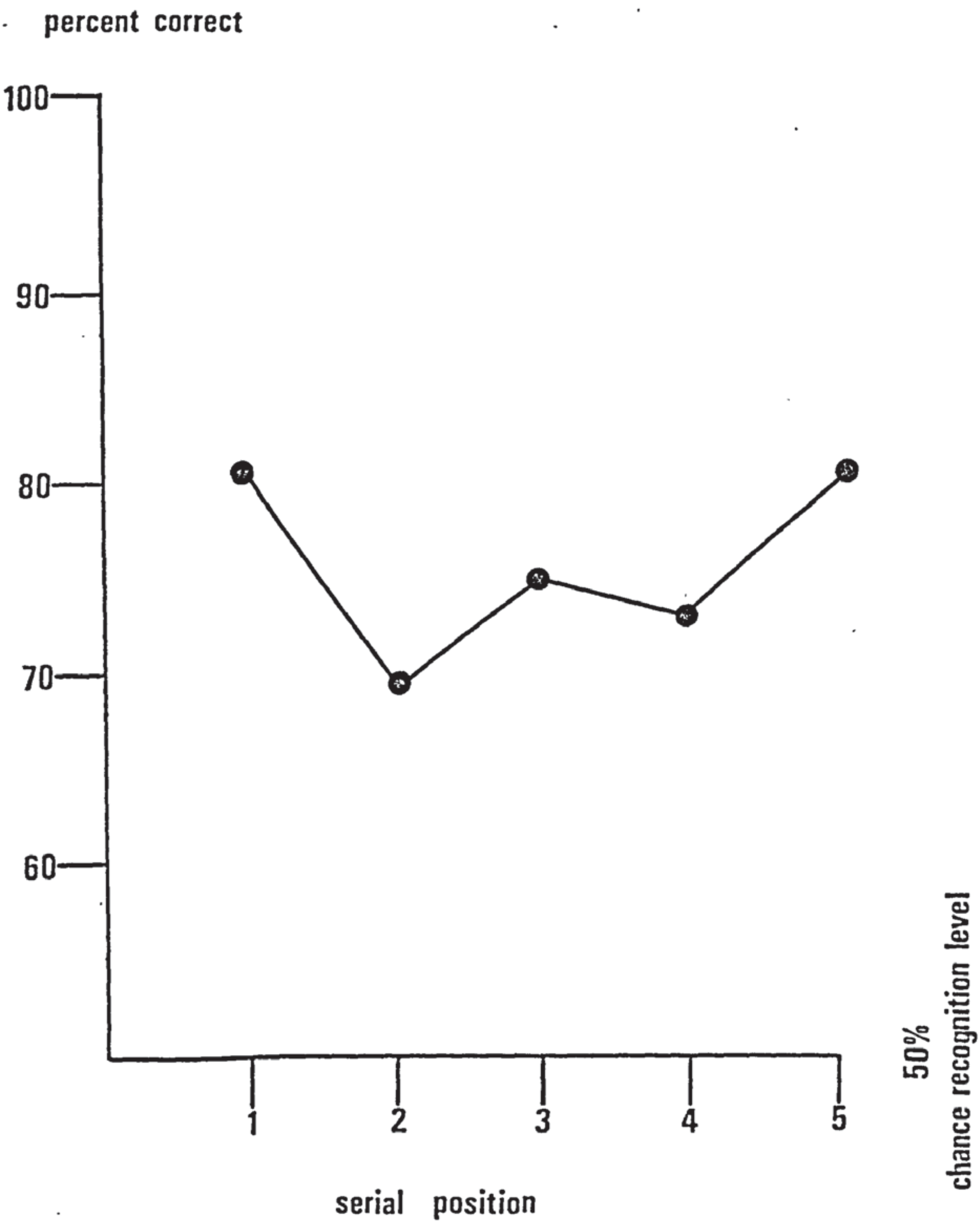

Figure 8.3 Left Ear Shadowing:- Percent correctly recognised as a function of serial position.

The pattern of results with respect to phonologically similar distractors, does not coincide as closely with the results of right ear shadowing as do those of semantic distractors. Both right and left ear recognition of unrelated items is superior to that of the right ear when matched with phonological distractors, ($q = 6.13$; $P < .05$) and ($q = 6.53$; $P < .05$) respectively. There is no difference between the recognition of items presented to the left and right ears and matched with unrelated distractors and left ear recognition of items matched with phonologically similar items. This contrasts with right ear shadowing where phonologically similar distractors reduced recognition performance on both right and left ears.

An explanation of this effect can be derived from our knowledge of the left hemisphere's responsibility for the phonological analysis of verbal stimuli (Levy, 1974; Cohen and Freeman, 1976). Thus the left hemisphere would appear to mediate left ear inputs, when the right ear is the shadowed ear. This is, of course, an example of the constraints of lateral differences interacting with the attempt to focus attention through the medium of the shadowing requirement.

The ANOVA based upon the data from both ears as the unshadowed ear, revealed no significant main effect of ear of arrival. There was a main effect of distractor type ($F = 3.92$; df 2,54; $P < .05$). Tukey's comparison indicated a significant difference between unrelated and phonemically related distractors in their effects ($q = 4.05$; $P < .05$), recognition was significantly impaired by phonemically similar distractors. There was no significant difference between semantically related distractors, and either the acoustic or unrelated distractors.

There was no significant main effect of serial position, but the serial position by ear of arrival interaction was significant ($F = 2.53$; df 4,216; $P < .05$). This interaction is represented in Fig. 8.4, and suggests that although there is no main effect of ear of arrival, a laterality difference in the efficiency with which early list items are recognised exists. The interaction between list type and serial position is also significant ($F = 2.87$; df 8,216; $P < .05$) and this interaction (Fig. 8.5) exhibits roughly similar features to other effects of ear of arrival in experiment II for example the effect of ear of arrival is greatest at early list positions as in the present case.

The three way interaction was also significant (Table 8.3) ($F = 3.18$; df 8,216; $P < .05$) thus the detailed analysis of two interaction effects was not entered into. The simple main effects of the three way interaction (Table 8.3) showed that ear of arrival affected the recognition of words matched with phonologically similar distractors at serial position two, and words matched with semantically similar distractors at the same serial position (Fig. 8.6). This finding was further analysed using Tukey's method for comparing complex means, the

Table 8.3 Both Ears Unshadowed

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	11.60	1	11.60	3.79	ns
C (TYPE OF DISTRACTOR)	24.01	2	12.00	3.92	<0.05
A x C	4.25	2	2.12	1	
SUBJECTS (within groups)	165.34	54	3.06		
B (SERIAL POSITION)	3.38	4	0.84	2.15	ns
A x B	3.98	4	0.99	2.53	<0.05
B x C	8.96	8	1.12	2.87	<0.05
A x B x C	9.92	8	1.24	3.18	<0.05
B x SWG	83.76	216	0.39		

Simple main effects of the 3-way interaction:

A at BC11	1.80	1	1.80	1.96	ns
A at BC12	1.25	1	1.25	1.35	ns
A at BC13	0.05	1	0.05	1	
A at BC21	5.00	1	5.00	5.43	<0.05
A at BC22	4.05	1	4.05	4.40	<0.05
A at BC23	0.80	1	0.80	1	
A at BC31	0.20	1	0.20	1	
A at BC32	0.20	1	0.20	1	
A at BC33	0.05	1	0.05	1	
A at BC41	2.45	1	2.45	2.66	ns
A at BC42	1.80	1	1.80	1.96	ns
A at BC43	0.45	1	0.45	1	
A at BC51	1.25	1	1.25	1.35	ns
A at BC52	0.80	1	0.80	1	
A at BC53	0.80	1	0.80	1	
Error Term		270	0.92		

Table 8.3a Comparison between means (Tukey's HSD):

Comparison	q	p
ABC121 - ABC221	4.76	0.05
ABC122 - ABC222	4.28	0.05

q' 0.05 = 2.42

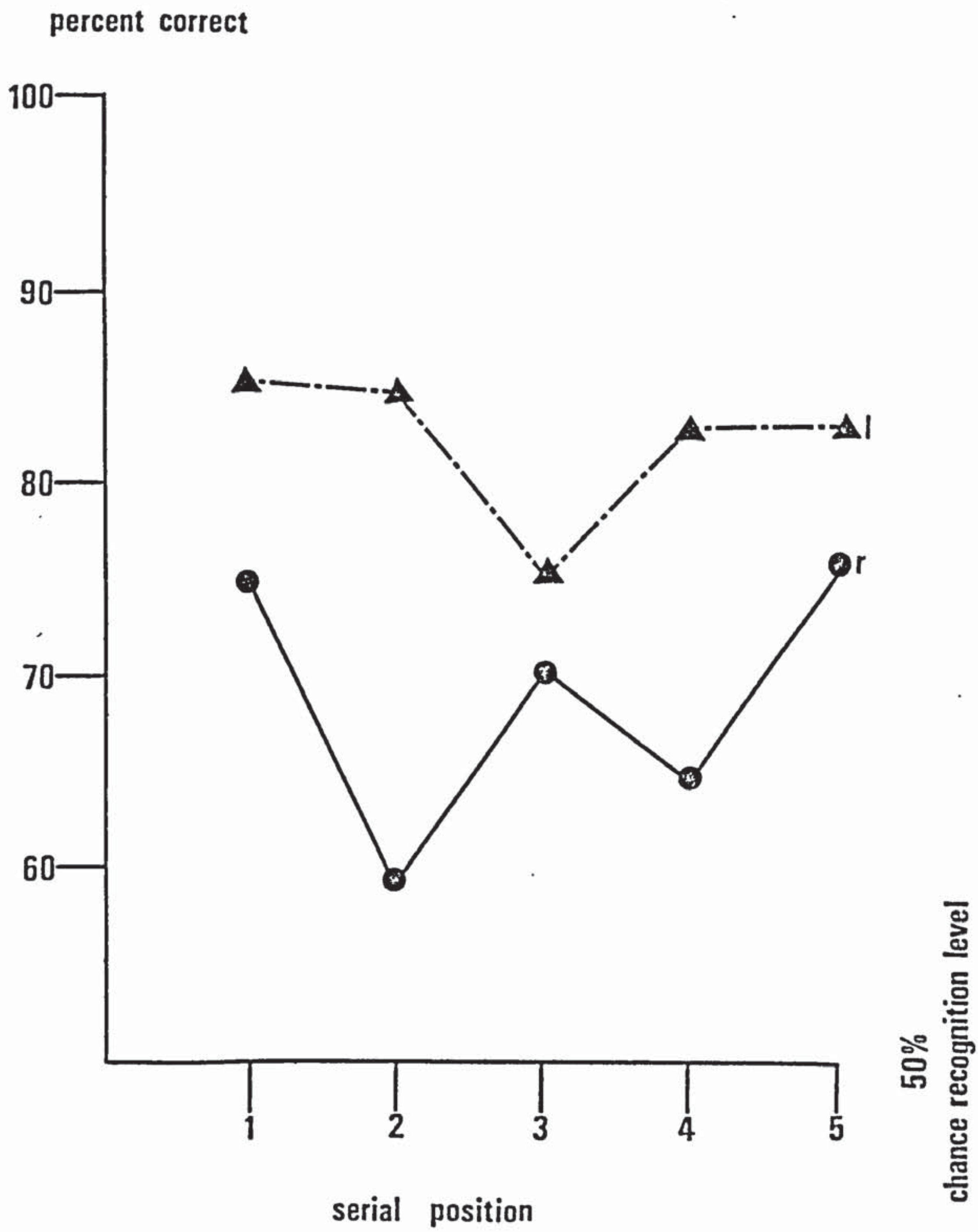

Figure 8.4 Left Ear Shadowing:-
Ear:- Percent correctly recognised as a function of serial position and whether shadowed or unshadowed.

