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ATTENTIONAL STRATEGIES AND PROCESSING
CAPACITY IN DICHOTIC LISTENING.

CITY UNIVERSITY OF NEW YORK, PH.D., 1978

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1978

ATTENTIONAL STRATEGIES AND PROCESSING CAPACITY
IN DICHOTIC LISTENING

by

JACK BOOKBINDER

A dissertation submitted to the Graduate Faculty
in Psychology in partial fulfillment of the
requirements for the degree of Doctor of
Philosophy, The City University of New York.

1978

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

ATTENTIONAL STRATEGIES AND PROCESSING CAPACITY
IN DICHOTIC LISTENING

by

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A person can attend to a verbal message in one ear while seemingly ignoring a second, simultaneously presented verbal message in the other ear. There is considerable controversy over the extent to which the unattended message is actually processed. A currently popular view is that simple perceptual processes occur in both inputs automatically without consuming any processing capacity. According to this view, the appropriate message is selected for attention only during later stages of cognitive processing. Proponents of the contrasting early-selection view maintain that few processes, if any, are resistant to attentional manipulations. Thus, according to this latter view, attention to one message can result in considerable impoverishment in the processing of the other message when there is a strain on the supply of processing capacity.

The increasing acceptance of the automatic processing view has been due in part to procedural faults in those dichotic listening experiments which seemed to provide evidence for early-selection. Criticism has centered on

inherent peculiarities of the popular shadowing task in which the listener must repeat one of the messages as it is presented. The purpose of the present experiments was to test for confirmation of the earlier conclusions in a non-shadowing task and to clarify the dependence of the results on available processing capacity.

In Experiment I, the subjects listened to dichotic messages consisting of 20 paired (simultaneous) single-syllable words. The message in the primary ear always contained 6 randomly placed color words; the message in the secondary ear never contained any color words. The main task was to press a button upon hearing each color word. In addition, the subject was to detect a non-color target word which was designated at the beginning of each trial and could appear in either ear. Except for the main task, Experiment II was identical. The main task was to press a button following every third word pair and thus did not require a semantic analysis of either message.

Approximately 80% of the target words were detected in either ear in Experiment II and in the primary ear in Experiment I. Less than 40% of the target words in the secondary ear in Experiment I were detected. While detection performance in the primary ear was independent of main task performance, there was a significant negative correlation between main task performance and secondary ear detection performance in Experiment I.

The same messages were used in Experiment III. Detection of a pre-designated target word was now the primary task. In the Pre-knowledge (focused) condition, the subject knew the target ear in advance. In the No-knowledge (divided) condition, the target could appear on either ear. The difference in processing capacity required was measured by the differences in rate of performance on a secondary task. The secondary task was the simultaneous performance of a simple written numerical exercise.

Target detection performance in Experiment III was almost perfect in the focused condition and significantly better than it was in the divided condition. While several subjects did perform the secondary task at a faster rate in the focused condition, the secondary task rates were similar for most subjects for the two conditions. In any case, the target detection task was performed more effectively and efficiently in the focused condition.

The entire pattern of results of the three experiments seems consistent with limited capacity models of attention which do not assume automatic processing. In addition, the existing evidence for automatic processing in dichotic listening is reviewed in detail and found to be inadequate.

ACKNOWLEDGEMENTS

I thank Professor Eli Osman for serving as my dissertation adviser and for inviting me to work in his laboratory early in my graduate school training.

I also thank Professors Eric Heinemann and Shel Feldman, members of the dissertation committee, for their helpful comments and for the time they contributed.

Sincere appreciation is expressed to the members of my family and to all of my friends for their patience and endurance; their encouragement has been invaluable.

This work was supported by grants (to Dr. Osman) from the U. S. Department of Health, Education, and Welfare (Public Health Service) and by Brooklyn College, City University of New York.

This dissertation is
dedicated to my parents,
Bernice and Selig.

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Chapter I

BACKGROUND

The dichotic listening paradigm, beginning with the experiments of Cherry (1953) and Broadbent (1958), has played a central role in the study of attention during the past two decades. In a dichotic presentation, different auditory messages are simultaneously presented to the subject's right and left ears by means of stereo headphones. These messages have ranged from tone bursts to sequences of letters of the alphabet to prose taken from familiar novels. In the contrasting conditions of divided and focused attention (Treisman, 1969), subjects must either attend to the messages in both ears or to only one of the messages. The results of such experiments are quite controversial. Posner and Snyder (1975a), for example, in developing the concept of automatic memory activation, cite certain dichotic listening studies as suggesting that very complicated processing occurs in the unattended ear in focused attention. Shaffer (1975, p. 161), on the other hand, states: "The more pessimistic views on the limits of human attention have derived support largely from the failure of subjects to handle simultaneous auditory messages." Such disparity accentuates the need for a thorough understanding of the attentional strategies available to subjects engaged in

various types of dichotic listening tasks. There is no reason why the performance of subjects attempting different kinds of tasks need converge in any simple way on a unitary concept of attention (Spelke, Hirst, & Neisser, 1976).

A central theme of Neisser's (1976) recent book provides a strong rationale for the use of dichotic listening in the study of attention. He argues that theories should say something about what real people do in real situations; they should have "ecological validity." In a highly critical discussion of contemporary visual research, Neisser notes that a typical tachistoscopic display comes close to not existing at all so that it is almost as if "ecological invalidity" was deliberately incorporated in the experimental design. In his view, tachistoscopic experiments do not tap normal perceptual skills and the term perception should not be applied to anything that occurs in them. In sharp contrast, Neisser applauds the technique of shadowing in dichotic listening. This procedure requires a subject to repeat back word for word the contents of a given message; when presented with dichotic messages, the subject is typically asked to shadow the message in one of the ears as a means of 'focusing his attention' on that ear. In the opinion of Neisser (1976, p. 81), shadowing " ... presents the subject with a more or less continuous and meaningful event over a

substantial period of time. It is one of the few experimental procedures that offer information to the perceivers in a natural way and allow the perceptual cycle to run its normal course."

It is obvious that presenting a subject with simultaneous dichotic messages falls short of the requirements for 100% ecological validity. Neisser's (1976) comments, though, are an indication of why the dichotic listening paradigm, especially when combined with shadowing, has maintained its popularity and usefulness in the study of central attentional processes.

Much of the ambiguity in dichotic listening research has been due to the possible role that memory might play in specific experimental tasks. If an experimental task has a memory component, it becomes unclear as to whether any attentional effects should be considered as occurring 'early' as opposed to 'late.' Early-selection models (Broadbent, 1958, 1971; Treisman, 1960, 1964; Treisman & Geffen, 1967) allow for analyses of simple physical features (e.g., spatial location, voice pitch) simultaneously but it is postulated that higher order analysis (i.e., semantic content) of all inputs simultaneously would overload the limited capacity of the perceptual system. For the most part, only the attended message is analyzed beyond the level of simple physical features. Introspective reports are generally consistent

with an early-selection approach. In commenting on the difficulty of shadowing, Norman (1976) suggests that one must try the task in order to appreciate the way it distracts attention from the other material; the impression you receive is that of a limited ability to process the material.

According to early-selection theories, certain attentional effects are truly perceptual in nature occurring prior to and/or independently of higher order cognitive processes. Alternatively, late-selection models (Deutsch & Deutsch, 1963; Norman, 1968, 1969; Shiffrin, 1975, 1976; Posner & Snyder, 1975a, 1975b) attribute all attentional effects to processes that follow full perceptual processing of all incoming stimuli. In the dichotic listening situation, it is assumed that there is an automatic analysis for meaning of all individual verbal items. Attentional mechanisms operating in short-term memory then determine which items (i.e., which ear) are analyzed beyond the level of simple meaning. Using the terminology of Shiffrin and Grantham (1974), "systemic processing" results in a flood of unattenuated sensory information being dumped into short-term memory. It is "cognitive processing" (i.e., control processes such as scanning, rehearsal, coding, and decisions) in short-term memory which makes demands on the limited capacity system. Attentional effects are thus seen to arise only during the

cognitive processing which follows automatic systemic (perceptual) processing.

When subjects are required to shadow the material in one ear, retention of the material presented simultaneously to the nonshadowed (nonattended) ear is poor (e.g., Cherry, 1953; Moray, 1959; Lyons, 1974). This finding can be explained either by assuming early-selection or by assuming late-selection during cognitive processing only. In reviewing the existing literature at the time, Egeth (1967, p. 48) commented: "It is surprising how difficult it is to find a study which actually could measure a perceptual effect uncontaminated by a possible influence of memory."

In recent years, there have been a number of demonstrations of simultaneous semantic processing of dichotically presented messages. This has resulted in the acceptance by many authors of the automatic processing view. The impact of several specific experiments is especially noteworthy. These experiments are worthy of careful scrutiny inasmuch as specific instances of simultaneous processing need not be inconsistent with non-automatic limited capacity models.

Review of the Evidence for Automatic Processing in Dichotic Listening

As noted above, experiments which are designed to directly tap the subject's memory for unattended items are

not likely to be decisive (e.g., Moray, 1959; Norman, 1969; Glucksberg & Cowen, 1970; Katzin, Corballis, & Lockhart, 1972). Performance decrements can usually be attributed either to a perceptual or to a memory deficiency. Several experimenters have taken a rather novel approach. The experimental task requires the subject to attend to only one ear and no responses are ever required to items on the other ear. The degree to which unattended items are processed is indirectly determined. In such situations, evidence for semantic processing of items on the unattended ear is taken as strong support for automatic processing.

Lewis (1970) was one of the first to use the indirect approach. His subjects shadowed a list of words in one ear while a different list of words was simultaneously presented to the other (unattended) ear. In order to prevent switching of attention between the ears, the words were presented at a fast rate (1 word/0.67 sec) and errorless shadowing was required. No subject was able to report any word from the unattended ear while maintaining errorless shadowing. Lewis recorded shadowing latencies; i.e., the time between the presentation of the word to be shadowed and the actual shadowing response. He found that shadowing latencies increased when a synonym of the shadowed word was presented simultaneously on the unattended ear. This suggested to Lewis that the unattended message did enjoy the benefit of full perceptual

(semantic) analysis; selection followed and storage or admission to awareness.

Treisman, Squire, and Green (1974) questioned Lewis' (1970) conclusion. They replicated the synonym effect but found that it only occurred for synonyms occurring early in the list. Furthermore, the data indicated that the early increased reaction time was due to a few very long latencies rather than a small increase on every trial. In discussing their results, Treisman et al. (1974) commented (p. 646): "This experiment again illustrates the difficulty of finding conclusive evidence for (or indeed against) consistent and unimpaired semantic analysis of 'unattended' words." The authors suggested that synonyms were recognized on the unattended ear because they were related to the shadowed word and that the other unattended words were not analyzed. This would be most likely on trials in which the unattended word began slightly ahead of the shadowed word allowing for serial identification of the unattended word prior to the shadowing response. The results of Treisman et al. (1974) were consistent with this hypothesis. Not only was the synonym effect confined to the early portion of the list and limited to a small proportion of the trials, the longer reaction times tended to occur for those synonyms which began prior to the onset of the shadowed word. (The authors reported mean asynchrony to be 40 msec, with a range of -112 to +143.)