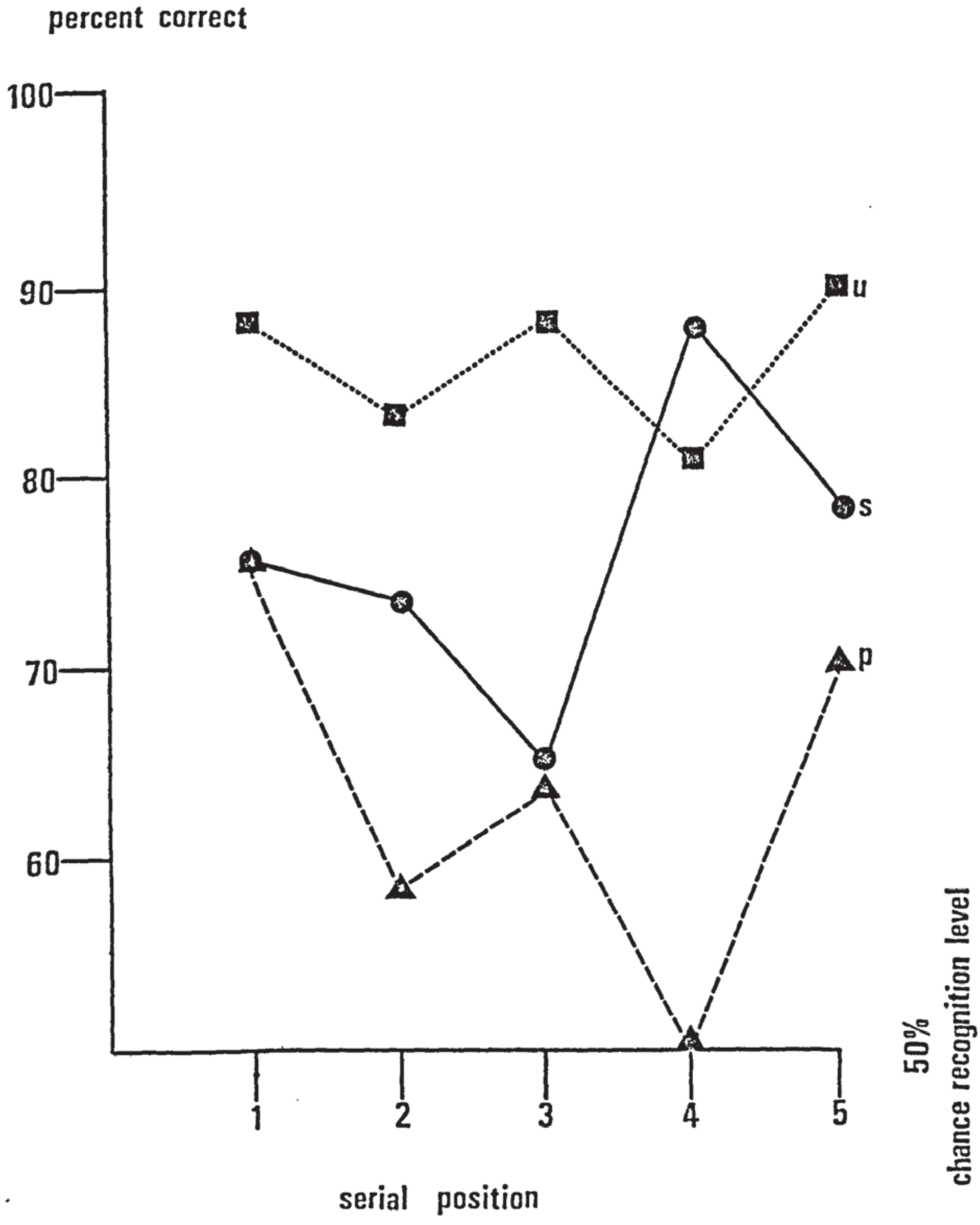

Figure 8.5 Right and Left Ear as Unshadowed Ear:- Percent correctly recognised as a function of the type of distractor and serial position.

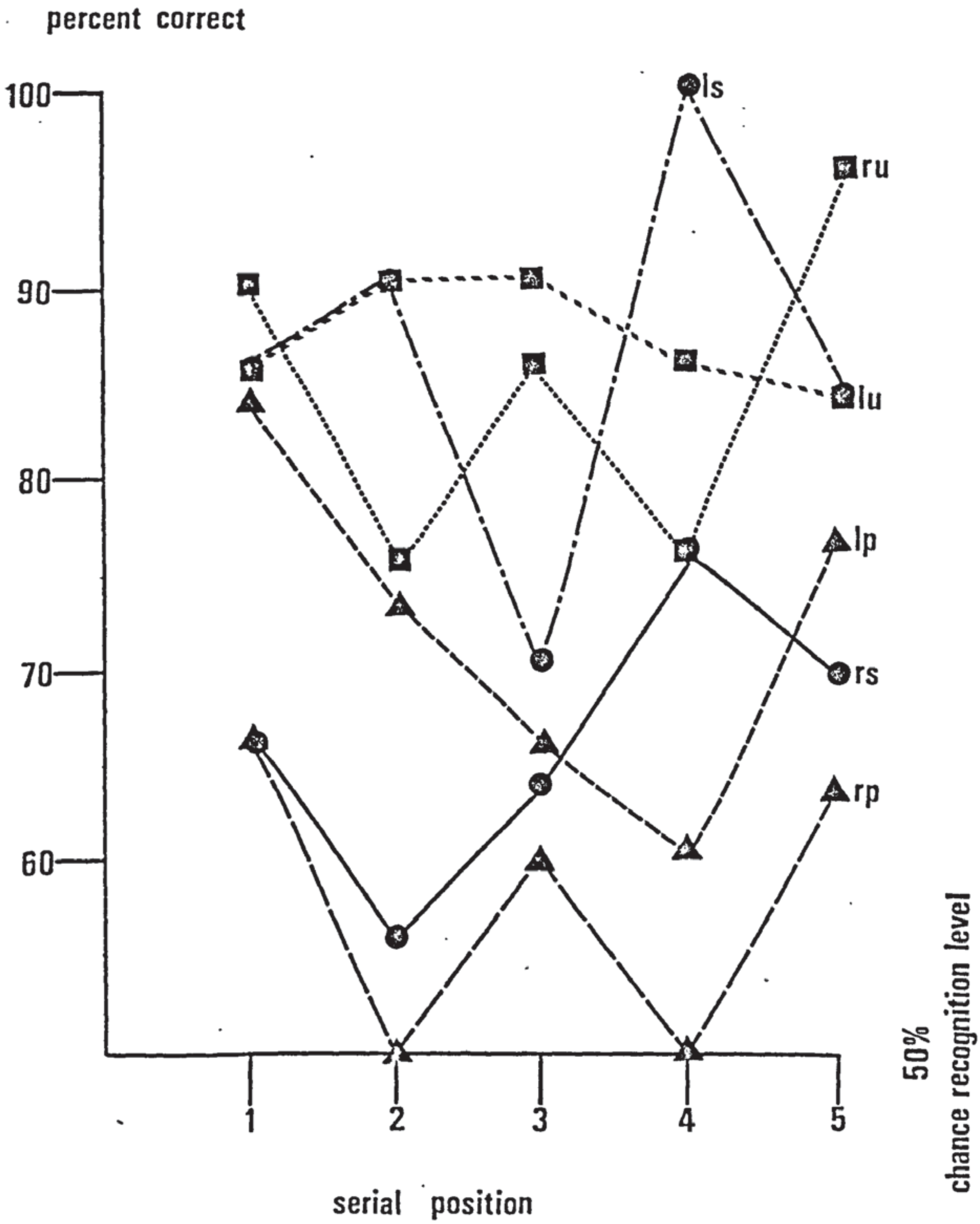

Figure 8.6 Right and Left Ear as Unshadowed Ear:- Percent correctly recognised as a function of distractor type, serial position and ear of arrival.

result reinforced the earlier discussion in that the right ear was less well recognized than the left when matched with both phonemically and semantically related distractor types ($q= 4.76$, $P. < 05$, and $q= 4.28$, $P. 05$) respectively (Table 8.3a)

That the effect of the three way interaction was confined to position two, confirmed and complemented the analysis based upon shadowed and unshadowed material. The right ear inputs are more prone to disruptions, the left, less so for two reasons; firstly because inputs are not susceptible to disruption at the phonological level because this information is not efficiently coded. Secondly, it can be suggested but perhaps not proven from the present data, that there is little effect of semantic distractors because this is not an important attribute code in the storage of left ear shadowed inputs. Certainly, the absence of any effect due to semantically related distractors upon left ear inputs, shadowed or not, would strongly support such a hypotheses.

In the analysis of the data from both left and right ears as the shadowed ear there was a significant main effect of ear of arrival ($F= 4.44$; df 1.54; $P.< 05$) (Table 8.4). There was also significant main effect of type of distractor ($F= 10.42$; df 2.54; $P < .001$). The interaction effect of ear of arrival and distractor type was found to be significant ($F= 4.29$; df 2.54; $P < .05$) and this interaction was further subject to simple effect analysis. The ear of arrival of stimuli was found to

Table 8.4 Both Ears Shadowed

SOURCE	SS	DF	MS	F	P
A (EAR OF ARRIVAL)	2.62	1	2.62	4.44	< 0.05
C (TYPE OF DISTRACTOR)	12.42	2	6.21	10.52	< 0.001
A x C	5.07	2	2.53	4.29	< 0.05
SUBJECTS (within groups)	32.08	54	0.55		
B (SERIAL POSITION)	1.09	4	0.27	1	
A x B	0.48	4	0.12	1	
B x C	14.59	8	1.82	4.44	< 0.001
A x B x C	4.72	8	0.59	1.43	ns
B x SWG	89.12	216	0.41		
Simple effects:					
A at C1 (semantic)	7.29	1	7.29	12.53	< 0.001
A at C2 (phonemic)	0.25	1	0.25	1	
A at C3 (unrelated)	0.16	1	0.16	1	
Error Term		54	0.59		
B at C1 (semantic)	9.50	4	2.37	5.78	< 0.01
B at C2 (phonemic)	4.64	4	1.16	2.82	< 0.05
B at C3 (unrelated)	1.54	4	0.38	1	
Error Term		216	0.41		

Table 8.4a Comparison between means (Tukey's HSD):

Comparison	q	p
AC11 - AC21	5.40	<0.01
	q' 0.01 = 5.18	
BC11 - BC12	3.00	<0.05
BC21 - BC22	3.33	<0.05
BC31 - BC32	4.06	<0.05
BC41 - BC42	3.66	<0.05
BC51 - BC52	1.66	ns
	q' 0.05 = 2.84	

Table 8.4b Total correct response for each distractor type:

	A1 (right)	A2 (left)	SD (right)	SD (left)
C1 (semantic)	99	126	2.11	1.49
C2 (phonemic)	108	113	1.89	1.55
C3 (unrelated)	135	131	1.20	1.45

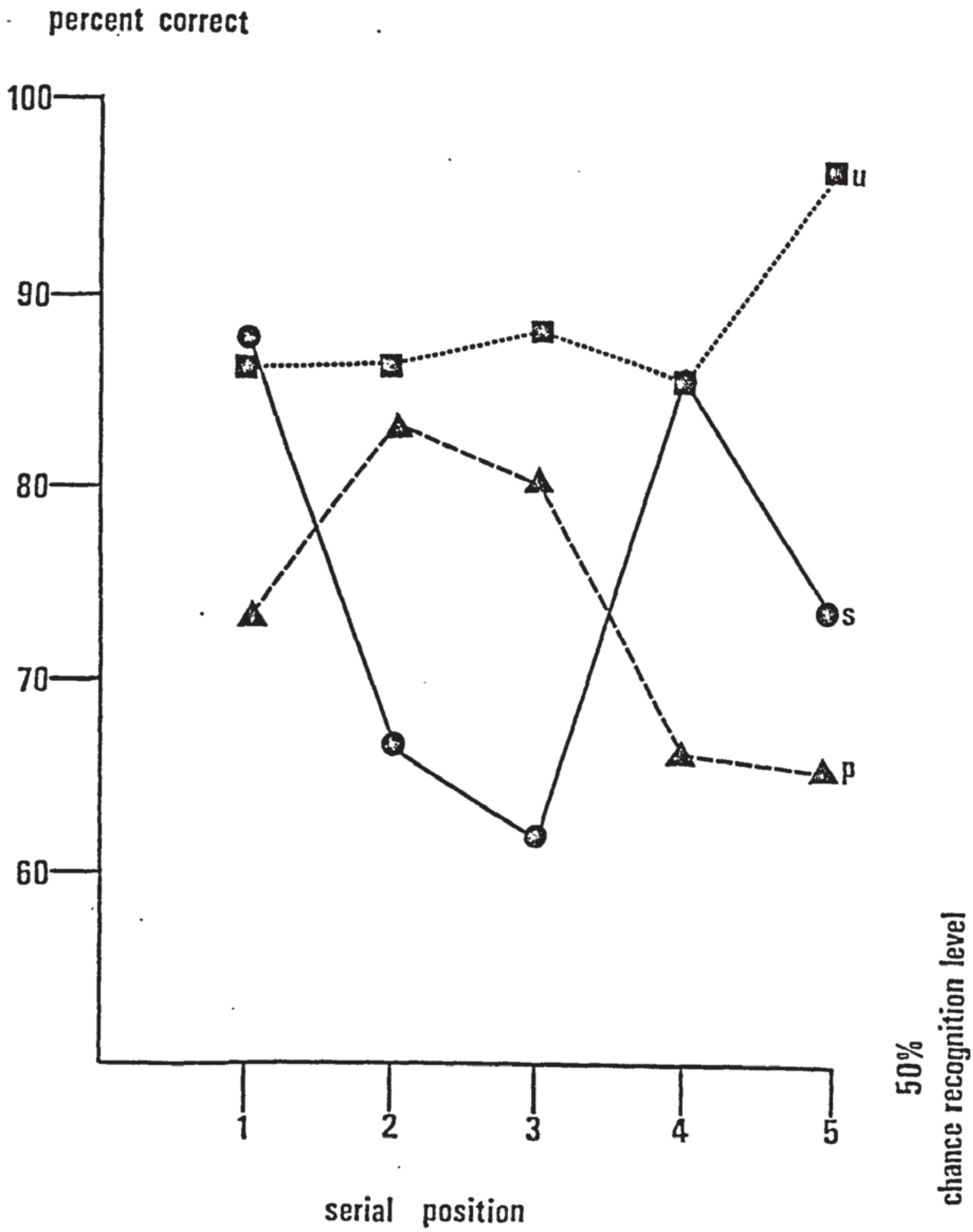

Figure 8.7 Right and Left Ear as Shadowed Ear:- Percent correctly recognised as a function of serial position and distractor type.

exert a significant influence only with respect to semantically related material. Using Tukey's multiple comparison of means test it was found that whereas left ear recognition efficiency was not influenced by semantically related distractors, inputs to the right ear were ($q= 5.49$; $P < .01$) (Table 8.4c).

It is clear then from the above result that the effect of ear of arrival is independent of the focussing of attention, at least with respect to this paradigm. This is an important finding in view of the number of studies which still fail to control for such an effect whilst studying problems of selective attention. It is also useful to note that whilst there is a non-significant tendency towards an effect of phonemically related distractors (see Table 8.4b). The significant interaction between distractor type and serial position ($F= 4.44$; df 8,216; $P <.001$) is shown by simple main effects analysis (Table 8.4) to consist of a significant effect of serial position upon the recognition of items matched with phonemically and semantically similar distractor items.

The main effect of serial position was not significant as was the case with the recognition of unattended items presented to the left and right ears. This most probably reflects the very high level of recall, presumably a function of the limited number of items presented in a list. The interaction between ear of arrival failed to approach significance. Finally, there was no significant effect of the three way interaction.

8.4 Discussion and Conclusions

The first conclusion to be drawn is that the results of this experiment confirm and extend the findings of experiments I to V. The possible lack of generalizability that it had been suggested might characterize the earlier findings was not found to be the case. Instead, the recognition technique served to provide converging evidence which supported the major findings of experiments based upon the use of lists comprised of semantically or phonemically similar items.

8.4.1 One of the most important findings of the present study was the high level, well above chance, of recognition efficiency for items paired with unrelated distractors. Whether attended or unattended, right ear or left, there was very little departure from the overall rate of 80% correct detections. This level of recognition efficiency is by no means beyond the scope of the accepted capacity of primary memory (Miller, 1956). The result is notable however, in so far as there was no overall difference between the level of recognition efficiency of attended and unattended inputs. Even though subjects in this experiment, as well as all previous studies, claimed no recall whatsoever for unattended inputs.

There is experimental evidence however that attention need not be paid in order for items to enter into long-term storage (Martin, 1978; Kellog, 1980). Kellog (1980) also reported that introspective reports of awareness are not correlated with recognition success, as was the case in the present study when subjects recognized items they denied having been aware of.

8.4.2 Having established that both unattended and attended lists of unrelated items are processed, we can now turn to the question of exactly what kind of processing effects their recognition efficiency.

It is immediately obvious that attended and unattended inputs differ in terms of the type of item attribute typically encoded in each condition. In the recognition of shadowed items semantic and phonological attributes would appear to be independently processed. And for example whilst the primacy portion of the list reveals no significicnt effect of phonologically similar distractors upon the recognition of shadowed items, there is a large effect of distractors which share a semantic relationship with presented items.

Conversely, the analysis of recognition data for unattended items showed that semantically and phonologically related distractors could both affect recognition efficiency in the primacy portion of the list. While the data from the recency portion of the lists, whether shadowed or unshadowed, demonstrated the predominance of the effect of phonologically similar distractors.

These results are in keeping with earlier studies in that they suggest that selectively attending to an input can reduce the number of stimulus attributes encoded. In effect, the requirement to shadow one channel of the dichotic input orients the subject in terms of a processing strategy. Wright, Ciccone and Brelsford (1977) employed semantic and non-semantic orienting tasks and their results suggested that the semantic orienting task led to the encoding of the semantic attributes of an item. Whereas the non-semantic orienting task led to the encoding of both semantic and non-semantic attributes.

There is a further line of experimental evidence which suggests that the findings of Wright, Ciccone and Brelsford (1977) can be generalized to the present study. It has been claimed by Lockhart, Craik and Jacoby (1976) that stimulus processing during acquisition proceeds only so far as the "target domain", that is the encoding of those attributes relevant to the performance of the task in question. Only very slight encoding occurs of attributes that occur prior to the "target domain". There exists therefore an initial and unilateral "core encoding", beyond which any processing is a function of task demands. Of course it is central to this theory that the greater the degree of elaboration, or the increase in attributes encoded, then the more effective is recall.

This last point leads to the solution of an interesting problem posed by Martin (1978) and reaffirmed in Experiment V. The resilience to output interference and superior durability of unattended inputs has not been explained previously. However, if we assume that unattended inputs are subject to a non-specific orienting in the sense proposed by Wright, Ciccone and Brelsford (1977) then we would expect both phonemic and semantic attributes to be encoded. Similarly the concept of the "target domain" as proposed by Lockhart, Craik and Jacoby (1976), cannot be directly applied to unattended inputs. In the absence of any implicit or explicit task demands with reference to the level of processing, an elaborated encoding will proceed in so far as it does not conflict with the capacities of the hemisphere to which inputs are lateralized.