Due to the fact that the synonym effect was evident only in the early portion of the list, Treisman et al. (1974) suggested that it might take time for capacity to become fully loaded by the attended message and for efficient focusing to take place. Direct support for this hypothesis comes from a study by Ambler, Fisicaro, and Proctor (1976). Evidence from a variety of experimental tasks has indicated that pupil dilation reflects the momentary mental effort invested in a given task (Kahneman, 1973). Ambler et al. (1976) found pupil dilation to be greater in a shadowing task than in a non-shadowing task in support of the idea that the amount of capacity invested in shadowing is reflected in the pupil dilation measure. Furthermore, they found that pupil size decreased over time as shadowing continued. The authors considered this result to be consistent with the proposal of Treisman et al. (1974) that it takes time for attention to become focused on the relevant message. Effects of the type of material on the unattended ear were also found. Pupil dilation was greater when there were words on the unattended ear than when there was white noise. Furthermore, categorical similarity between the items on the two ears interfered with the ease of focusing on one ear. When subjects had to shadow letters on one ear, pupil size did not decrease with list position when the items on the unattended ear were also letters.

The experiments of Treisman et al. (1974) and Ambler et al. (1976) are important because they cast considerable doubt on the automatic processing interpretation which Lewis (1970) offered for his results. It is not particularly surprising that Ambler et al. (1976) found, at best, only small decreases in pupil size as shadowing continued when there was categorical similarity between the dichotic lists. The authors discussed their results in terms of Kahneman's (1973) notion of spare capacity. When shadowing, subjects do not use all of the available processing capacity. Some of the spare capacity is used when shadowing becomes more difficult due to interference from the unattended message; the result is no increase in shadowing errors but an increase in pupil size. This is consistent with the report of Salter (1973) that his subjects demonstrated considerable success in the simultaneous shadowing of messages in both ears, thus suggesting that there was spare capacity available when only one ear was shadowed.

Mackay (1973) used a procedure which was similar to Lewis (1970) in that no response was required to the unattended message. The subjects shadowed lexically ambiguous sentences in the attended ear. Without the subject's knowledge, a disambiguating word was presented on the unattended ear during the presentation of the sentence. For example, the sentence might be "They threw

stones at the bank" and the corresponding word on the unattended ear would be "river" or "money." Later, a recognition test would be given for the shadowed messages. For the examples cited, the recognition test sentences would be "They threw stones at the side of the river" and "They threw stones at the financial institution." Despite claims by the subjects that they were unaware of the words on the unattended ear, the recognition test results suggested that the word in that ear biased the lexical analysis of the shadowed sentences. Mackay (1973) concluded that unattended words are processed at the meaning level but memory for them decays rapidly. He postulated that attended items are simply processed at deeper levels so that awareness and long-term storage result. This analysis is consistent with the currently popular levels-of-processing approach (Craik & Lockhart, 1972) to memory. Lackner and Garrett (1972) reported findings similar to Mackay (1973).

Experiments such as those of Lewis (1970) and Mackay (1973) were received with enthusiasm by proponents of automatic processing because semantic analysis of the unattended messages was indicated despite the fact that there was no reason for the subjects to 'switch attention' to the unattended ear. Posner and Snyder (1975a) cite these experiments in the context of discussing evidence for automatic activation of memory pathways. They note,

though, a degree of circularity (p. 60): "In these experiments there is a semantic relationship between the attended and unattended items; thus, the effect could depend upon having an already activated locus in memory related to the unattended item." This is similar to the remark of Treisman et al. (1974) that the synonym effect of Lewis (1970) might have occurred because the critical words were synonyms and not because all unattended words were analyzed for meaning.

Of particular interest are several experiments which have measured galvanic skin responses (GSR) to critical events on the unattended ear. As Posner and Snyder (1975a) note, these experiments have eliminated the problem of relatedness discussed above. Corteen and Wood (1972) presented their subjects with a tape-recorded list of 12 words which was repeated three consecutive times. Three of the words were city names and the rest were common nouns. The subject received a mild electric shock upon each presentation of a city name. In Part II, the subjects shadowed a prose message in one ear while a list of words was simultaneously presented to the other ear. The unattended word list was played at the rate of 1.6 words/sec and contained 480 words. Twelve of these words were critical: 6 words from Part I including the 3 shock-associated city names and 3 non-city names, and 6 new words including 3 city names and 3 non-city names. GSR

measurements were taken as the subject shadowed the message in the attended ear. Significant GSR changes were recorded 33.7% of the time in response to the original shock-associated city names and 22.8% for the new city names. This compared to 12.3% for Part I non-city names and 8.7% for new non-city names. Post-experimental questioning indicated that the subjects were not aware of having heard any of the critical words.

The findings of Corteen and Wood (1972) were quite important since they were consistent with the somewhat intangible concept of semantic processing without awareness. In discussing the experiment, Corteen and Dunn (1974, p. 1143) commented: "but the study would be quite trivial if it could be demonstrated that Ss were aware even momentarily of the significant words." The subjects could have been aware of the critical words at the time of presentation but forgotten this fact when questioned later. To remedy this situation, Corteen and Dunn (1974) adopted the procedure introduced by Treisman and Riley (1969). During Part II of the experiment, the subject was to immediately stop shadowing and press a buzzer upon detecting any city name; otherwise, the procedure followed that of Corteen and Wood (1972). For all subjects, there were 114 instances of a city name in the unattended message but the buzzer was pressed only once. Aside from this single detection, there were 41 instances of a

significant GSR change, 38 of which were in response to city names. The results were taken as support for the position that semantic processing could occur without conscious awareness. The reader will surely appreciate how crucial are the Corteen and Dunn (1974) results for automatic processing theories.¹

Other experimenters (Moray, 1970; von Wright, Anderson, & Stenman, 1975) have also reported GSR changes in response to critical items on the unattended ear. The GSR findings have important implications for all aspects of perceptual and cognitive functioning. In particular, the relevance to such controversial topics as subliminal perception and perceptual defense is obvious (see Erdelyi, 1974). Recently, however, the GSR findings have come under attack. Bowers and Brenneman (1974) attempted an exact replication of the Corteen and Wood (1972) experiment. The original findings were not replicated. In fact, the response rate to previously shocked city names was less than to any other class of critical words and this was true

¹There is one rather disturbing aspect of the Corteen and Dunn (1974) results. The extremely low detection rate (1 out of 114) is quite atypical for detection of verbal targets in the nonshadowed message. The subjects of Treisman and Geffen (1967) also shadowed prose and were required to make detection responses on a continual basis. They detected 8% of the nonshadowed targets. While shadowing prose, Sullivan's (1976) subjects detected just under 50% of the nonshadowed targets. The Treisman and Riley (1969) study is discussed in detail in the next chapter.

for all subjects. The authors report that Corteen indicated to them in a personal communication that he has been unable to replicate the effect after the first two studies (Corteen & Wood, 1972; Corteen & Dunn, 1974).

Another replication of Corteen and Wood (1972) was attempted by Wardlaw and Kroll (1976). The GSR rate for the originally shocked city names (28.7%) was not greater than that for the other nouns (32.9%). The authors report that 83.3% of the subjects said they had expected to hear, and receive shocks following, the original city names during the presentation of the dichotic lists. In contrast to Corteen and Wood (1972), 66.7% of the subjects in Wardlaw and Kroll (1976) heard and remembered words from the unattended ear; 16.7% remembered specific city names.

The failures to replicate the results of GSR dichotic listening experiments are quite important because of the frequency with which such experiments are cited as evidence for automatic processing. The concluding paragraph of Wardlaw and Kroll (1976, p. 360) is pertinent:

It would seem that the semantic processing of words presented in the nonattended message, while subjects shadow the attended message, is more difficult to obtain than one would believe from a cursory reading of the literature. We made every attempt to replicate the experiment by Corteen and Wood but did not obtain any indication of such processing. The experiments by Moray (1970) and von Wright et al. (1975) are provocative but hardly definitive. In fact, we believe that after a careful reading of these two experiments, the reader will be more impressed with the

difficulties involved with this type of research than with the robustness of the effect.

Of relevance also is Neisser's (1976) discussion of experiments which have used indirect measures of the influence of unattended information. Neisser (1976, p. 94) cautions:

In stressing that these findings are difficult to replicate, I do not mean to deny that they are genuine. There is now no doubt that some "naive" subjects pick up the meanings of some "irrelevant" words, at least under some conditions. It has been suggested that this fact invalidates filter theory, and it probably does. We need not conclude, however, that all subjects pick up all meanings of all irrelevant words, and it would be a mistake to theorize about attention as if this had been demonstrated.

It would seem, therefore, that although there has been a growing trend toward acceptance of automatic processing, the evidence favoring this view is not convincing. The present experiments were aimed at testing the automatic processing assumption.

Chapter II
EXPERIMENTS I AND II

A. Introduction

Treisman and Riley (1969) performed an experiment which has stirred considerable controversy. The experiment was performed in response to criticism (Deutsch & Deutsch, 1967; Lindsay, 1967) of an earlier experiment (Treisman & Geffen, 1967) which had produced results consistent with the predictions of early-selection. Treisman and Riley (1969) presented their subjects with computer-synchronized simultaneous dichotic messages consisting of 16 pairs of items at a rate of 1.8 pairs per sec. One pair consisted of a digit on one ear and a letter on the other while both members of the remaining pairs were digits. The primary task was to shadow as accurately as possible the digits on one ear. The secondary task was to stop shadowing immediately and to tap with a ruler upon detection of a letter in either ear; target letters appeared equally often in each ear. The two messages of each dichotic pair were recorded by the same male voice. In one condition, however, the target letter was recorded by a woman and the subject was told before each trial whether the letter would be spoken by the male voice or the female voice.

The important aspect of this experimental design is

that the secondary response (i.e., target detection) is immediate and does not involve memory limitations. In addition, the secondary response is identical regardless of which ear the target appears in. Nonetheless, when the target letter was in the same (male) voice, Treisman and Riley (1969) found that many more targets were detected in the shadowed ear compared to the nonshadowed ear ('corrected' scores of 76.4% and 33.4%, respectively). The authors argued that their results confirmed the hypothesis of a perceptual limit in this type of selective listening task. Detection performance was almost perfect in both ears for the different (voice) targets; this result is consistent with the findings of equal detection performance in the shadowed and nonshadowed ears when the targets are tones and thus are quite distinct from the background message (Lawson, 1966; Zelnicker, Rattock, & Medem, 1974).

Although the main findings of Treisman and Riley (1969) have been confirmed in several related studies (e.g., Treisman & Geffen, 1968; Underwood & Moray, 1971; Underwood, 1974), they have not proved fatal to late-selection automatic processing theories (see Shiffrin, Pisoni, & Castenada-Mendez, 1974; Shiffrin, 1976.) The use of shadowing has been the main source of controversy. Shadowing is a difficult task which does contain a memory component. The average shadowing response lag of 3 items

(1.2 sec) found by Treisman and Geffen (1967) was about the same as the target detection latency. It seems possible, if not likely, that the covert processes (i.e., rehearsal) involved in preparing to shadow the target item might impart a substantial advantage to the detection of targets in the shadowed message even though the detected targets themselves were not shadowed in Treisman and Riley (1969). A further problem in interpreting shadowing experiments arises from the finding (Sullivan, 1976) that detection of word targets in the nonshadowed messages increases with the redundancy (approximation to English) of the shadowed message. Underwood and Moray (1971) questioned the reliability of the shadowing technique because of an interaction involving the sex of the shadower and the sex of the target voice; less targets were detected when the shadower's own voice was similar to the target voice than when it was different.