Following on from the above argument it can be suggested that unattended inputs are likely to be represented in memory by more than one attribute, which would indicate a more resilient and durable trace. In contrast, attended inputs are processed solely on the basis of that attribute which is most appropriate for the performance of the auditory tracking requirement in the dichotic shadowing task. This will necessarily engage the left and right hemisphere to a different extent.

The restricted nature of the processing afforded attended items in a dichotic shadowing task is reflected in the limited and unstable trace of attended items noted by Martin (1978) and in Experiment V. On the other hand, when the effects of an absence of any conscious awareness of unattended inputs is circumvented by the use of a recognition paradigm, it becomes clear that such inputs can be recognized with a high degree of accuracy.

A further aspect of the results from the present study would appear to support these conclusions. Language comprehension has long been known to be centred upon the left hemisphere, both with respect to written and spoken words (Gazzaniga and Sperry, 1967; Sperry, Gazzaniga and Bogen, 1969). It is not surprising, therefore, that recognition accuracy for items presented to the right ear as shadowed ear, were reduced by semantically similar distractor items. Simiarly there was a large but non-significant trend towards an effect of semantic distractors upon right ear inputs when they were unattended. By comparison there was no effect of semantically similar distractor on the left ear inputs, whether shadowed or unattended.

Thus we can conclude that ear of arrival effects are independent of the focussing of attention, or rather that attention can be focussed as far as such effects allow. This is, of course, a problem for theories of selective attention based upon the shadowing technique. The pattern of results concerning the encoding of phonological attributes confirms this finding and underlines the view that unattended items can be subject to a more elaborated form of encoding which in the present case involved both phonological and semantic attributes of an item.

As the left hemisphere is known to mediate decisions based upon phonological attributes (Levy, 1974; Cohen and Freeman, 1976) a similar pattern of results as arose with respect to semantically similar distractors might have been expected for phonologically similar distractors. Such was not the case however, the effect of phonologically similar distractors was significant on the right ear, whether that ear was shadowed or not. The difference between semantic and phonological distractors lies in the fact that the unshadowed left ear also included a significant reduction in recognition efficiency as a function of phonologically similar distractors. Furthermore the left ear as shadowed ear was found to exhibit a non-significant trend towards an effect of phonological distractors (se Table 8.2a). This is, of course, in line with the suggestion made earlier that unattended inputs would exhibit both semantic and phonological coding where possible.

The constraints imposed by lateral differences in cerebral functions are far less clear with respect to phonological attributes than they are in the case of a semantic analysis of inputs. An explanation of this divergence is required and must rest in part upon some characteristic failings of the recognition technique when applied to the study of hemispheric differences in intact subjects.

The recognition process consists of matching some internal representation of a word against the written form of that word and a distractor item. If the form in which that comparison is made is verbally mediated in any way, and there must be some mediation of the written words for comparision with the internal representation, then the left hemisphere may predominate in the comparative process by virtue of its dominant role in speech production and language comprehension (Sperry, Gazzaniga and Bogen, 1969). Moreover the shadowing response in this study is functionally dependent upon the left hemisphere, as the right hemisphere is known to be incapable of sustained speech (Zaidel, 1976). Affording another opportunity for the left hemisphere to influence the encoding of left ear inputs.

Consideration of the results from the condition in which the left ear was the shadowed ear, suggests however that in some aspects at least, the processing of inputs presented to the right ear was unaffected by and independent of the left hemisphere. Although a comparison of right and left ears as the shadowed ear revealed no overall difference between them in terms of recognition efficiency, there was no significant effect whatsoever of either semantically or phonemically related distractors upon the recognition of left ear inputs.

It can be concluded therefore that right hemisphere processes inputs in such a manner that neither semantic or phonemic attributes are central to the successful recognition of an item presented to the left ear. Following on from this point the fact that the processing carried out by the right hemisphere is effective in terms of recognition efficiency must suggest that those attributes of an item processed by the right hemisphere may be important in the recall of material which is not lateralized. Evidence from the study of split-brain and partially anaesthetized patients has led some workers to propose that both hemispheres have valuable contributions to make to the memory capacity of the intact individual (Milner, 1978).

In conclusion it would seem reasonable to suggest that the preconscious or unattended processing of right hemisphere inputs is largely derived from the fact that the right hemisphere has not direct access to speech (Zaidel, 1976). It follows, therefore, that poor right hemisphere performance on certain tasks can be attributed to inappropriate testing procedures. Indeed a programme of research which is currently underway, has already advanced our knowledge of right hemisphere linguistic competence by developing procedures which by-pass the lack of expressive competence (Zaidel, 1976, 1978).

It follows from the above that if cognitive psychology is to make any further use of the dichotic shadowing technique, and it does show promise as a tool for exploring laterality effects in intact subjects, then some effort must be expended to devise more elegant and less discriminatory (in the sense of favouring one hemisphere rather than the other) testing procedures.

The results of this experiment also contribute to the evidence that has accumulated throughout, that the dichotic shadowing task is not appropriate for the purposes of studying selective attention. Shadowing does not focus attention so much as the processing effort, that is to say the task concentrates effort on one particular level of item analysis. Moreover, this concentration of resources is heavily constrained by hemispheric differences which must figure largely in any use of this technique. The issue of laterality effects must also reflect on any theory building that has been based on the use of this technique in the past.

CHAPTER NINE

CONCLUSIONS

9.0 Conclusions

The experiments reported in the main section of this thesis, will be discussed in the present chapter with reference to their implications for theories of selective attention and laterality effects. The first part of this chapter will be concerned with selective attention and in particular the theoretical significance of the evidence for the processing of unattended information. Subsequently, the results will be interpreted in relation to current theories of laterality effects. Finally, some effort will be made to integrate the study of selective attention and lateral differences in performance that arise from the use of dichotically presented verbal stimuli.

9.1 Dichotic listening and models of selective attention.

The rationale behind the first experiment in this thesis was to increase our understanding of the circumstances under which the processing of unattended information can occur. Whereas Treisman, Squire and Green (1974) had argued that such processing was carried out in a serial fashion while the central processor was only partially loaded, Lewis (1970), argued that parallel processing of unattended inputs was unconstrained by serial position and hence by the processing load placed upon the central processing device.

The results of experiments I, V and VI allow the conclusion to be drawn that the parallel processing of dichotic inputs can occur, but that the processing afforded to the unattended material is dependent upon the ear of arrival of that material. This position suggests a number of failings of both early and late models of auditory selective attention.

The models of early selection between simultaneous verbal inputs (Treisman et.al, 1974; Traub and Geffen, 1979) cannot accommodate the finding that unattended items are processed in parallel with attended items and that this is unaffected by the serial position of an item (experiment I). It is explicit within these models, that parallel processing can occur only at the beginning of a list prior to the point at which the single channel is fully occupied by the processing of attended items.

More fundamental in its consequences for both early and late selection models of selective attention, in the finding that the processing of dichotic inputs is affected by their ear of arrival. Late selective models (Norman, 1969) include the proposition that all inputs are processed to the level of meaning before selection occurs. It is clear from the results of experiments I, V and VI that all inputs are not processed to the same level before selection. Thus in the sense that late selection models (Deutsch and Deutsch, 1963; Norman, 1969) presume that attended and unattended inputs are processed in an equivalent fashion, then they are incorrect.

The reasons for such a conclusion can be found in a close analysis of the results of experiment I in particular. Synonyms had no effect upon shadowing latencies when the left ear was being shadowed. The explanation of this effect can be found in the difference between the left and right hemisphere lexicon. Fonagy (1977) found that whereas words presented to the left hemisphere evoked common linguistic associations, those directed to the right hemisphere gave rise to words associated with one another in terms of common spatial characteristics.

In effect therefore, two words sharing common semantic features are synonyms with reference only to the left hemisphere lexicon. The lack of a left ear synonym effect was due to the fact that there were no synonym pairs presented to the left ear, in so far as there were no word pairs matched with reference to the right hemisphere lexicon. Similarly in experiment VI there was no significant effect of semantically related distractors upon left ear presentations (Table 8.2b, 8.4b), largely it would seem because they were not similar within the frame of reference of right hemisphere auditory linguistic capacity.

An explanation of the laterality effect associated with reduction in verbal reaction time as a consequence of homophone word pairs in experiment I, can be attempted within the same framework. Although two words might sound the same, they can give rise to a number of different associations on right ear presentation. The left hemisphere would be primarily concerned with the semantic characteristics of an input, whereas the right hemisphere representation of language would not involve this level of discriminatory activity. Consequently, the right ear shadowing condition would not reflect the consequences of homophony in a decreased verbal reaction time, whereas the level of auditory language representation in the right hemisphere would suggest an effect of homophony in the absence of semantic attributes upon which to distinguish between dichotic inputs. Similarly in experiment VI, phonemic similarity was seen to influence the recognition of both left and right ear inputs.

It can be concluded, therefore, that both words of a dichotic pair undergo some processing (experiments I and V), and that the 'level' or nature of this processing reflects the constraints of the differing linguistic capacities of the two hemispheres (experiments II, III, IV and VI). In effect inputs in a dichotic shadowing task are directed to two separate channels for the representation of language, which channels are essentially different in the manner in which they represent linguistic inputs. It follows therefore that dichotically presented stimulus pairs do not both receive the same level of processing, a conclusion which contradicts the assumptions of a late selective model. Even if both inputs undergo 'full' processing, it will reflect the constraints of the differing linguistic capacities of the two hemispheres.

It has already been noted in Chapter II that there is evidence to support a 'channel' theory of the processing of lateralized stimuli (Dimond, 1972; Hines, 1975). This theory suggests that the cerebral hemispheres can process information in parallel but that the success of this depends upon the relationship between the nature of the stimuli and the processing propensities of the hemisphere at which it arrives. Present knowledge of the linguistic organization of the right hemisphere suggests that it contains a rich auditory lexicon, accompanied by a poor comprehension of long non-redundant sentences and a limited short-term verbal memory (Zaidel, 1978), a point to which we shall return later in the discussion.

It would seem, therefore, that short lists of unrelated words are an ideal vehicle for the right hemisphere to display its limited linguistic capacity. This last point is reinforced by evidence which suggests that the imposition of a secondary task of known lateralization, the shadowing requirement in the present case, gives rise to larger and more reliable laterality effects (Hellige, Cox and Litvac, 1979; Moscovitch and Klein, 1980).

The experiments reported in this thesis are therefore likely to have ensured that verbal materials presented to the left ear were processed at the right hemisphere, at least in part because the left hemisphere bore the brunt of the responsibility for speech production (Gazzaniga and Sperry, 1967). It is in the light of this conclusion that we must now consider the evidence from the studies reported here and elsewhere which are based upon the dichotic shadowing task and would seem to suggest the existence in subjects of a capacity for processing unattended inputs.

9.1.2 Processing of unattended information.

Considerable evidence has been provided to support the view that unattended inputs in auditory selective attention experiments are analysed for semantic content (Lewis, 1970, 1972; Corteen and Wood, 1972; Mackay, 1973, Corteen and Dunn, 1974; Treisman, Squire and Green, 1974; Forster and Govier, 1978). Without exception however, these studies employed a paradigm, dichotic shadowing, the results of which can be explained by reference to a model which presumes that a limited bilateral representation of lexical capacity permits the parallel processing of dichotic inputs. Once again the strongest evidence for this model can be derived from the detailed nature of the semantic processing afforded to unattended inputs.

Firstly, it must be made clear that none of the studies mentioned above made any explicit reference to the possible effects of hemispheric differences. Furthermore, few of these studies made any attempt to control for the effects of ear of arrival, and as was argued in Chapter IV, designs balanced for ear of arrival such as that employed by Treisman <u>et al</u> (1974) fail to achieve this end. Even more interesting perhaps, is the fact that of those studies which include information concerning which ear was designated as the unattended ear, all employed the left ear as the unattended ear (Corteen and Wood, 1972; Corteen and Dunn, 1974; Forster and Govier, 1978). The one exception is the failure to replicate the finding of semantic processing unattended information reported by Wardlaw and Kroll (1974), who employed a balanced design in which all levels of experimental treatments were presented to both left and right shadowing groups.

It has already been shown that the 'Lewis effect' an effect based upon the semantic relationship between two dichotically presented inputs (Lewis, 1970; Treisman <u>et al</u> (1974) is confined to right ear shadowing conditions. Studies based upon the use of shock-conditioned words in the unattended channel and a Galvanic Skin Response (G.S.R.) have also found a limited capacity for the semantic processing of unattended information.

Forster and Govier (1978) in a most elegant study of processing of unattended inputs, employed conditioned target words and homonyms of target words either in or out of a meaningful context on both ears. It was found that the cue given by the meaning of the context in which a target was placed led to an increased accuracy of the G.S.R. response in the shadowed ear. No such benefit was found for unattended ear responses, where target words and homonyms both gave rise to a G.S.R., a meaningfull context having had no effect upon the accuracy of target identifications.

In the experiment reported by Forster and Govier (1978) the unattended ear was, of course, the left ear and the results are entirely in keeping with the known characteristics of the right hemisphere's capacity for linguistic comprehension (Zaidel, 1978).

This would seem to suggest that in so far as there is evidence of the parallel processing of dichotically presented inputs, the unattended ear has often been the left ear and has, characteristically, exhibited the constraints of right hemisphere processing of linguistic material. Experiment VI has confirmed that whereas both ears can process inputs as the unattended ear, they do so in a quite different manner. This is an important result because hitherto few experiments have been designed in which the capacities of the right ear as unattended ear of arrival have been examined. It should be noted that although in experiment V it was found that the meaning of unattended list whether presented to the left or right ear, could influence recall; this was concluded to be the consequence of processing that took place after the list was presented.

It would seem clear then, that the processing of unattended material depends in part upon the fact that dichotic shadowing very effectively lateralizes inputs thereby affording an opportunity for parallel processing at the two cerebral hemispheres. This position must reflect upon the increasing theoretical importance that has been given to evidence of processing without attention. Some authors attribute the possibility of parallel processing to the unconscious nature of the processing afforded to unattended inputs:-

> "The researches by Corteen and his colleagues and by Forster and Govier, imply a further talent of preconscious perceptual mechanisms - namely the capacity for simultaneous processing of two unrelated inputs without interaction or loss." (Dixon and Henley, 1980, p.40)

However, the lack of interference in the experiments mentioned, arises not because of the unconscious nature of the processing for this is a quality of, not a causal factor in, the right-hemisphere processing of linguistic information. The right-hemisphere is 'unconscious' in its processing of language material largely because there is no linguistic representation of the process. As MacKay (1978, 1980) has argued, consciousness with respect to language is the product of verbal 'tracking' a representation of events both external and internal, something which the right hemisphere can neither control nor carry out independently of the left hemisphere. Consequently the implication made by Dixon and Henley (1980) that parallel processing without mutual interference is possible because it is preconscious, is only valid in so far as the use of lateralized inputs allows it to be so.

A great deal of evidence would seem to suggest therefore that dichotic shadowing is a very efficient technique for exploring the linguistic capacities of the right hemisphere in intact subjects. Moreover some conclusions can now be drawn as to the relative merits of dichotic shadowing and the more traditional technique, dichotic listening for use as tools in the examination of laterality effects.

It is obvious if a subject can meet the demand to shadow one channel of a dichotic message then prior to this requirement, for example in a simple dichotic listening task, there is spare processing capacity. Indeed it has been shown that even when shadowing, subjects still have sufficient spare capacity to shadow some 'unattended' words (Salter, 1973). A major consequence of the residual processing capacity available during dichotic listening would appear to be the poor lateralization of inputs this technique achieves (Hellige, et al, 1979; Moscovitch and Klein, 1980).

However loading one hemisphere, the left, with a further task such as shadowing, removes the principle source of variability in dichotic listening, the inherent flexibility afforded by the underemployed linguistic capacity of the left hemisphere. Thus in dichotic shadowing the secondary task loading of the left hemisphere forces the two hemispheres to act independently in meeting the demands of dichotic stimulation. The consistency of the consequent laterality effects is notable throughout the experiments reported in this thesis. It would seem therefore that dichotic shadowing is a useful technique, perhaps more so than dichotic listening, for the examination of laterality effects.

Following on from conclusions as to the utility of dichotic shadowing in research upon hemispheric differences, must be some caveat as to appropriateness of the same technique for studies of selective attention. At the core of selective attention research based upon the use of auditory stimuli is the concept of a single channel of finite processing capacity. The review of the literature in Chapter One, suggested that the empirical research underpinning the assumption can be subject to alternative explanation.

As it would seem that there are two, qualitatively different, processing devices for lateralized verbal stimuli (Zaidel, 1978) and dichotic shadowing would appear to be an effective technique for lateralizing dichotic inputs, the assumption that the requirement to shadow one channel of a dichotic message focusses attention upon that input alone, would appear to be invalid. Alternatively, it seems as though attention in the form of processing capacity, is differentially allocated between both inputs in a dichotic shadowing task.

The assumption that shadowing an input acts to focus and control attention, is the basis upon which the use of this technique is established. One conclusion to be drawn from the experiments contained in this thesis, is that the dichotic shadowing technique can no longer be argued to fulfill that role. Notwithstanding this, there are a number of reasons why dichotic shadowing deserves consideration as a tool for the exploration of laterality effects.

9.2 Laterality effects in the dichotic shadowing tasks.

Having outlined the importance of the present series of experiments for theories of selective attention, consideration must now be given to their implications for theories of laterality effects. Some conclusions can also be drawn as to the nature of hemispheric differences which might underly such effects.

The strongest conclusions which can be drawn from the experiments reported in this thesis concern laterality differences in the serial position of items recalled. The principal finding was the superiority of right over left ear recall at early list positions in experiments II and III. Recent work with patients who have undergone surgical lesioning of the temporal lobe for the treatment of epilepsy has provided an independent corroboration of this result. Joccarino-Hiatt (1975, 1978) has shown the effect of hippocampal lesions of the left temporal lobe upon the free recall of lists of 30 common nouns. When recall is compared with normal control subjects, the recall of items from the primacy portion of the list was found to be considerably reduced in the treatment group. Although the study reported by Joccarino-Hiatt (1978) used stimuli which were not lateralized, nonetheless, the effect of a left hemisphere dominance for recall from the primacy portion of a list was replicated. The effect can therefore be considered robust and an accurate indication of normal left hemisphere function.

It is possible in the light of these converging lines of evidence to conclude that the left hemisphere is particularly implicated in the recall of items which are retrieved from secondary memory, a more durable or long-term representation of verbal inputs.

There is evidence which would indicate that mnemonic factors play a large part in this recall superiority of right over left at the primacy portion of the list. In other words we must conclude not that left hemisphere items enter a more permanent store, but that the attributes processed by the left hemisphere are either different, more effectively recalled or both. In effect the evidence supports a process view of memory rather than a structural conception.

Firstly there is the evidence that common semantic or phonemic features can influence the recall of items presented to the attended ear. In experiment II semantic relatedness benefitted recall, phonemic relatedness reduced recall and there was no interaction with ear of arrival. In experiment III both semantic and phonemic similarity gave rise to a level of recall performance superior to that of unrelated items; again there was no interaction with ear of arrival. Thus we can see that both input channels can benefit from encoding common stimulus attributes.

Experiments V and VI showed however that the effect of phonemic similarity limited to early list positions benefitted right ear inputs rather more than left ear inputs. It would appear therefore that although both cerebral hemispheres can make some positive use of stimulus attributes such as semantic and phonemic similarity, the left hemisphere is more effective in employing phonemic similarity. It might be suggested therefore that the left hemisphere can encode more attributes of a verbal item,which facility might prove to be the source of the right ear advantage. However, the experiments reported in this thesis do not sample a sufficiently representative number of possible item attributes to support this contention. Furthermore the evidence would seem to suggest that the right hemisphere encodes different, and not fewer attributes of lateralized inputs, than does the left hemisphere.

The most important evidence in support of the view that the right hemisphere affords a different, rather than simply less encoding for lateralized inputs, derives from the results of experiment VI. It was found that semantic or phonemically similar distractor items reduced recognition efficiency of right but not left ear inputs. Although it is clear that left ear inputs are not so dependent upon the phonemic or semantic attributes of an item, the left ear inputs are nonetheless recognized with a high degree of efficiency. Which indicates the importance of other stimulus characteristics, perhaps less amenable to manipulation in the dichotic listening paradigm, to the processing characteristics of the right hemisphere.

Once again the work of Joccarino (1975) provides an indication as to the likely role of this dual representation of inputs. Employing patients who had undergone unilateral temporal lobectomy Joccarino (1975) showed that whereas short-term memory for pictures was unimpaired by right temporal lobe lobectomy, twenty-four hours later the performance of the same patients was considerably inferior in comparison with normal controls. Thus it was argued that the long-term capacity for reproducing experiences depends upon the joint participaton of both sources of information, the left and right hemispheres. For whereas the left hemisphere compensated for a right hemisphere deficit in the short-term, this strategy cannot succeed over a longer period. Principally (it would seem) because the right hemisphere makes a significant contribution to the process of transferring items to a long term store. For example in increasing the number of item attributes by which the item may be recalled.