There is one aspect inherent in shadowing one message in a dichotic presentation which is of particular importance. In order for a subject to shadow one of the two messages, he is forced to distinguish between the two messages. Assuming that the individual items in both inputs do indeed contact their memory representations (Posner & Snyder, 1975a, 1975b), the subject must be sure to shadow the correct one. If memory activation is automatic, there should be considerable opportunity for

the subject to shadow items in the 'wrong' message. In fact, Treisman and Riley (1969) did report a high percentage (14%) of intrusions from the wrong ear and Treisman (1969) has suggested that part of the difficulty in divided attention tasks may be due to the requirement to distinguish between the inputs. It would seem mandatory that the subject develop an active strategy to prevent shadowing of the wrong message. The task of shadowing one of two dichotically presented messages is made more difficult by the assumption of automatic processing of both inputs. The difficulty in shadowing may not arise so much from the act of shadowing itself but from the requirement not to shadow the other message. Salter (1973) required his subjects to shadow one (primary) message and also to repeat as much as possible from the other (secondary) message. The slight performance loss in shadowing the primary message was more than compensated for by the additional words shadowed in the secondary message.

Inasmuch as the requirement to shadow one message seems to demand that the subject 'ignore' the other message, a result other than the one obtained by Treisman and Riley (1969) would be rather surprising regardless of one's theoretical position. The purpose of Experiment I in the present study was to create a situation in which equal target detection performance in both messages of a

dichotic presentation would not at all be unlikely but where failure to obtain such a result would be clearly inconsistent with the concept of automatic processing. The experimental design was similar to that of Treisman and Riley (1969) with the important exception that the main task did not involve shadowing.

Experiment I was designed to ensure that any difference in target detection performance between the two dichotically presented messages could not be attributed to differential memory requirements or the requirement that the two inputs be distinguished (i.e., knowing which message came from which ear). The main task was to immediately press a button upon hearing each of several color words which were interspersed among 20 dichotic word pairs. In addition, the subject was to detect a single pre-designated non-color word on each trial which could appear on either ear. The color words, however, only appeared on one ear (primary ear) and never on the other (secondary) ear. If both inputs are processed automatically, this arrangement should be of little consequence. The subject's knowledge of which ear receives the color words is actually irrelevant to the response requirements of the task. The subject need only press the button whenever he hears a color word. Thus, the subject should do equally well in detecting the non-color target words on both ears.

Experiment II served as a control condition for Experiment I. Except for the nature of the main task, Experiments I and II were identical in every respect. The main task in Experiment II was to press the button after every third word. Although this task is relatively simple, the maintaining of dual-task conditions in both experiments allows for a fairer comparison of the target detection results than had a single-task control been used (see Kantowitz, 1974; Kantowitz & Knight, 1976a).

The dichotic word pairs used in the present study, while approximately simultaneous, were not computer-synchronized. Treisman (Treisman & Riley, 1969; Treisman, 1970) notes that it is difficult for a subject to identify which ear a sound is coming from unless at least part of it coincides with silence on the other ear. With precise synchrony of onset, it is more difficult for subjects to separate the two messages. It was considered important in the present study that the subject hear two clearly distinct messages with as little fusion (Treisman, 1970) of the two messages as possible.

B. Method

Apparatus

The word lists were recorded and played to the subjects on a Sony Model TC-270 tape recorder. The recording of the stimulus tapes as well as the experiments themselves took place in a soundproof chamber. The subjects heard the stimuli over Telephonics TDH-39 headphones. The outputs of the tape recorder were first sent through a Krohn-Hite Model 3202 Filter set to pass frequencies below 6500 Hz. This procedure reduced tape hiss considerably while having little noticeable effect on voice quality. While the subject listened to the word lists, the experimenter monitored the stimulus tape on a second set of headphones. The specific activities of the experimenter were hidden from the subject's view by the tape recorders which stood on the experimenter's table between the subject and the experimenter.

The output of the right channel of the tape recorder was re-recorded on the right channel of another tape on a second tape recorder as each subject listened to the stimulus tape. The output of a Clark-Hess Model 743 Function Generator was also fed into the right channel of the second tape recorder via an open push-button switch. When the subject pressed the button, a tone was recorded. (No tone was heard during the experiment.) A microphone was connected to the left channel of the second tape

recorder. Thus, the second tape recorder was simultaneously recording the verbal contents of the right channel of the stimulus tape, button-pressing responses (tones), and verbal responses of the subject. Upon listening to the 'subject tape' at the end of the experimental session, the experimenter could determine when the subject pressed the button or made a verbal response in relation to the words on the stimulus tape. The experimenter and the apparatus were located on one side of the chamber while the subject sat a few feet away on the other side with the push-button directly in front of him on the table.

Stimuli

All word lists were recorded by the same female voice at the same rate by keeping in rhythm with the clicks of a memory drum. The clicks were previously recorded on tape at the rate of 1 click/0.6 sec and the speaker listened to them on headphones as she recorded each list. The words used were frequent one-syllable words chosen from Kuçera and Francis (1967). No word appeared in more than one list or more than once within the same list. Special color words (red, blue, green, pink, white, black, brown, and gray), however, did appear repeatedly but a given color word did not appear more than once in the same list. These were the only color words present in any of the lists.

Five monaural lists, each consisting of 20 words, were

recorded on the right channel of the tape. Six of the 20 words were color words occurring randomly within the list with the restrictions that no more than two consecutive words were color words and a color word could not occur earlier than position 4 or later than position 18. Each list began with the introductory words "One, Two, Three" which were recorded in rhythm with the 20 words which followed.

Ten dichotic lists were recorded. The right channel list of each dichotic pair was similar to the monaural lists except that different non-color words were used. The left channel list contained 20 non-color words and was not preceded by the words "One, Two, Three." After the right channel list was recorded, the left channel was recorded with each pair of the 20 right-left pairs occurring approximately simultaneously.

There were three main criteria for acceptance of each pair of dichotic lists: (1) each list had to be recorded in an uninflected monotone, (2) the two lists had to be of approximately equal loudness, and (3) the members of each word pair had to begin approximately simultaneously. It was not essential that onset asynchrony be reduced to zero. A word pair was accepted as being simultaneous if there was no obvious onset asynchrony that was readily apparent upon listening to the tape. The asynchrony was measured, however, by feeding the two channels of the tape recorder

into a dual storage oscilloscope and making a direct visual comparison between the onset times of both members of each word pair. The complete word lists with the approximate asynchronies of each word pair are presented in Appendix A.²

The 15 lists (5 monaural and 10 dichotic) were recorded consecutively on the same tape with an interval of about 40 sec between the lists. Before each list was played, one non-color word was designated as a target word. The target word always appeared in the list; in the dichotic lists, the target could appear in either the right or left channel. When it appeared in the left channel it never appeared opposite a color word on the right channel. The target word never occurred earlier than position 4 or later than position 17.

The 15 lists were presented to the subject in consecutive order three times at a comfortable listening level. Each target word was used only once. The targets used during the first (practice) presentation were designated as Set P. The other targets comprised Sets 1

²While these asynchrony measurements are not precise, they do indicate that there was no tendency for one member of the word pairs (right or left channel) to lead the other. It was particularly difficult to determine the exact onset time for words beginning with a "sh" or "s" sound; this difficulty is reflected in the rather large asynchrony estimates given for many pairs containing such a word. While most estimates are accurate to within 5 msec, some of the larger asynchronies may have been over-estimated by as much as 25 msec.

and 2. The targets in these two sets for the dichotic lists had a special relationship. For a given list, the target in Set 2 occurred in the same position as the target in Set 1 but on the opposite channel. In other words, the two targets for a given list were the right and left channel members of one of the 20 simultaneous pairs in the list. Subjects were not informed of this arrangement. During each of the three presentations of the 10 dichotic lists, 5 targets appeared in the right channel and 5 in the left channel. Targets did not appear in the same channel for more than three consecutive lists. The specific target words used are presented in Appendix B; also indicated is the list position and approximate asynchrony for each target word.

Experiment I: Subjects

Sixteen right-handed Brooklyn College students of both sexes took part in the experiment. Eleven undergraduates participated to fulfill the requirements for an introductory psychology course. Two advanced undergraduates and three graduate students volunteered.

Experiment I: Procedure

Inasmuch as the main task was to respond to color words, the right channel lists containing the color words are referred to as primary messages. The left channel lists are referred to as secondary messages. The terms "primary" and "secondary" are used only as a means of

identifying the color and non-color word lists, respectively.

The 16 subjects were divided evenly into two groups. The Right Primary Ear Group heard the monaural lists and the primary messages of the dichotic lists in the right ear and the secondary messages in the left. The headphones were reversed for the Left Primary Ear Group.

The subject was first presented with the five monaural lists in consecutive order. Before each list was played, a card with a target word printed on it was placed on the table in front of the subject and remained visible during the playing of the list. The experimenter also pronounced the target word out loud. The subject's main task was to press the button in front of him immediately upon hearing each color word. When the subject heard the target word, he was to immediately say the word "Now" and stop pressing the button even though the list would continue. The subject was reminded several times during the experiment that button-pressing was the main task and it should be as accurate as possible. The eight color words used in the experiment were read to the subject before the first list was presented. The subject was told to immediately release the button after each press so that he would be prepared to press it again. It was emphasized that it was just as important not to press at the wrong places (non-color words) as it was to press to color words. During

the break between each list, the next target word was presented and the subject waited for the next list to begin (with the words "One, Two, Three").

The 10 dichotic lists were then presented to the subject. The subject was told that he would again hear a list of words in the same (primary) ear as in the monaural condition and that he should again press the button each time he heard a color word; a list of 20 different words would be presented simultaneously on the other ear and the target word could appear in either ear. It was specifically mentioned that no color words would ever appear in the other (secondary) ear. If the subject missed the target word, he simply continued the main task until the list ended. The procedure was otherwise identical to that in the monaural condition. The introductory words "One, Two, Three" were heard only in the primary ear.

The first playing of the 15 lists constituted a practice presentation. Two experimental presentations followed with a break of a few minutes between each presentation. Half of the subjects in each group listened to the targets in Set 1 during the first experimental presentation and for the Set 2 targets during the second experimental presentation. The other subjects listened for the targets in the reverse order. Before the first experimental presentation, the subject was told that he

might recognize some of the words in the next set of lists since the same words were used in the previous (practice) presentation.

Following the playing of the monaural lists, the subject was always informed that the dichotic lists were about to begin. The purpose of presenting the monaural lists prior to the dichotic lists was to give the subject practice in the main task after each break in an easier condition and to re-emphasize the fact that the color words would only appear in the primary ear; the latter was also the reason for having the introductory words presented to the primary ear only. The experimental session was completed in about one hour.

Experiment II: Subjects

Sixteen right-handed Brooklyn College undergraduates of both sexes participated in the experiment to fulfill the requirements of an introductory psychology course. Four other subjects were replaced due to erratic button-pressing in the main task.³

³These four subjects made consistent errors in the main task while all other subjects made only an occasional error, if any. This was not the result of a 'trade-off' with the target detection task as each of the four subjects detected less than the mean number of targets detected by the other subjects; target detection performance was extremely poor for two of the replaced subjects. The four subjects commented that listening for targets made them 'lose track' of button-pressing.

Experiment II: Procedure

Except for the nature of the main task, the procedure was identical to that of Experiment I. Instead of pressing to color words, the subjects were required to press the button immediately after every third word; in the dichotic condition, this meant pressing after every third pair of words. This does not require semantic analysis of the words in either message. However, since the same stimulus tapes were used as in Experiment I, one message always contained six color words. For consistency, this message is still referred to as the primary message and the non-color message as the secondary message. The subjects were again divided into two groups: Right Primary Ear and Left Primary Ear. Upon detecting a target word, the subject said "Now" and stopped button-pressing.

The subjects were told before hearing the first practice list that each list contained a number of color words because the same lists were used in a different experiment in which the color words were important. They were told that in this experiment, however, the color words had no special significance. As in Experiment I, the introductory words were heard only in the primary ear. The experimental session was completed in about one hour.

C. Results and Discussion

Upon completion of each experimental session, the experimenter listened to the subject response tape. The experimenter heard the re-recorded primary message and the tones signifying a button-press in the right headphone. The verbal detection response "Now" was heard in the left headphone. The approximate latency of each response was determined. If a response occurred before the word following the appropriate word (i.e., color word or target word), the latency was considered to be "immediate." If the response was made during the presentation of the following word, the latency was "1/2 word;" if it was made during the interval between the following word and the next word, the latency was "1 word," etc. The results reported are from the two experimental presentations and not from the practice presentation.

Main Task Performance in Experiment I

The measure of performance used is "% correct button-presses." For each list, the number of color words which occurred prior to the target word was determined. This number represents the maximum number of correct responses for the list. For the dichotic lists, the maximum number of correct responses for all trials is 58; 29 for the 10 lists in each experimental presentation. The maximum number of correct responses for all monaural trials is 27;

12 when listening for the targets in Set 1 and 15 for Set 2. Inasmuch as the results for the two presentations were quite similar, the data were combined. The measure of performance is defined as:

$$\% \text{ correct button-presses} = \frac{\text{total number of correct button-presses}}{\text{maximum number of correct button-presses}} \quad (1)$$

If a subject missed the target word, he kept responding to color words which followed the target word. Only responses made to color words occurring prior to the target word were considered however. Thus, the percentages for all subjects are based on the same maximum. There were only a few scattered instances of false button-presses in the entire experiment and these responses have been ignored in the analysis.

The performance scores for each subject are shown in the last two columns of Table 2.1. For all subjects, the mean values for the dichotic and monaural conditions were 81.6% and 90.3%, respectively. The latency for most responses was "immediate." This means that most responses were made within about 0.6 sec from the onset of the color word. With few exceptions, all responses were initiated with latencies of 1 1/2 words or less; within approximately 1.2 sec from the onset of the color word. This compares with the mean shadowing latency reported by Treisman and Geffen (1967) of about 3 words which was equivalent to

1.2 sec in that experiment (Treisman, 1967).

Main Task Performance in Experiment II

Most subjects responded perfectly, responding precisely after every third word. Other subjects made an occasional error on one or two lists such as responding after words 3, 6, 10, 12, 15 instead of 3, 6, 9, 12, 15. Some subjects had a tendency to make slightly delayed responses so that the tone on the subject tape partly overlapped the word following the third word. The generally excellent performance in this task was expected inasmuch as the responses occurred at well-defined equal time intervals (see Hamilton & Hockey, 1974).

Target Detection Performance in Experiments I and II

The number of target words detected by each subject in the primary and secondary messages was determined for each experimental presentation. Inasmuch as the results for the two presentations were quite similar within each experiment, the data were combined in Experiment I and in Experiment II. Each subject had the opportunity to detect 10 targets in the monaural lists and 10 targets each in the primary and secondary messages in the dichotic lists. The number of dichotic list targets detected by each subject in Experiment I is given in Table 2.1. The results for Experiment II are shown in Table 2.2. Except for Subject 5 who detected 8 targets, detection performance in Experiment I was perfect for the monaural lists. Except

Table 2.1
Individual Subject Data for Experiment I

<u>Subject #</u>	<u>Number of targets detected</u>		<u>D*</u>	<u>% correct button-presses</u>	
	<u>Primary</u>	<u>Secondary</u>		<u>Dichotic</u>	<u>Monaural</u>
<u>Right primary ear</u>					
1	10	4	+6	72.4	92.6
2	9	3	+6	82.8	100.0
3	7	8	-1	75.9	85.2
4	9	3	+6	93.1	96.3
5	8	2	+6	84.5	74.1
6	9	0	+9	86.2	88.9
7	10	4	+6	70.7	66.7
8	6	6	0	81.0	88.9
Mean (n = 8)	8.500	3.750	+4.750	80.8	86.8
<u>Left primary ear</u>					
9	8	8	0	79.3	100.0
10	8	3	+5	81.0	88.9
11	10	6	+4	70.7	100.0
12	6	0	+6	98.3	85.2
13	10	0	+10	96.6	96.3
14	9	6	+3	79.3	100.0
15	10	6	+4	79.3	96.3
16	4	1	+3	74.1	85.2
Mean (n = 8)	8.125	3.750	+4.375	82.3	94.0
MEAN (N = 16)	8.31	3.75	+4.56	81.6	90.3

*D represents the difference between the number of targets detected in the primary and secondary messages. "+" indicates that more targets were detected in the primary message than in the secondary message. "-" indicates the reverse.

Table 2.2
Individual Subject Data for Experiment II

<u>Subject #</u>	<u>Number of targets detected</u>		<u>D*</u>
	<u>Primary</u>	<u>Secondary</u>	
<u>Right primary ear</u>			
1	10	9	+1
2	10	7	+3
3	8	7	+1
4	9	10	-1
5	7	3	+4
6	8	10	-2
7	10	5	+5
8	7	9	-2
Mean (n = 8)	8.625	7.500	+1.125
<u>Left primary ear</u>			
9	10	8	+2
10	9	7	+2
11	8	10	-2
12	7	9	-2
13	6	10	-4
14	7	4	+3
15	4	5	-1
16	7	9	-2
Mean (n = 8)	7.250	7.750	-0.500
<u>MEAN (N = 16)</u>	<u>7.94</u>	<u>7.62</u>	<u>+0.31</u>

*D represents the difference between the number of targets detected in the primary and secondary messages. "+" indicates that more targets were detected in the primary message than in the secondary message. "-" indicates the reverse.

for Subject 15 who detected 9 targets, detection performance in Experiment II was perfect for the monaural lists.

The difference between the mean number of targets detected in the primary and secondary messages in Experiment I (8.31 and 3.75, respectively) was highly significant (correlated $t(15) = 5.97$, $p < .001$). Of the 16 subjects, 13 detected more targets in the primary message than in the secondary message with the difference ranging up to the maximum possible of 10 (see the column headed "D" in Table 2.1).

The difference between the mean number of targets detected in the primary and secondary messages in Experiment II (7.94 and 7.62, respectively) was clearly non-significant (correlated $t(15) = 0.47$, $p > .60$). Half of the subjects detected more targets in the primary message and half detected more targets in the secondary message with the largest obtained difference being 5 (see the column headed "D" in Table 2.2). This contrasts sharply with the results of Experiment I in which 4.56 more targets, on the average, were detected in the primary message.

The results can perhaps be better appreciated by looking at the detectability of individual target words.⁴

⁴There was no obvious relationship between the detectability of individual target words and word onset asynchrony.

The data in Table 2.3 indicate the number of subjects who detected each target word in the two experiments. For example, 14 subjects detected the primary message target of List 1 in Experiment I and 15 subjects detected it in Experiment II; the difference of -1 is indicated under the heading on the right side of the table. The secondary message target for List 1 was detected by only 6 subjects in Experiment I compared to 11 in Experiment II; the same target word was detected by 5 less subjects in Experiment I. For every list, the secondary message target was detected by less subjects in Experiment I than in Experiment II; the mean difference was -6.2. The results are quite different for the primary message targets. Some targets were detected by more subjects in Experiment I while other targets were detected by more subjects in Experiment II. Overall, an average of 0.6 more subjects detected a primary message target in Experiment I than in Experiment II; the maximum was only 4 subjects.

Table 2.3 also shows, for each experiment, the difference (D) between the number of subjects who detected the primary message target and the secondary message target for each list. With the exception of List 7, all primary message targets were detected by more subjects in Experiment I than the corresponding (simultaneous) secondary message target; the mean difference was 7.30 (correlated $t(9) = 6.54$, $p < .001$). In Experiment II, the

Table 2.3

Number of Subjects Who Detected Each Target Word in Experiments I and II

List #	Experiment I			Experiment II			Exp. I - Exp. II	
	Primary	Secondary	D*	Primary	Secondary	D*	Primary	Secondary
1	14	6	+8	15	11	+4	-1	-5
2	16	6	+10	14	11	+3	+2	-5
3	15	7	+8	14	13	+1	+1	-6
4	12	8	+4	8	15	-7	+4	-7
5	15	3	+12	15	10	+5	0	-7
6	13	7	+6	15	13	+2	-2	-6
7	7	7	0	10	13	-3	-3	-6
8	13	2	+11	12	10	+2	+1	-8
9	15	7	+8	13	13	0	+2	-6
10	13	7	+6	11	13	-2	+2	-6
MEAN	13.3 (83.1%)	6.0 (37.5%)	+7.3	12.7 (79.4%)	12.2 (76.2%)	+0.5	+0.6	-6.2

*D represents the difference between the number of subjects who detected the primary message target and the number of subjects who detected the secondary message target. "+" indicates that more subjects detected the primary message target; "-" indicates that more subjects detected the secondary message target.

mean difference was only 0.50 in favor of the primary message (correlated $t(9) = 0.44$, $p > .60$).

The target detection results of the two experiments are quite clear. The requirement to respond to color words in the primary message severely disrupted the detection of target words in the secondary message while having little effect, if any, on the detection of target words in the primary message.⁵ As discussed previously, this result is quite important inasmuch as the main task in Experiment I did not require the subject to distinguish between the two ears (inputs) in any way. There was, however, a wide range of performance in the detection of secondary message targets in Experiment I (from 0 to 8 targets). This aspect of the data is discussed next.

Priority of the Main Task in Experiment I

It was carefully explained to each subject that it was quite important that button-pressing be as accurate as possible. Inasmuch as performance was fairly good (mean correct button-presses = 81.6%) for the dichotic lists, it seems that the subjects followed the instructions. However, performance ranged from 70.7% to 98.3%

⁵In Experiment I, considerably more targets were detected in the primary message regardless of which ear it was presented on. If one ignores which message each target occurred in but considers which ear it occurred in, the mean number of targets detected in Experiment II in the right and left ears were 8.19 and 7.38, respectively. This small right ear advantage was not statistically significant (correlated $t(15) = 1.28$, $p > .20$).

correct button-presses. This suggests the possibility that those subjects who did better in the target detection task did so at the expense of button-pressing performance; i.e., a trade-off between the two tasks.

Examination of Table 2.1 reveals the following information. All subjects who achieved performance above the mean in the main task (81.6%) detected fewer than the mean number of secondary message targets detected (3.75). All subjects who detected more than the mean number of secondary message targets detected had button-pressing scores below the mean. (Subjects 10 and 16 scored below the mean in both tasks.) The strength of the inverse relationship between the two performance measures is quantified by the correlation coefficient (Pearson r) which was found to be -0.588 ($t(14) = 2.72$, $p < .02$). In contrast, there was no obvious relationship ($r = -0.079$) between performance in the main task and the detection of primary message targets.

The relationship between performance in the two tasks of Experiment I is summarized in Table 2.4. Note that monaural button-pressing was high even for those subjects whose dichotic button-pressing performance was inferior. Of most interest is the fact that while the mean number of secondary message targets detected for all subjects was 3.75, the mean number of targets detected by those subjects with superior main task performance was only 1.33.