Further evidence which helps to form the conclusions to be drawn from experiment VI comes from work reported by Milner (1978). Patients with well-lateralized brain lesions were given ipsilateral injections of sodium amytal, the standard technique for pre-operatively determining the location of speech function (Branch, Milner and Rasmussen, 1964). During the ipsilateral hemiplegia that follows the injection, subjects were asked to memorize either two pictures or a line from a nursery rhyme. Despite the fact that the injection of sodium amytal was to the same hemisphere as had suffered the lesion, thus leaving active the intact hemisphere, recall was seriously impaired.

The significance of this experiment has in the finding that recognition performance was very high; with completely accurate recognition of the pictures and a 90% successful recognition of the test sentence amongst distractors drawn from the nursery rhymes. Once again there is evidence that without co-operation between the two cerebral hemispheres in terms of a pooling of encoded attributes, recall is reduced. Recognition however is to a certain extent free of the limitations imposed by the lateralization of inputs. It would seem appropriate therefore to characterize the high level of recognition of left ear inputs, as representing the level of retention of verbal inputs rather more accurately than would a simple test of recall.

There is an interesting corollary of the assumption of hemispheric interdependence with regard to the successful recall of verbal inputs. If lateralized inputs access the mnemonic properties of one hemisphere rather more than those of the other, which would seem to be the most useful conceptualization of dichotic listening and shadowing, then we must consider the likelihood that the right ear advantage represents not the superiority of recall due to the left hemisphere dominance for processing verbal stimuli, but rather a relatively smaller decrement as a result of a reduced right hemisphere contribution to recall performance. Similarly in the reverse situation the level of recall from left ear presentations must reflect the reduction in performance caused by the absence of the left hemsipheres' contribution to the efficiency of recall.

One simple test of this model is, of course, the comparison carried out in experiments II and III between right and left ears (shadowed) and the result of a monophonic list which was also shadowed. It is clear from the graphs of these functions (Figs. 5.4, 5.9) that monophonically presented items are recalled more effectively at early serial positions, where mnemonic factors are known to influence recall, but not at the recency portion of the list.

The evidence would suggest, therefore, that lateralizing inputs actually reduces the level of recall, primarily at early list positions, and rather more for left than right ear presentations. This is, of course, entirely in keeping with the model of the R.E.A. proposed above. This conceptualization has a number of ramifications for theories of laterality effects.

Structural models explain the R.E.A. as reflecting the advantages of the most direct pathway to the dominant hemisphere for speech. As the reduction in recall performance caused by directing inputs primarily to the right ear is less than in the reverse situation, it is perhaps accurate to characterize the left hemisphere as the dominant hemisphere for speech. However the present model would suggest that the R.E.A. occurs only in so far as both left and right hemispheres process speech inputs. For it is only when both hemispheres are occupied, that the mnemonic superiority of the left hemisphere can be independently expressed. Similarly it is because both hemispheres can process speech and that they carry out this task differently, that any R.E.A. occurs at all.

In effect then the structural model of laterality effects must be updated to accommodate recent evidence of a right hemisphere capacity for representing linguistic information (Zaidel, 1976, 1978). To a certain extent the concept of 'functional cerebral distance' proposed by Kinsbourne and Hicks (1979) represents the degree to which attentional models already meet this requirement. Furthermore the direct access model, or structural interpretation of laterality effects (Kimura, 1976) must also be adapted in order to explain the results of dual-task situations (Hellige, Cox and Litvac 1979; Moscovitch and Klein, 1980).

The concept of functional cerebral distance affords an explanation of data arising from dual-task studies. Where a task is directed to the hemisphere which is not specialized for a particular task, then the functional distance between the area carrying out the primary and secondary task will be reduced. More 'space' will be required to carry out, inefficiently, the task lateralized to the inappropriate hemisphere. This model does not contradict or even overlap with the explanation of the R.E.A. given above, there is, however, a point at which they can be integrated.

The concept of an area of uncommitted functional cerebral space which separates processing areas and is progressively taken up by any particular task is central to the theory proposed by Kinsbourne and Hicks (1979). A model based upon mutual interdependence at least for mnemonic efficiency does not require such a characteristic of the brain. Instead the representation of language in the cerebral hemispheres can be considered as a coupled system which can be broken down, progressively into two loosely independent or decoupled systems with different linguistic properties.

In the case described by Milner (1978) we can observe the consequences of completely decoupling the system, only the most concrete prompting, that is recognition, will promote the acknowledgement of previously memorized items. The decoupling in the present experiments occurs when the left hemisphere is fully occupied by the addition of the secondary task, shadowing. A requirement similar to that employed in other recent studies which have revealed inadequacies in both the attentional (Kinsbourne, 1975) and direct access models (Kimura, 1967).

Decoupling can be brought about by fully occupying one channel and thereby causing both channels to operate independently rather than as an integrated unit. This would seem to be the most economical model of laterality effects as far as verbal stimuli are concerned. For example rather than relying on the occlusion of ipsilateral fibres and the larger number of contralateral fibres (Kimura, 1967) for the superiority of the contralateral transfer of information in dichotic listening. Both of which assumptions have been subject to much criticism (c.f. Chapter II). The present model of a flexibly coupled complementary system for representing linguistic stimuli actually requires both ipsilateral and contralateral transfer of information for the existence of laterality effects. It is suggested that the normal functioning of such a system is based upon the comparison and integration of the information processed at the left and right hemispheres. Decoupling is argued to occur under the circumstances described above, which means that in order to explain lateralization it is only required to postulate that one hemisphere is fully occupied; there is no requirement to invoke special mechanisms to explain laterality effects.

This theory is clearly in a good position to explain the host of studies which have demonstrated laterality effects without the use of lateralized stimuli (Bakker, 1969, 1970; Frankfurter and Honeck, 1973; Cohen and Martin, 1975; Murray and Richards, 1978). Essentially the model predicts localization patterns as a function of concurrent activity not as a direct result of the ear to which items are presented.

There is one prediction which an hypothesis based upon a flexibly coupled language processing system generates which distinguishes between the coupled processor(s) model and the functional cerebral space conception. Kinsbourne and Hicks (1979) viewed their model as an explanation of interference effects, a large number of which have arisen in dual task studies (e:g. Moscovitch and Klein 1980). A coupling hypothesis can accommodate such effects if it is argued that they represent the relative success with which any two tasks de-couple the integrated system, by efficiently occupying available processing capacity.

The model proposed by Kinsbourne and Hicks (1979) and indeed direct access models (Kimura, 1967) do not however predict the superiority of recognition over recall as reported by Milner, (1978) Joccarino (1978) and partially confirmed in the present study (note the high level of recognition of left ear inputs in experiemnt VI as compared with recall performance in experiment II). The coupled linguistic system can however accommodate the superiority of recognition over recall. First because it is proposed that there are two independent representations of the same stimuli, thus enhancing the chances that sufficient information will survive for recall to occur. Second, and perhaps just as importantly,there is the opportunity to carry out comparisons, in effect on internalized recognition test, the information concerning a given stimulus as represented in the right hemisphere can be compared with the representation of the same stimulus, but consisting of different attributes at the left hemisphere. It is this matching process which presumably lies at the heart of the superior mnemonic performance of the integrated system, that is under normal listening conditions.

Up until now only indirect references have been made to the question of hemispheric differences in performances. It has been an assumption of this thesis that laterality effects are the expression of such differences as they interact with the current demands made upon the subject. There is little therefore that experiments of the kind reported here can add to our knowledge of basic differences in the capacities of cerebral hemispheres.

One result however indicates the relationship between the strategic response to the demands of a task and hemispheric differences. Experiment III highlighted the difference in the recall of an items serial position when this was an overt rather than an implicit feature of task demands. The significant superiority of the spontaneous level of right over left ear recall items in their correct serial position occurred only when subjects were instructed to use free recall. The accuracy of fine temporal discriminations, which it has been argued underlies this superior sequencing capacity (Bosshardt and Hörmann, 1975) has been shown to be located in the left hemisphere (Efron, 1973 a; Albert, 1972). This facility in temporal discrimination and sequencing (Hécean and Albert, 1978) has been linked to the superior verbal capacities of the left hemisphere (Teuber, 1969) and so represents a major difference, in terms of hemispheric specialization rather than laterality effects, between the right and left hemispheres.

It is interesting to note that such a powerful expression of hemispheric differences, can disappear in terms of any lateral difference in performance simply as the result of focussing attention upon that characteristic. When the subjects were required to recall items in the same order as they were presented no overall difference between the ears was found (experiment II), nor indeed was there any effect of ear of arrival when free recall was required, only when these protocols were rescored for ordered recall was a significant overall effect of ear of arrival apparent (experiment III). Thus it is only when there is an opportunity for the spontaneous expression of lateral differences and attentional compensation is not a feature of the task, that the decoupled contributions of right and left hemispheres to memory become explicit.

One further conclusion can be drawn which implies that in some ways, previous interpretations of the consequences of the left hemisphere's superiority in sequencing may be inappropriate. A comparison of results from experiments II and III forces the conclusion that the ordering of dichotic inputs is or rather can be independent of the ability to represent language alone. For instance there is no interaction with serial position whatsoever, in the overall superiority of right over left ear spontaneous recall of serial position and there is no difference between the ear input channels in their ability to meet the overt requirements of the task (i.e. free recall).

It would seem therefore that the sequencing function is relatively independent of linguistic capacity and not an underlying cause of the left hemisphere's superiority in this respect as has been proposed (Teuber, 1969; Bosshardt and Hörmann, 1975).

Temporal sequencing would seem to be a further example of a critical sub-process which although highly lateralized, can be manipulated independently of the higher function, speech towards which it contributes. Furthermore, this function need not exhibit consistent laterality effects, due to susceptibility to changes in other factors such as the focus of attention. This example serves to underline the importance of describing the consequences of behaviour such as language in its many forms, not as a unitary function but as a complex integration of sub-processes which can have a separate existence in temporal, neurophysiological and logical terms both from one another and the behaviour such as language, which is ultimately being studied.

Finally some statement concerning the possible source of laterality effects in selective attention experiments should be made. It can be argued that laterality effects arise not because a specific technique allows the experimenter to assess the independent functions of specialized cerebral hemispheres. But rather that certain combinations of functional requirements which can occur both within the laboratory and in the world at large, provoke the break-down or de-coupling of a highly integrated system. It would seem therefore that dichotic shadowing is a technique which provides an opportunity for examining the dissassemblled system.