Table 2.4

Performance Summary for Experiment I

	<u>% correct button-presses</u>		<u>Number of targets detected</u>	
	<u>Dichotic</u>	<u>Monaural</u>	<u>Primary</u>	<u>Secondary</u>
Mean values for subjects with superior performance in the main task* (n = 6)	90.2	90.1	8.50	1.33
Mean values for subjects with inferior performance in the main task* (n = 10)	76.4	90.4	8.20	5.20

*For all 16 subjects, the mean value for performance in the dichotic condition was 81.6% correct button-presses. The performance of Subjects 2, 4, 5, 6, 12, and 13 (Table 2.1) was at a level above the mean. The remaining 10 subjects performed at a level below the mean. The mean value divides "inferior" and "superior" performance.

Discussion

The pattern of results generated by the two experiments is inconsistent with late-selection or automatic processing views of perception and attention. While such models (e.g., Shiffrin, 1976) might be able to adequately explain the results of certain shadowing experiments (e.g., Treisman & Geffen, 1967; Treisman & Riley, 1969), they cannot deal effectively with the present results. The results are compatible with capacity sharing models of attention which do not assume automatic processing (e.g., Kahneman, 1973; Norman & Bobrow, 1975). In performing the relatively easy main task of Experiment II, the subjects were able to divide their attention evenly between the two ears and detect a large proportion of the target words (approximately 80%). In Experiment I, however, the subjects found it necessary to focus their attention on the primary ear in order to respond to color words present in that ear. This uneven distribution of attention lowered considerably the probability of detecting a target in the secondary ear. Some subjects raised this probability by deploying additional attention (capacity) to the secondary ear; the cost of this strategy was a worsening of performance in the main task. Surprisingly, perhaps, there was no loss in the detectability of target words in the primary message.

The terminology introduced by Norman and Bobrow (1975)

is quite useful in describing the picture that emerges from the present results. Since it appears that main task performance in Experiment I was dependent on the amount of processing capacity allocated to the primary ear, this task is "resource-limited." Investment of a relatively small amount of capacity in the secondary ear improved target detection in that ear; the task is "resource-limited." The corresponding small decrease in the capacity available to the primary ear did not result in any noticeable drop in the high detection rate of primary message targets; the task is "data-limited."

Implicit in this discussion is the assumption of a central source of limited capacity which can be freely allocated to different mental activities (Kahneman, 1973). The subjects showed flexibility in attentional strategy by regulating the disparity between the capacity allotment to each ear; this is reflected in the negative correlation between main task performance and secondary message target detection. Note that subjects were able to effect a relatively large increase in secondary message target detection at the cost of a relatively small decrease in main task performance (see Table 2.4). Such a strategy is appropriate for subjects more concerned with optimal overall performance (Kahneman, 1970) than with optimal performance in the main task.

Chapter III
EXPERIMENT III

A. Introduction

The results of Experiment I suggested that the subjects had to 'focus' on one ear in order to respond to color words in that ear. This strategy was adopted at the expense of missing targets in the other ear. If the subjects could have attended to both ears equally well (divided attention), it is not obvious why a focusing strategy was adopted. It appears that the requirements of the two tasks exceeded the limited capacity supply. The purpose of Experiment III was to attempt to measure the processing capacity demands associated with different target detection conditions but where target detection was always the main task.

In two of these conditions, the subject listened for a single target word in a pair of dichotic lists on each trial. The No-knowledge condition resembled Experiment II in that the subject did not know which ear the target would appear in. The subject was informed as to which ear would be the target ear in advance of each trial in the Pre-knowledge trials. Results of similar experiments (Treisman & Davies, 1973; Ninio & Kahneman, 1974) suggest that target detection performance should be superior in the Pre-knowledge condition. Such a finding would

demonstrate the increased effectiveness of a focused attention strategy. As Kahneman (1973) notes, though, a given level of effectiveness can be achieved at different levels of efficiency; efficiency is the relation between the quality of performance (effectiveness) and the effort invested in it. Perhaps the success of a particular attentional strategy might better be evaluated in terms of its efficiency rather than its effectiveness. Thus, measures of effectiveness and efficiency were obtained in the present experiment.

The finding of equal performance in focused and divided conditions in dichotic listening (e.g., Shiffrin et al., 1974) is in accordance with automatic processing models. However, it is possible that the divided condition draws more capacity than the focused condition despite equal performance levels. This would be possible as long as the capacity requirements in the divided condition did not exceed the limited supply. If all of the processing resource allocated to both ears in a divided condition were allocated to one ear in a focused condition, performance in that ear would not improve if performance were data-limited in the focused condition. In fact, the efficiency of performance would decrease in the focused condition with increasing resource allocation and unchanging performance effectiveness.

Since efficiency is inversely related to resource

allocation, an automatic process might be defined as one that is infinitely efficient in that it does not require any resource (cf. Posner & Warren, 1972). According to automatic processing models, simple perceptual (systemic) processing is accomplished with infinite efficiency. According to the limited capacity models of Kahneman (1973) and Norman and Bobrow (1975), equal levels of performance (effectiveness) can be achieved at different levels of efficiency. A finding of equal performance in two experimental conditions (e.g., divided and focused attention) does not, therefore, qualify as sufficient evidence for automatic processing (cf. Shiffrin et al., 1974). Proponents of automatic processing should be able to demonstrate, at the very least, that two critical tasks which are performed with equal effectiveness are also performed with equal efficiency. Of course, such a test of automatic processing requires that the tasks involved are minimally dependent on cognitive processing (Shiffrin & Grantham, 1974).

The determination of efficiency necessitates measuring the amount of processing capacity (resource) consumed in the performance of the task. A popular method for assessing the capacity demands of a task is the secondary (subsidiary) task technique (Kerr, 1973; Kahneman, 1973). The subject is instructed to perform the primary task as well as possible and to devote only the

remaining or spare capacity to a secondary task; the capacity allocated to the primary task is referred to as expended processing capacity (EPC; Griffith, 1976).

Performance on the secondary task is used as a measure of EPC of the main task. An improvement in performance in an unchanging secondary task is assumed to reflect an increase in spare capacity due to a decrease in EPC of the main task. If performance is equal in two similar primary tasks, then the difference in secondary task performance is indicative of a difference in efficiency.

While listening for the target word in the main task, the subjects in Experiment III performed the same arithmetic operation repeatedly on a column of numbers until the target word was heard. Rate of performance was used as the dependent variable for the secondary task. A decrease in rate implies that the EPC of the main task has increased. As noted by Kantowitz and Knight (1976b, p. 354), rate "... is a natural and obvious indicant of any system's ability to process increases in load ..."

While the subject was performing the secondary task, no overt responses were made to the stimuli of the main task. The response to the target word defined the end of the secondary task. There was no response competition between the two tasks. Any changes in secondary task rate would be attributable to capacity interference rather than structural interference (see Kahneman, 1973; Wickens,

1976). Kahneman (1973) argues that aside from the capacity demands of the separate tasks, the requirement to perform two tasks simultaneously demands processing capacity in and of itself. Nevertheless, secondary task scores obtained in dual-task conditions within a given paradigm do reflect relative processing demands for varying levels of the primary task (Kerr, 1973).

While listening for targets in the dichotic lists, the subject sometimes knew (Pre-knowledge) and sometimes did not know (No-knowledge) the target ear. In the Binaural condition, the subject listened for a target in a single list presented to both ears and heard in the center of the head. One might reasonably expect performance in the detection of a single target word in a single list to be (almost) perfect. Performance might not deteriorate in a dichotic presentation if the subject knew which ear the target word would appear in. (Ninio and Kahneman (1974) reported that only 2.8% of the presented targets were missed in a focused attention condition.) A difference in secondary task rates, though, would indicate a difference in efficiency. Given the structure of Experiment III, it is not obvious how such a finding could be accounted for by an automatic processing model (e.g., Shiffrin, 1976). On the other hand, detection performance might be equal in the two dichotic conditions but inferior to that in the Binaural condition. Secondary task performance can be used

as an indicator of efficiency differences between the Pre-knowledge and No-knowledge trials. The models of Kahneman (1973) and Norman and Bobrow (1975) would be consistent with the finding of an efficiency difference between the two conditions. Note that it is also possible for secondary task rates to be equal even though detection performance is not equal for the two conditions. In that case, however, superior detection performance would coincide with improved efficiency. Inferior target detection performance accompanied by an increase in the secondary task rate might merely reflect a performance trade-off (e.g., Experiment I).

In addition to the three target detection conditions, there was also a control condition which was included to obtain a base rate of secondary task performance. As discussed previously, performance in a single-task condition would not serve as a proper control (Kantowitz, 1974; Kantowitz and Knight, 1976a). Instead, subjects performed the secondary task while listening to the word lists over the headphones as in the other conditions but did not listen for a target word. The experimenter would suddenly stop the tape recorder so that the word list being presented was abruptly halted. The subject was to immediately stop the number task and press a button upon detecting the cessation of the auditory stimulus. This task is quite simple and, intuitively, would seem to

require a minimum of processing resource. At the same time, though, it retains the dual-task nature of the three target detection conditions and is thus an appropriate control for the purpose of determining a base rate of secondary task performance.

Each subject was tested under all four conditions. The conditions ranged from merely detecting the stopping of the tape recorder to detecting a target word in the No-knowledge dichotic condition. The range of EPC among the four conditions should certainly be large enough to be reflected in differences in obtained secondary task rates. A finding of no differences between any of the conditions would strongly suggest that the secondary task chosen was not sensitive to changes in spare capacity; the secondary task was data-limited. (The alternative is that there actually were no differences in EPC.)

The secondary task technique is useful only if it can be safely assumed that the subject invests the EPC necessary for optimal performance in the main task. Kahneman (1970) notes that it is often difficult to evaluate the results of dual-task experiments because of the ambiguity inherent in the instructions read to the subject. In recognition of this problem, the subjects were monetarily rewarded for doing the secondary task quickly but the payoff was contingent upon detection of the target word in the primary task.

B. Method

Apparatus

Except for the following, the apparatus was identical to that used in Experiments I and II. The experiment was conducted in a quiet room with the subject's headphones encased in Amplivox Audiocups so that any outside noise was effectively attenuated. No microphone was used as no verbal responses were required. The second tape recorder was used as before to re-record the stimulus lists and to record button-presses. The headphones were reversed for half of the subjects.

Stimuli

The subjects listened to the same stimulus tapes used in Experiments I and II. The single lists recorded on the right channel were presented binaurally instead of monaurally. The right channel output was sent to both headphones so that the subject heard the single list in the center of the head. (Note that the single lists are referred to as "monaural" in Appendix A.) Each of the 10 dichotic lists began with the introductory words "One, Two, Three" presented binaurally so that these words were heard in the center of the head prior to presentation of the dichotic lists separately to the two ears.⁶

⁶For the presentation of the binaural lists, the mode selector of the tape recorder was put in position "R" which fed the right channel output into both headphones. For the dichotic lists, the experimenter quickly put the

For the secondary task, the subject was given sheets of paper (8.5 in X 14.0 in) on which there were typed five separate columns of two-digit numbers with 40 items in each column. The digits "0" and "5" did not appear. The target word for the primary task was printed at the top of the appropriate column. On a given sheet, each column was prepared independently of the others. The subject's task was to circle the two digits if they were both above "5" and to put a slash (line) through them if they were not. The probability that an item would require a circle was 0.5; the sequences of circles and slashes were randomly determined with the restriction that there were no more than five consecutive items of the same classification. There were no doubles (e.g., "33" or "77").

The target words for the primary target detection task are indicated in Appendix C. They ranged in list position from 7 to 17. For the dichotic lists, only one member of a given word pair could serve as a target.

Design

There were three target detection conditions:

(1) detection in the single binaural lists, (2) detection

selector in the "STEREO" position as soon as the word "Three" was heard. The subject heard "One, Two, Three" binaurally (mode position "R") and the following paired lists dichotically (mode position "STEREO"). There was sufficient time between presentation of the word "Three" and the first word pair for this to be accomplished smoothly and efficiently.

in the dichotic lists when the subject was told in advance on which ear the target would appear (Pre-knowledge condition), (3) detection in the dichotic lists when the subject was not informed in advance of the target ear (No-knowledge condition). When the subject detected the target word, he was to immediately stop the number task and press the button next to him on the table. There was also a No-target (control) condition in which the button was to be pressed when the tape recorder was suddenly turned off in the midst of a list.

For any trial in the experiment, the experimenter knew the position of the critical target item in the word list and the number of secondary task items successfully completed. This information could then be converted into a rate (number of secondary items/word) of secondary task performance. For example, the rate would be 1.5 items/word for a trial in which the subject detected a target word in list position 10 while completing 15 items in the secondary task.

Each trial in a given condition was matched with a trial in each of the other conditions so that proper comparisons of rate could be made. For a given trial in a given condition, assume that the target word appeared in position n . There was a trial in each of the other conditions in which the target also appeared in position n . For the No-target condition, the experimenter simply

stopped the tape recorder immediately after the word in position n was heard. Furthermore, for each of the matched trials, the column of numbers presented to the subject was identical. Thus, the subject worked on the identical number sequence in the secondary task for those trials in all conditions where the position of the critical item was the same. All subjects received the same number sequences.

The auditory stimulus sequence and the order of the target words were identical for all subjects. Three sets of target words were prepared (Appendix C). Set P (Practice) was used on the first run followed by Sets 1 and 2. On each run, the subject heard five binaural and ten dichotic lists in the same consecutive order. The No-target condition was run after the three target detection conditions.

Each target set consisted of 15 words: 5 Binaural targets, 5 Pre-knowledge dichotic targets, and 5 No-knowledge dichotic targets. During the presentation of the dichotic lists, the Pre-knowledge and No-knowledge trials alternated. The target words were matched for position within Set 1 and within Set 2. The first five dichotic lists were paired with the last five dichotic lists so that the target words for Pre-knowledge and No-knowledge trials occurred in the same list position. For example, the target in Set 1 for the first dichotic list occurred in position 13 as did the target for List 6, but

List 1 was a No-knowledge trial and List 6 was a Pre-knowledge trial. Similarly, the targets in Lists 2 (Pre-knowledge) and 7 (No-knowledge) occurred in the same position (16). This same pattern was maintained for the remaining lists. The binaural targets occurred in the same five positions as the dichotic targets. Target Set 2 had a similar arrangement but the positions of the targets were different than in Set 1 and the dichotic lists began with a Pre-knowledge trial. Combining both target sets, there were 10 Binaural trials, 10 Pre-knowledge trials (5 Right Channel, 5 Left Channel), and 10 No-knowledge trials (5 Right Channel, 5 Left Channel) with matching target positions for each subject (see Appendix C).

Each target word was printed in upper case letters on a separate card. For Pre-knowledge targets, the words "right ear" or "left ear" were printed in lower case letters below the target word and enclosed in parentheses. Two sets of cards were prepared since half of the subjects heard a given Pre-knowledge target in the right ear while the others heard it in the left ear.

Subjects

Sixteen Brooklyn College undergraduates of both sexes participated in the experiment. All were right-handed and were paid according to the schedule described below. One additional subject was disqualified for not following instructions.

Procedure

The secondary task was explained to the subject first. He was shown a column of two-digit numbers which was previously completed according to task instructions; if both digits were above "5," the pair was circled and, if not, a line was drawn through them. It was carefully explained that the task was to work down a column of numbers as quickly as possible without making errors. If a mistake was made, the subject was to continue working without correcting it. The subject practiced the secondary task on 10 columns (two sheets) of numbers with the experimenter allowing 15 sec for each column.

The target detection task was explained next. The subject's task was to press the button on his right immediately upon hearing the target word. The card with the target word from Set P for the first binaural list was placed in front of the subject and the first list was played. While listening for the four remaining Set P Binaural target words, the subject simultaneously performed the number task, stopping to press the button upon hearing the target. The trial was concluded when the subject pressed the button; he did not resume working on the number task. It was emphasized that the subject should not delay in pressing the button when he heard the target. The subject proceeded from one column to the next. At the top of each column of numbers, the appropriate target word

was printed. At the conclusion of each trial, the experimenter placed the next card (target word) on top of the next column so that the beginning portion of it could not be seen. The subject pushed the card aside and began the number task when he heard the word "One" (of "One, Two, Three").

The payoff schedule was explained to the subject before he began performing the two tasks simultaneously. It was emphasized that target detection was primary and that the subject would receive 3¢ for each target detected. The subject received 0.5¢ for each number successfully completed but lost 0.5¢ for any numbers done incorrectly. The subject lost 2¢ for any incorrect button-presses. The payoff for the secondary task was made contingent on a correct target detection response. If a subject missed a target, he received nothing for the trial regardless of the number of secondary task items completed. Each subject was guaranteed \$3.00 regardless of performance.

After the nature of the dichotic lists was explained, the subject attempted to detect a Pre-knowledge and a No-knowledge target in the first and second dichotic lists, respectively. The subject then listened for the remaining 8 dichotic targets of Set P while performing the secondary task. It was carefully explained that the subject should not try to guess which ear the target would appear in during a No-knowledge trial. Following a short break, the

subject attempted to detect the targets of Set 1 while performing the secondary task. The subject was handed a new number sheet after the 5 binaural lists and again after the first 5 dichotic lists. The 15 lists were presented consecutively with approximately 40 sec of silence between lists. After another short break, the procedure was repeated with the Set 2 target words.

The subjects were told that they might notice the presence of several color words in each list. It was explained that the same tape was used in a different experiment which dealt with colors but the color words had no special significance in the present experiment. None of the target words was a color word or appeared simultaneously with a color word in the dichotic lists. Before listening for the targets in Set 1, the subjects were told that they might recognize some of the words in the lists since the same words were used in the previous lists (i.e., Set P).⁷

The No-target condition was run last. The subject performed the secondary task while the 10 dichotic lists

⁷The subjects' comments in the first two experiments suggested that there was very little retention of individual words as a result of repeated presentations of the lists. Retention of ear location information for individual words in the dichotic lists would make No-knowledge targets functionally equivalent to Pre-knowledge targets. Recent studies (Mewhort, 1973; Kahneman, 1975; Massaro, 1976), however, show that retention of spatial information for dichotic lists is poor; this is even so when the recognition test is given immediately after a

were heard. As each list was played, the experimenter suddenly stopped the tape recorder at the appropriate position in the list. The subject was to immediately stop the number task and press the button. At the conclusion of each trial, a blank card was placed over the beginning portion of the next column of numbers. As before, the subject began when he heard "One." The entire experimental session was completed in about 90 minutes.

short list is presented. A pilot study conducted prior to Experiment III verified these findings. The procedure closely followed that of Experiment III but there was no secondary task and a surprise recognition test was administered after the subject listened for the targets of Set P and Set 1. Statistical analysis of the results of the confidence-rating recognition experiment indicated little, if any, retention of spatial information. Recognition performance itself (ignoring ear location responses) was poor; hit and false alarm rates did not significantly differ.

C. Results and Discussion

The secondary task technique was used to assess the expended processing capacity (EPC) for different conditions of the main task. It would have been possible for a subject to increase his secondary task rate by delaying his target detection response in order to complete a few additional items in the secondary task. The subjects did not do so however. All of the subjects stopped working on the number task without unwarranted delay.

Target Detection Performance

Each subject had the opportunity to detect 10 targets in each condition. No targets were missed in the Binaural condition. The number of targets detected by each subject in the Pre-knowledge and No-knowledge conditions is given in Table 3.1; $\bar{X} = 9.62$ for Pre-knowledge and $\bar{X} = 7.50$ for No-knowledge (correlated $t(15) = 5.51$, $p < .001$). Ten of the 16 subjects did not miss any Pre-knowledge targets while the others missed only 1 target each. For No-knowledge targets, 12 subjects missed more than 1 target.

The No-knowledge condition is roughly equivalent to Experiment II in that the subject's attention was in no way focused on or directed to one ear. Despite the fact that target detection was the primary task in Experiment III but not in Experiment II, detection performance was

Table 3.1

Target Detection Data for Experiment III

Subject #	Pre-knowledge			No-knowledge		
	Right ear	Left ear	Total	Right ear	Left ear	Total
1	5	4	9	4	3	7
2	5	5	10	2	2	4
3	5	5	10	5	5	10
4	5	5	10	5	5	10
5	5	5	10	2	5	7
6	5	5	10	3	3	6
7	5	4	9	5	2	7
8	5	4	9	5	2	7
9	4	5	9	3	4	7
10	4	5	9	4	3	7
11	5	5	10	4	4	8
12	5	5	10	5	4	9
13	5	5	10	4	3	7
14	5	5	10	5	2	7
15	5	5	10	4	4	8
16	5	4	9	5	4	9
<u>MEAN</u>	4.88	4.75	9.62	4.06	3.44	7.50

Note. The individual entries represent the number of targets detected; for each ear in each condition, the maximum possible is 5. For Subjects 1-8, the right channel of the stimulus tape was presented to the right ear and the left channel to the left ear. The headphones were reversed for Subjects 9-16.

not superior in Experiment III; in Experiment II, $\bar{X} = 7.78$. This is not surprising since the main task in Experiment II (pressing the button after every third word) was not especially difficult.⁸

Secondary Task Rates

Secondary task rates for each subject are given in Table 3.2. For a given trial, only the number of words through the target position was included in the rate computation. A given trial was included in the rate computation only if the targets in the matched trials of the other conditions were all detected. For example, if a No-knowledge target in position 16 was missed, then the corresponding trials (i.e., those with the target in position 16) in the Binaural and Pre-knowledge conditions were discarded in determining the average rates for that subject. The corresponding trial in the No-target condition was also discarded. Thus, the rate for each condition was based on the same total number of stimulus words for an individual subject allowing for a fair comparison of rates.

There were few errors in the secondary task. When an error was made, it was taken into account in the

⁸Examination of Table 3.1 indicates that there might be a right ear advantage in the No-knowledge condition. As was the case in Experiment II, the difference between the ears was not significant (correlated $t(15) = 1.62, p > .10$).

determination of the secondary task rate. For a given trial, the number of errors was subtracted from the number of correctly completed items. For example, if a subject completed 16 secondary items of which 15 were correct and 1 was incorrect, the (adjusted) number used in the rate computation would be 14.