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Appendix A: Experimental Materials

I Practice Lists

Channel One	Channel Two	Channel One	Channel Two
1) PLATE	TOM	1) CAUGHT	ROW
2) BUY	MAD	2) TONE	FEED
3) STUFF	HORN	3) SINK	BONE
4) TEND	BEEN	4) WHEEL	PIE
5) FUR	SELF	5) COIN	AIM
6) TWICE	JANE	6) RAIL	WOLF
7) DECK	PAN	7) DEED	BAKE
8) SAKE	CAST	8) LAD	VAIN
9) URGE	SAD	9) LOCK	STIR
10) BOND	HIT	10) NAIL	JIM

1) FLEET	COURT	1) DINE	TERM
2) LAND	JUMP	2) GAP	WAGE
3) MARK	GAZE	3) WORST	PRAY
4) TEST	SILK	4) HATE	GLOW
5) JACK	GUN	5) SLEPT	BOW
6) DESK	LOG	6) PARK	WORN
7) SAINT	GRAND	7) BOG	SPITE
8) CARD	SHAME	8) PINK	GOAT
9) EARN	TIP	9) MASS	ROAM
10) FOUGHT	CROP	10) POLE	GAY

	Channel One	Channel Two		Channel One	Channel Two
1)	AUNT	BY	1)	COAST	FOUR
2)	POUR	SPENT	2)	DICK	KEY
3)	TASK	SILK	3)	FIX	KNEW
4)	WEALTH	PACE	4)	CRIME	FLESH
5)	SALE	GREEK	5)	SUM	TRACE
6)	BOWL	LEAP	6)	BOIL	SHEEP
7)	DUTCH	FORE	7)	NO	THROWN
8)	WOKE	DEBT	8)	CLOTH	BREAD
9)	NEW	WHEAT	9)	TRICK	WHOLE
10)	MAIN	BOUGHT	10)	GLANCE	FLEW

1)	RODE	DAN	1)	SHELL	BARK
2)	WOULD	CHARM	2)	WOOD	BRUSH
3)	STEAM	PRIDE	3)	SMART	GRAIN
4)	DREW	OWE	4)	HAS	SENT
5)	STOOD	RENT	5)	OR	MUCH
6)	LIE	GROWN	6)	SONG	MEAT
7)	SOME	FOR	7)	YOU	HOLE
8)	EAT	TOO	()	GAVE	RED
9)	NOD	SOON	9)	HOLD	NOR
10)	DISH	HIGH	10)	THEIR	HIM

	Channel One	Channel Two		Channel One	Channel Two
1)	SHOT	EASE	1)	PLAIN	WEIGHT
2)	WAIT	BARE	2)	STAMP	BLAME
3)	FLOUR	SLIGHT	3)	TAX	FLOOD
4)	HIDE	PACK	4)	BIRTH	THEY
5)	IF	RAVE	5)	WHERE	DINE
6)	TURN	FOUR	6)	TUNE	FUN
7)	SOME	MILE	7)	HOW	AID
8)	NOW	STARE	8)	PULL	THERE
9)	TWO	NOR	9)	LOOK	ON
10)	HORSE	JOHN	10)	FARE	LED

1)	THROAT	CALM	1)	STYLE	CHAIN
2)	CAP	SEEN	2)	DEATH	BOOK
3)	AN	KNIGHT	3)	GIVE	DOUBT
4)	CLUB	CLOTHE	4)	THREW	AN
5)	HAD	FINE	5)	HAIR	MIND
6)	THROUGH	GIVE	6)	PINE	GOES
7)	OUT	FAITH	7)	DASH	MERE
8)	STETCH	STRIP	8)	NOISE	BURST
9)	PRIZE	BRAVE	9)	WOUND	HUNT
10)	MEANT	LOOSE	10)	SKY	OLD

Channel One		Channel Two	Channel One		Channel Two
1)	DRAG	CELL	1)	TEAM	BORE
2)	BREATHE	LEAD	2)	SPORT	THROUGH
3)	FINE	WRITE	3)	SCENE	EACH
4)	BRANCH	CLOTHES	4)	CLUB	HAD
5)	FROM	DOUBT	5)	BLUE	FROM
6)	IT	ONCE	6)	TWELVE	BOUND
7)	FAULT	PURE	7)	STRUCK	BAR
8)	SMELL	CHEAP	8)	NOON	WEIGH
9)	BREAST	FLASH	9)	TALE	BEACH
10)	HEAD	SMITH	10)	EAT	OLD

1)	CARE	FEEL	1)	CHAIN	DREAM
2)	OF	GAVE	2)	FIVE	HEAD
3)	HALF	HE	3)	LEAVE	LIFT
4)	IS	RED	4)	CALL	MAY
5)	MOST	SAME	5)	LAST	NEW
6)	FIRE	DRIVE	6)	CLIMB	TALL
7)	MISS	CAN'T	7)	CHIEF	DROP
8)	LAW	STREET	8)	MIGHT	PART
9)	FLEW	WHICH	9)	CLOCK	NAME
10)	CLOTH	TOWN	10)	SHORT	FIRST

Experiment I

List One

Channel one		Channel two
1)	HAVE	SPRING
2)	ROUND	TRIED
3)	SHOULD	TOOK
4)	AIR	NOTE
5)	FARM	HAND
6)	BLOW	POUND
7)	TIME	SAIL
8)	HOPE	LIP
9)	PAID	LIFE
10)	OLD	BUILT

List Two

Channel one		Channel two
1)	TIME	PUT
2)	MILK	RUSH
3)	TRADE	SAY
4)	SPEND	SAFE
5)	WILL	PAGE
6)	DRY	CAN
7)	LAUGH	STAR
8)	DARE	HOUSE
9)	BUILD	TEN
10)	UNCLE	SAW

List Three

Channel one		Channel Two
1)	PAGE	MUST
2)	SPOKE	REACH
3)	TILL	LAW
4)	BAY	JOY
5)	COST	LEARN
6)	NICE	SUCH
7)	MANE	NEST
8)	SIT	FRESH
9)	AGE	PLACE
10)	BAG	COOL

List Four

Channel one		Channel two
1)	SIX	WISE
2)	HELD	WAY
3)	HELD	GUESS
4)	RING	DROP
5)	LED	BRIGHT
6)	AIL	CHAIR
7)	INCH	NEED
8)	MARCH	SEEK
9)	SINCE	MOUNT
10)	EGG	FORCE

Each list of ten pairs has a target pair of one type at positions 3 and 9, giving a 12 item dichotic tape. Twelve sets of four lists were created by allocating all 12 sets of two targets, for each typed target, to the four basic lists in a random fashion.

Synonyms

1)	HURT	HARM
	BIG	LARGE
2)	SHAPE	FORM
	HER	SHE
3)	KEEP	SAVE
	LEAVE	PART
4)	MAY	MIGHT
	CLOSE	NEAR
5)	GET	GAIN
	GO	MOVE
6)	CALL	NAME
	LOVE	CRUSH
7)	GUIDE	LEAD
	HEAD	CHIEF
8)	FULL	WHOLE
	ACT	PLAY
9)	BUILT	MADE
	GROUP	SET
10)	HARD	FIRM
	CLIMB	MOUNT
11)	BACK	REAR
	SONG	TUNE
12)	STOP	HALT
	EAT	DINE

Antonyms

1)	LEAVE	TAKE
	FRONT	BACK
2)	GIRL	BOY
	DOWN	UP
3)	SMALL	LARGE
	RIGHT	WRONG
4)	FOUND	LOST
	COLD	HOT
5)	DAY	NIGHT
	WORK	PLAY
6)	LONG	SHORT
	NO	YES
7)	YOUNG	OLD
	GOOD	BAD
8)	BLACK	WHITE
	FAR	NEAR
9)	HARD	SOFT
	DO	DON'T
10)	LOSE	GAIN
	SAVE	SPEND
11)	LIFT	DROP
	SHORT	TALL
12)	FIRST	LAST
	WORK	PLAY

Unrelated

1)	MIGHT	CHURCH
	FEAR	LEG
2)	TREE	WAR
	THIS	DEAD
3)	PRESS	MAY
	BEAT	WENT
4)	PEST	ME
	LET	PRINCE
5)	EARTH	LEAST
	COOK	SENSE
6)	WENT	BEAT
	NORTH	WATCH
7)	PAIN	SPOKE
	ARM	FOOD
8)	HOME	MARK
	SHIP	MUST
9)	CROSS	WALL
	BORN	EDGE
10)	HAT	STREAM
	BALL	LIP
11)	POINT	WALK
	DATE	YARD
12)	SHORT	BLOCK
	BARE	EASE

Homophones

1)	BYE	BUY
	COURT	CAUGHT
2)	FOUR	FORE
	KNEW	NEW
3)	KNOW	NO
	WHOLE	HOLE
4)	WOULD	WOOD
	WAIT	WEIGHT
5)	RIGHT	WRITE
	SCENE	SEEN
6)	SON	SUN
	THEIR	THERE
7)	TWO	TOO
	MEET	MEAT
8)	LEAD	LED
	NIGHT	KNIGHT
9)	BEAR	BARE
	PIECE	PEACE
10)	CENT	SENT
	FOR	FOUR
11)	ONE	WON
	SEE	SEA
12)	BLUE	BLEW
	THROUGH	THREW

Experiments II, III and V

Semantically similar lists.