Intuitively, the relative difficulty of the primary task might be expected to decrease in the order No-knowledge, Pre-knowledge, Binaural, No-target. If relative difficulty is positively correlated with EPC in the primary task, the amount of spare capacity available and consequently the secondary task rates should increase in the order of conditions given above. Table 3.2 reveals that the mean rates did indeed increase in the anticipated order. The results are best appreciated, though, by examination of the rate changes exhibited by individual subjects. These changes are expressed in percentage form in Table 3.3. Each entry represents the relative change in the secondary task rate for the indicated conditions. For example, the rate for Subject 1 increased from 1.09 in the Binaural condition to 1.28 in the control (No-target) condition. The change in rate, +0.19, corresponds to a 17.4% increase.⁹

⁹The empirical meaning of these rate changes should be kept in mind. A rate of 1.00 means that, on the average, 1 item in the secondary task was completed for each word (pair) presented. A 10% rate increase means that the

Table 3.2

Secondary Task Rates for Experiment III

<u>Subject #</u>	<u>No-knowledge</u>	<u>Pre-knowledge</u>	<u>Binaural</u>	<u>Control</u>
1	0.41	0.73	1.09	1.28
2	0.80	1.09	1.25	1.62
3	0.35	0.46	0.62	0.87
4	0.77	0.76	0.90	1.14
5	1.12	1.10	1.26	1.39
6	0.90	0.93	1.24	1.51
7	1.14	1.22	1.24	1.68
8	0.53	0.54	0.65	1.04
9	0.63	0.78	0.87	1.22
10	1.30	1.22	1.42	1.53
11	1.11	1.11	1.20	1.35
12	1.25	1.20	1.40	1.57
13	0.80	0.90	1.19	1.46
14	1.46	1.38	1.51	1.80
15	1.04	1.02	1.14	1.29
16	1.16	1.12	1.27	1.48
<u>MEAN</u>	<u>0.92</u>	<u>0.97</u>	<u>1.14</u>	<u>1.39</u>

Table 3.3

Secondary Task Rate Changes in Experiment III*

<u>Subject #</u>	<u>No-knowledge to Pre-knowledge</u>	<u>Pre-knowledge to Binaural</u>	<u>Binaural to Control</u>	<u>Control Rate</u>
1	+78.0%	+49.3%	+17.4%	1.28
2	+36.2%	+14.7%	+29.6%	1.62
3	+31.4%	+34.8%	+40.3%	0.87
4	- 1.3%	+18.4%	+26.7%	1.14
5	- 1.8%	+14.5%	+10.3%	1.39
6	+ 3.3%	+33.3%	+21.8%	1.51
7	+ 7.0%	+ 1.6%	+35.5%	1.68
8	+ 1.9%	+20.4%	+60.0%	1.04
9	+23.8%	+11.5%	+40.2%	1.22
10	- 6.2%	+16.4%	+ 7.7%	1.53
11	0.0%	+ 8.1%	+12.5%	1.35
12	- 4.0%	+16.7%	+12.1%	1.57
13	+12.5%	+32.2%	+22.7%	1.46
14	- 5.5%	+ 9.4%	+19.2%	1.80
15	- 1.9%	+11.8%	+13.2%	1.29
16	- 3.4%	+13.4%	+16.5%	1.48

*See text for explanation.

The data in Table 3.3 clearly support the rationale of using the secondary task technique in the present context. All subjects performed the secondary task at a faster rate in the control condition than in the Binaural condition. Except for one subject (10), the rate increased by at least 10% for each subject. The requirement to listen for a single target word in a single list consumed enough processing capacity to slow the rate of secondary task performance relative to the control condition. It is noteworthy that the difference in EPC between the two conditions was tapped by the secondary task technique despite perfect performance in the Binaural condition and comments by subjects as to how easy it was.¹⁰

There was a further increase in EPC when the subjects listened to the dichotic lists. This was even so when the target ear was known in advance. The Pre-knowledge condition is quite similar to the Binaural condition in that the subject had to listen for a target embedded in a 20-word list; the difference is that the list is presented to one ear while an irrelevant list is simultaneously

subject completed 11 secondary task items during the presentation of 10 words compared to 10 items in the previous condition; the differences in rates translates into 1 item/6 sec.

¹⁰Although the control condition was run last, it is quite doubtful that the increased rate in that condition was simply a practice effect. Recall also that the subject did have to detect the sudden cessation of the taped lists so that the dual nature of the other conditions was maintained.

presented to the other ear in the Pre-knowledge condition. Recall that no subject missed more than 1 target in this condition. Yet, all subjects performed the secondary task at a faster rate in the Binaural condition than in the Pre-knowledge condition; the rate exceeded 10% for 13 of the 16 subjects.

For 11 subjects, there were only slight changes in going from the No-knowledge to the Pre-knowledge condition. These changes ranged from -6.2% to +7.0%. For these subjects, the secondary task rate was not appreciably affected by the factor of whether or not the target ear was known in advance. This would imply that EPC did not differ in the two conditions. This means, however, that the primary task was performed more efficiently in the Pre-knowledge condition since target detection performance was superior in that condition. In other words, the improved performance in the Pre-knowledge condition was not achieved by means of a trade-off strategy in which secondary task performance suffered.

Given the sensitivity of the secondary task rate demonstrated in the other conditions (Table 3.3), it might be expected that pre-knowledge of the target ear would result not only in more efficient detection performance but also in a saving of EPC. Five subjects did provide evidence of such a saving. For these subjects, the secondary task rate increased in the Pre-knowledge

condition from between 12.5% to a remarkable 78.0%. Examination of Tables 3.1 and 3.3 reveals no obvious relationship between rate changes, control rate, and detection performance.

The possibility remains that EPC differences between the two dichotic conditions were present for most or all subjects but went undetected in Experiment III. This possibility is supported by further inspection of the data. In addition to the rate changes shown in Table 3.3, gross rate changes in going from the Pre-knowledge to the No-target condition were also determined. For the 5 subjects (1, 2, 3, 9, 13) who showed appreciable rate changes in going from the No-knowledge to the Pre-knowledge condition, the gross rate changes ranged from 48.6% to 89.1%. This indicates that the secondary task rate was fairly sensitive to changes in the amount of available spare capacity. Of the remaining 11 subjects, only 3 subjects (4, 6, 8) displayed gross rate changes comparable to those of the subjects mentioned above. The other subjects showed relatively small gross rate changes (21.6% to 37.7%) suggesting that the secondary task rate was less sensitive to changes in spare capacity. The lack of large gross changes in rate for these subjects allows for the possibility of undetected increases in EPC for the No-knowledge condition relative to the Pre-knowledge condition; the detection of EPC differences for 5 subjects

lends further support to this possibility.

Discussion

Norman and Bobrow (1975) defined a data-limited process (or task) as one in which performance does not improve with an increase in resource (capacity) allocation. This concept has important implications for the secondary task technique as applied in the present experiment. Performance in the secondary task is assumed to reflect the amount of spare capacity available as the main task is being performed. However, increases in spare capacity would not be reflected in increases in secondary task performance if that performance were data-limited over the pertinent range of resource allocation. The secondary task, therefore, must be one which is likely to be sensitive to changing capacity demands of the main task; it should be resource-limited. Still, small changes in the processing demands of the main task might be difficult to detect.

The primary tasks in the No-target and Binaural conditions were quite easy. Yet, the secondary task technique proved successful in detecting the additional capacity demands associated with the simple task of detecting a single word in a single list. A further increase in EPC was found for the dichotic conditions. The comparison of secondary task rates in the Pre-knowledge and No-knowledge conditions, however, was complicated by

the finding of inconsistent performance patterns among the subjects. The lack of a difference in the secondary task rates for these conditions (for a given subject) could have resulted from no difference in spare capacity or the data-limited nature of the secondary task at lower performance levels.

The latter alternative is consistent with the idea that a subject can focus his attention on a given ear in order to listen for a target word. Such a strategy should require less EPC than listening for a target in both ears. In other words, memory activation is not automatic.

Kahneman (1975) has made an important distinction between two types of attentional strategies. The strategy of focusing or directing processing capacity to one ear is "active." Kahneman cautions, however, that the difficulty of a task may not always correlate with the amount of effort (capacity) the task elicits. Specifically, he points out that while the task of listening to two long dichotic lists is quite difficult, it does not appear to elicit much effort. Subjects deploy a "passive mode" of attention when they realize that any attempt to actively attend to the words coming into both ears results in words being missed. The comments of several subjects in Experiment III were quite consistent with Kahneman's (1975) observation; as one subject put it, he just waited for the target to "pop up" in the No-knowledge condition.

Although the strategy of focusing may have slowed down the secondary task somewhat (relative to the Binaural condition), it was quite successful in terms of the primary detection task. The EPC investment was surely worthwhile and was consistent with task instructions. However, the allotment of still additional capacity in an active strategy in the No-knowledge condition may not have been efficient. The results of Experiments I, II, and III suggest, in fact, that detection performance may be data-limited when the target word can appear on either ear. With the exception of the Pre-knowledge condition in Experiment III and the secondary message (i.e., no color words) in Experiment I, mean detection performance had a total range of only 75% to 83%. Investing relatively large amounts of processing capacity in the detection task would therefore be inefficient inasmuch as it would not result in improved performance while it would slow down the secondary task rate. Any spare capacity might better be utilized if it were allocated to the secondary task.

The obtained results could therefore be explained by assuming an active strategy in the Pre-knowledge condition and a more passive strategy in the No-knowledge condition. As measured by the secondary task, EPC was the same for the primary task (for most subjects) in both conditions. The difference was that the allocated EPC was concentrated in the appropriate ear in the Pre-

knowledge condition to ensure maximum detection performance. Regardless of whether or not EPC was equal in the two conditions, it is clear that the inferior detection performance in the No-knowledge condition consumed at least the same amount of processing capacity as in the Pre-knowledge condition. By definition (Kahneman, 1973), detection performance was achieved with greater efficiency in the Pre-knowledge condition. This finding is quite consistent with models of attention which do not assume automatic processing. Furthermore, the concept of efficiency of performance is relevant to certain perceptual studies (e.g., Shiffrin et al., 1974) which have provided support for automatic processing by demonstrating no differences in performance between focused and divided conditions. Proponents of automatic processing should not only be concerned with the effectiveness of attentional strategies but also with their efficiency.

Chapter IV
GENERAL DISCUSSION

Any comprehensive model of perception, memory, or general cognitive functioning must deal with the issue of attention. In doing so, most contemporary models of information processing assume the existence of a limited supply of processing capacity. To say that a task consumes processing capacity is synonymous with saying that it requires attention. It is quite safe to assume that much cognitive activity (i.e., memory, decision, response processes) is dependent on the availability of this capacity. Performance suffers when the capacity demands of a task exceed the available supply.

Considerable controversy surrounds the role that attentional mechanisms play in non-cognitive perceptual processes. Indeed, the very distinction between perceptual and cognitive processes is considered by some (e.g., Neisser, 1967; 1976) to be vague or even non-existent. Of major concern is the degree to which simple perceptual processes are dependent on the limited supply of processing capacity. An increasingly popular view is that such processes occur automatically and independently of the limited capacity supply. Attentional effects are assumed to occur during 'cognitive processing' and not during 'systemic (perceptual) processing' (Shiffrin & Grantham,

1974). Analagous to this distinction is the one between a 'conscious process' and an 'automatic process' (Posner & Warren, 1972). The present study was designed to test the assumption of automatic processing models which states that individual verbal items, presented auditorily, are perceived automatically. Familiar items are assumed to contact their memory representations automatically which allows for a simple semantic analysis without involvement of the limited capacity processing system. The major research paradigm used to test the assumptions of automatic processing has involved the simultaneous presentation of different messages. Specific experimental procedures are geared to determining the ability of subjects to process such messages or, on the other hand, the ability of subjects to prevent the analysis of a given message. The difficulty in interpreting the relevant results can be traced to two main factors. First, evidence for simultaneous processing need not necessarily imply automatic processing. Limited capacity models which do not assume automatic processing do allow for simultaneous processing in situations where the demand for processing capacity does not exceed the available supply. Second, evidence against automatic processing is often judged invalid because of the cognitive demands of the task. This leads to a somewhat circular state of affairs. Automatic processing theories must be tested under

conditions which minimize cognitive components of the task. These conditions, however, are also likely to minimize the strain on the limited capacity supply so that simultaneous processing is not inconsistent with models which do not assume automatic processing. An attempt was made in the present series of experiments to obtain attentional effects that could not be attributed to the cognitive demands of the task.