Channel one		Channel two	Channel one		Channel two
1)	HIGH	PIPE	2)	STAND	YARD
	TALL	THROW		FIX	BOARD
	GREAT	FALSE		STOP	SOURCE
	LONG	BLOCK		HALT	WALK
	BIG	ONE		STAY	POINT
3)	HURT	SPEED	4)	TASTE	WEIGH
	WOUND	NURSE		FEEL	NOON
	PAIN	LIST		TOUGH	HUNG
	HARM	CROWN		SMELL	WENT
	KILL	HEEL		HEAR	BREAD
5)	SEE	JUNE			
	LOOK	THROW			
	STARE	FALSE			
	GLANCE	BLOCK			
	VIEW	WON			

Accoustically similar lists

	Channel one	Channel two		Channel one	Channel two
1)	BAD	SMITH	2)	MAY	BLAME
	HAD	DEAD		SAY	CHARM
	LAD	SLIP		RAY	BARE
	MAD	GREET		PAY	STAMP
	SAD	KNOW		DAY	BLACK
3)	PAIN	CHURCH	4)	POOR	CRIME
	SAME	IN		SAW	BEST
	FAME	LIVE		WAR	SOME
	TAME	MIGHT		LAW	GREAT
	RAIN	BAR		DOOR	WORK
5)	CAT	GUARD			
	MAN	HOW			
	CAP	FUN			
	CAN	NOW			
	CAD	PLAY			

Unrelated Lists

	Channel one	Channel two		Channel one	Channel two
1)	EDGE	PEST	2)	FOLD	BROOK
	TRIAL	BRING		SHIP	LET
	CROSS	PORCH		LEAST	EASE
	HELD	SENSE		FILL	HOME
	WALL	MILL		COOL	KING
3)	LIVE	WATCH	4)	NEST	OUGHT
	BORE	BARK		HIS	DRESS
	FALSE	FRIEND		MAN	GREW
	THROW	STAGE		LOSS	HERE
	SHORT	MUST		QUIET	MAKE
5)	SKIRT	JUNE			
	TROOP	OLD			
	BROWN	SKY			
	CHANGE	BEACH			
	FLOWER	PRIDE			

Experiment IV

Semantically related lists

1)	TOUGH	BLOOD	BIG	EGGS
2)	FEEL	LIP	GREAT	FISH
3)	SEE	ARM	LONG	CREAM
4)	VIEW	FOOT	WIDE	FRUIT
5)	SMELL	BRAIN	LARGE	MEAT
6)	SCENT	SKIN	DEEP	GRAIN
7)	HEAR	BREAST	TALL	MILK
8)	SENSE	TEETH	HIGH	BREAD
9)	TASTE	HAIR	BROAD	DRINK

Phonemically related lists

1)	WAR	BAD	MAY	GAME
2)	SAW	SAD	SAY	LAME
3)	LAW	LAD	RAY	PAIN
4)	DOOR	HAD	PAY	NAME
5)	FOUR	FAD	WAY	FAME
6)	JAW	DAD	DAY	MAIN
7)	POOR	MAD	LAY	TAME
8)	NOR	LAD	BAY	RAIN
9)	RAW	PAD	GAY	SAME

Unrelated

1)	DOES	BROOK	AT	ATE
2)	GIRL	LET	BOY	CHAIR
3)	SIT	DAN	FRENCH	SWORD
4)	NEST	EASE	OUGHT	HEIGHT
5)	HIS	BLAME	DRESS	ROPE
6)	MAN	CHARM	GREW	OAK
7)	LOST	BARE	HEAR	PLAY
8)	QUITE	STAMP	MAKE	BILL
9)	SUCH	BLACK	SO	LED

Experiment VI

List I

Channel One Words	Distractor Items: Semantic	Phonemic	Unrelated
a) NEAR	CLOSE	HEAR	THIN
b) HARM	HURT	FARM	JOY
c) GET	GAIN	LET	STONE
d) FULL	WHOLE	PULL	PICK
e) TALL	HIGH	WALL	THREE

Channel Two Words	Semantic	Phonemic	Unrelated
a) FIRM	HARD	TERM	WHITE
b) CLIMB	MOUNT	TIME	BOTH
c) PART	LEAVE	HEART	FROM
d) NAME	CALL	SAME	DOWN
e) STOP	HALT	CROP	COST

List One

Channel One	Channel Two
NEAR	CLIMB
HARM	FIRM
GET	PART
FULL	NAME
TALL	STOP

Experiment VI

List 2

Channel One Words / **Distractor Items**

		Semantic	Phonemic	Unrelated
a)	MADE	BUILT	PAID	LOAD
b)	GO	MOVE	LOW	SKY
c)	SET	GROUP	WET	DASH
d)	HEAD	CHIEF	BED	CHAIN
e)	MAY	MIGHT	SAY	DOUBT

Channel Two Words

		Semantic	Phonemic	Unrelated
a)	SHE	HER	WE	SPORT
b)	WRONG	BAD	LONG	CAP
c)	LEAD	GUIDE	NEED	PINE
d)	REAR	BACK	FEAR	OLD
e)	SAVE	KEEP	WAVE	GOES

List Two

Channel One	Channel Two
MADE	SHE
GO	WRONG
SET	LEAD
HEAD	REAR
MAY	SAVE

Experiment VI

List 3

Channel One Words

		Distractor Items		
		Semantic	Phonemic	Unrelated
a)	PLAY	ACT	WAY	BAR
b)	SCENT	SMELL	WENT	NOON
c)	FULL	WHOLE	PULL	BLUE
d)	TUNE	SONG	ROOM	SPORT
e)	DINE	EAT	FINE	BRANCH

Channel Two Words

		Semantic	Phonemic	Unrelated
a)	RIGHT	GOOD	LIGHT	FLASH
b)	CRUSH	LOVE	BRUSH	TAIL
c)	FORM	SHAPE	WARM	BORE
d)	REAR	BACK	FEAR	WEIGHT
e)	WIDE	BROAD	PRIDE	WELVE

List Three

Channel One	Channel Two
PLAY	RIGHT
SCENT	CRUSH
FULL	FORM
TUNE	REAR
DINE	WIDE

Appendix B: Handedness Inventory

Name ....

Age .... Sex ....

Have you ever had any tendency to left-handedness? ....

Please indicate your preference in the use of hands in the following activities by putting + in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put ++. If in any case you are really indifferent put + in both columns.

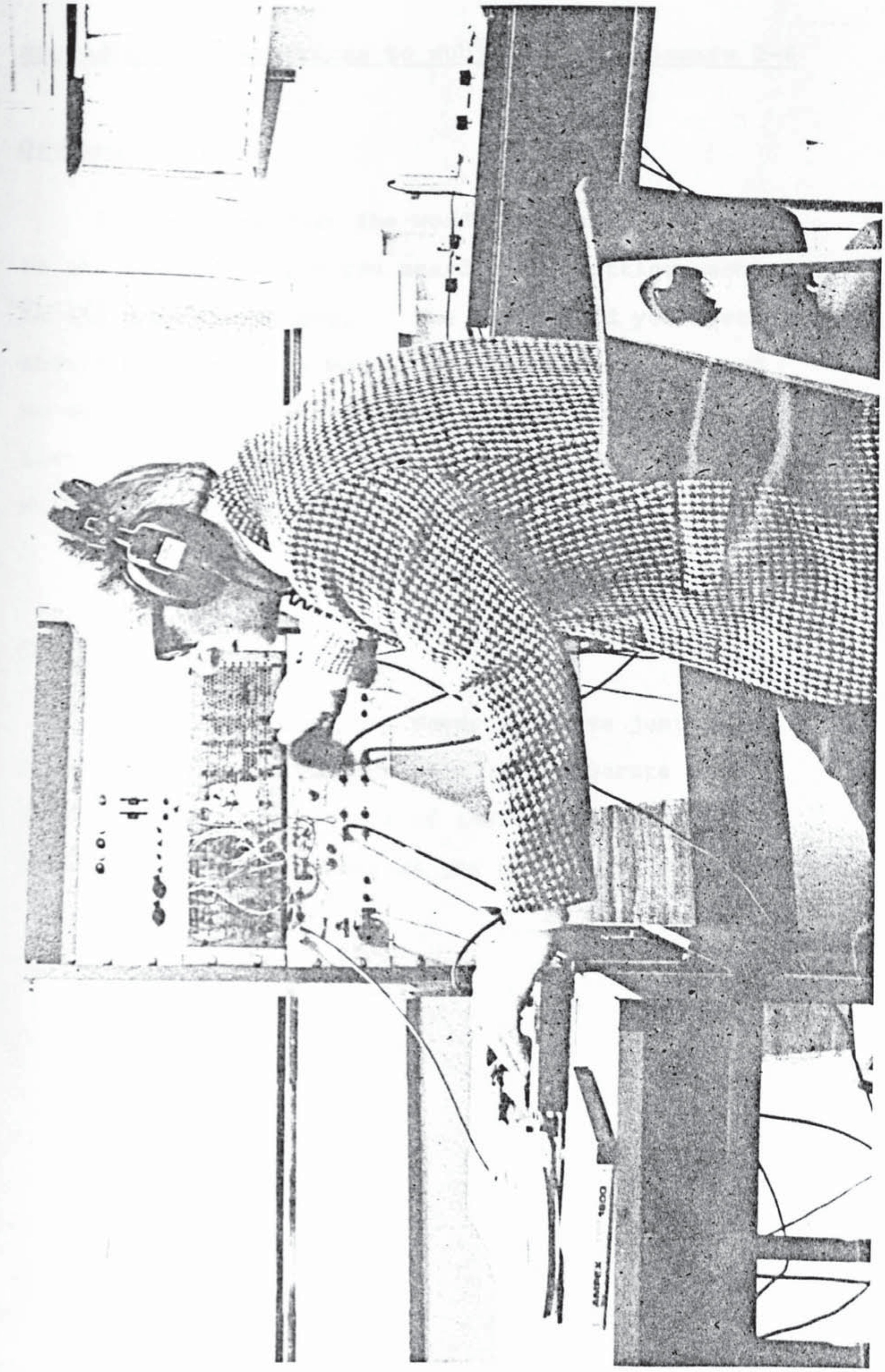
Some of the activities require both hands. In these cases the part of the task or object for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave blanks if you have no experience at all of the object or task. The tasks and objects are listed on the reverse of this sheet.

PLEASE TURN OVER ....

		LEFT	RIGHT
1.	Writing	....	....
2.	Drawing	....	....
3.	Throwing	....	....
4.	Scissors	....	....
5.	Comb	....	....
6.	Toothbrush	....	....
7.	Knife (without fork)	....	....
8.	Spoon	....	....
9.	Hammer	....	....
10	Screwdriver	....	....
11.	Tennis racket	....	....
12.	Knife (with fork)	....	....
13.	Broom (upper hand)	....	....
14.	Rake (upper hand)	....	....
15.	Striking match (match)	....	....
16.	Opening box (lid)	....	....
17.	Dealing cards (card being dealt)	....	....
18.	Threading needle ('moving' part)	....	....

Appendix C: The DITMA Experiment



Appendix D: Instructions to subjects, Experiments 2-6

Ordered recall

Please write down the words you have just heard in the order in which you heard them, putting each word in its appropriate box. The first word you heard should be written in box 1, the second in box 2 and so on. If you can remember hearing a word in the list, but not where it came, then make as good a guess as you can. Any questions?

Free recall

Please write down the words you have just heard in any order, putting each word in a separate box. If you cannot remember all of the words in the list, then make as good a guess as you can.