A. Shiffrin's Model of Attention

The purpose of the introductory chapter (I) was to demonstrate the inadequacy of several crucial experiments which have been cited frequently in the literature as providing evidence for automatic processing in dichotic listening. In this section, the results of the present experiments will be examined in the context of automatic processing theory. While these results are certainly consistent with limited capacity models of attention (e.g., Kahneman, 1973; Norman & Bobrow, 1975) which allow for early-selection and do not assume automatic processing, it is important to critically evaluate the degree to which the present results can be accounted for by automatic processing.

Of the various proponents of automatic processing, Shiffrin (1976) has dealt most directly with attentional issues in dichotic listening. He restates the view that

there are automatic stages of sensory processing and that "there is no gating or filtering or attenuating of sensory information, either between or within modalities." Sensory information is dumped into short-term store (STS) in parallel from all sources with almost no subject control. Most of this information will be lost very quickly so that the subject must select certain aspects of the information for rehearsal, coding, and decision making. The locus of selective attention is thus seen to reside in STS. What is especially pertinent is Shiffrin's (1976) discussion of the experiments of Treisman and Geffen (1967) and Treisman and Riley (1969). He says (p. 191):

... In such cases, I will argue that a target is missed, not because it is forgotten before a decision can be made, but because new stimuli are constantly arriving and demanding processing. In order not to fall behind, a subject can allot only a certain amount of time to make a decision about the most recently presented information and must then switch to decision making for newly arriving information. In this way, above-threshold stimuli can be missed.

In attempting to detect a target, the search of STS will be less likely to locate the relevant information (before new inputs arrive) in divided attention than in focused attention simply because there are more relevant inputs to search in the divided condition.

In the Treisman and Riley (1969) study, subjects shadowed the digits on one ear but stopped shadowing and tapped when detecting a letter on either ear. When the target letters and the digits were in the same voice, many

targets were missed on the nonshadowed ear. According to Shiffrin (1976), targets are located by means of a "controlled search" of STS and shadowing forces the search to begin with the material being shadowed. By the time the search switches to the other ear, the target there may have been already replaced by a new item or new material on the shadowed ear requires the search to return there. Thus, many targets will be missed on the nonshadowed ear.

The question at hand is whether Shiffrin's (1976) approach can adequately handle the results obtained in the present experiments. In Experiment I, performance in the detection of a specific target word was poor in the secondary ear as subjects pressed a button in response to color words occurring randomly in the primary ear. Following Shiffrin's (1976) reasoning, this result could be explained by assuming that the primary task (pressing to color words) caused the controlled search for the target word to begin in the primary ear. Such an explanation is not very convincing for several reasons. Of particular importance are the specific differences between the shadowing task and the primary task in Experiment I. Shadowing is made difficult by several factors: (1) The task requires the subject to distinguish between the inputs, thus forcing the subject to attend to one ear, (2) the subject must give continuous responses to each item presented, and (3) each response is dependent on the

specific verbal item presented with the response usually made after several other items have been presented. The primary task in Experiment I did not force the subject to distinguish between the inputs and did not require the subject to respond to each item presented. Furthermore, the simple button-pressing response was identical regardless of the specific identities of the color words. Button-pressing responses were immediate or only slightly delayed.

Assuming that the information in both messages was automatically deposited in STS, it is not at all clear why the color words could not be responded to without a controlled search beginning with the material in the primary ear. There were only two inputs, easily separable by location, clearly perceivable, and presented at a fast but not excessive rate. The targets themselves were single-syllable frequent words. Such phonemic targets are easier to detect than category targets (Treisman & Geffen, 1967; Sullivan, 1976). For Shiffrin (1976), it is convenient to have all of the incoming information present in STS in explaining why subjects might respond (incorrectly) to material in the unattended ear in a focused attention task. The assumption of automatic processing, however, makes the explanations of certain divided attention effects (e.g., Experiment I) somewhat strained.

It should be noted that theorists who do not assume

automatic processing attack the problem from the opposite perspective. Meaning, expectations, and context all play important roles in the models of Treisman (1960; 1964; Treisman & Geffen, 1967), Broadbent (1971), and Kahneman (1973). They are necessary to explain why some items in the unattended or secondary input are responded to in the absence of automatic processing. The problem for Shiffrin (1976) is reversed; rather than explaining why some targets are detected, he is faced with the task of explaining why most are not.

In Experiment I, target detection performance in the secondary ear was extremely poor for those subjects with superior button-pressing performance. Using Shiffrin's (1976) terminology and assuming automatic processing, good performance in the primary task required that a controlled search for the target word (secondary task) begin in the primary ear. As a result of the fast presentation rate and decisions necessary in the primary task, search time for targets in the secondary ear was limited and insufficient. When this search time was increased, more secondary targets were detected as fewer color words in the primary ear were responded to. If this is indeed the case, it seems that fewer primary ear targets should have been detected as search time in the secondary message increased. However, detection performance in the primary ear was independent of detection performance in the secondary ear and button-

pressing performance.

Ninio and Kahneman (1974) performed an experiment in which the subjects listened to lists of 10 dichotic pairs of words and had to press a button upon detecting an animal name. Detection performance was worse and reaction time (RT) greater in divided attention compared to focused attention (i.e., pre-knowledge). The authors suggested that according to filter theory (Broadbent, 1958), RT in the divided condition should be more variable than in the focused condition. On those trials in which the subject happens to be listening to the target ear at the moment of target occurrence, RT in the divided condition should be short and approximately equal to that in the focused condition. RT should be longer on those trials in which the subject is listening to the wrong ear at the time of target occurrence and then must switch attention to the other ear. The same logic seems to be applicable to a model which postulates automatic processing followed by a controlled serial search. Ninio and Kahneman (1974) found, however, that there was little overlap between the distributions for the divided and focused conditions in the range of fast RTs. Specifically, the difference between the means of the three fastest responses for each subject in the two conditions (121 msec) was almost as large as the difference between the overall means for the two conditions (136 msec).

Ninio and Kahneman (1974) interpreted their results as being inconsistent with the concept of attention switching between the ears. Instead, the results support Kahneman's (1973) effort theory of attention. While parallel processing of simultaneous inputs is possible, it is achieved with reduced efficiency and at a reduced speed. These effects are due to a division of processing capacity between the two inputs and not to any type of switching mechanism. In the present study, the subjects divided their attention equally between the two ears when listening for a target in either ear (Experiment II, No-knowledge condition in Experiment III). Performance was good but inferior to that in the focused condition (Pre-knowledge condition in Experiment III). When the subject had to make repeated responses to color words (Experiment I) in the primary ear, the distribution of attention could not be even, due to the high level of total effort required; according to Kahneman's (1973) model, attention is evenly divisible only at low levels of total effort. As a result, many targets were missed in the secondary ear; the low detection rate was not due to a lack of time for a controlled search of STS for automatically processed secondary message target words.

Shaffer and Hardwick (1969) suggested that the commitment to translate a signal into a response might limit or interfere with the recognition of items on the

other ear. Moray (1975) and Sorkin (Sorkin & Pohlman, 1973; Sorkin, Pohlman, & Woods, 1976; Pohlman & Sorkin, 1976) have incorporated the concept of an "interrupt" process in their models of attention; the detection of a target on one channel interrupts processing on another channel. In terms of Shiffrin's (1976) model, one might speculate that the detection of a color word interrupts the controlled search for items on the secondary ear. Since the subject was making repeated responses at a rapid rate, the controlled search for the target word would have little opportunity to switch to the secondary ear. Shiffrin (1976) notes that negative decisions concerning the presence of a target may be faster than positive decisions due to possible rechecking in the case of positive decisions. In Experiment II, in which no positive decisions occurred until the target appeared, the subject might have been able to conduct a controlled, back-and-forth search in both inputs so that detection performance was good in both ears. An efficient controlled search would be impeded in Experiment I because of the repeated, longer positive decisions required in the primary color word detection task.

Acceptance of an interrupt hypothesis as the explanation for the results of Experiment I suggests that the detection of a given secondary ear target should be at least partly dependent on its proximity to color words on

the primary ear. Such was not the case however. Detection performance was uniformly poor for targets in the secondary message and did not improve for targets that were relatively distant from color words. Furthermore, examination of individual subject response patterns did not reveal any relationship between target detection and misses of adjacent color words; i.e., there was no tendency for secondary message targets to be detected when nearby color words were missed.

The target word in List 9 occurred in position 4 before any color words appeared. Yet, only 7 subjects detected this secondary message target in Experiment I compared to 13 in Experiment II (see Table 2.3). This result is particularly impressive for it demonstrates that overt responses are not a necessity for attention to be 'locked' into a selected message. Thus, strong attentional effects were obtained despite the fact that the popular shadowing technique was not used as a method of directing the subject's attention to a given ear.

B. Attentional Strategies

Moray (1975) has summarized a series of dichotic listening experiments conducted in his laboratory which have utilized both non-verbal tonal stimuli (Moray, Fitter, Ostry, Favreau, & Nagy, 1976) as well as verbal stimuli

(Ostry, Moray, & Marks, 1976). The design and basic results of all of the experiments are quite similar. The task requires the subject to detect targets in long, continuous messages. In Ostry et al. (1976, Experiment 2), dichotic word lists were presented at the rate of 2 word pairs/sec. Onset of the members of each pair was approximately simultaneous but computer synchronization was not used. The list presented to a given ear contained 200 items; 20 animal names and 180 non-animal nouns. If one member of a pair was an animal name the probability that the paired item was also an animal name was 0.5. In the divided condition, the subject pressed a button with his right hand upon detecting a target (animal name) in his right ear, a button with his left hand upon detecting a target in his left ear, and both buttons upon detecting a pair of simultaneous targets. Subjects performed this task for one hour a day for several days. On the final day of the experiment, the selective condition was run in which the subject was to respond to targets in only one of the ears although targets still appeared in the other ear.

The most important result obtained by Ostry et al. (1976) was that performance in the divided condition was not impaired relative to the selective condition when no target or response was associated with the other channel; i.e., for those list positions in one ear for which a non-animal noun was paired on the other ear and a response

with the other hand was not made. Performance in the divided condition was severely disrupted when the subject responded to the other channel. The authors considered their results to be consistent with the interrupt hypothesis of Sorokin and Pohlman (1973). A subject can monitor two input channels for a target but the presence of a target on one channel 'interrupts' processing of the other channel until the processing of that target is completed. Target detection performance on a given channel in divided attention should be equal to that in selective attention as long as no event on the other channel causes an interruption.

In Experiment I of the present study, detection of the specific target word of the secondary task required that the subject divide his attention between the two ears. Recall that such targets never appeared simultaneously with a color word and so could not be missed due to the interruption caused by responding to a color word. Nonetheless, the results indicated that divided attention between the two ears was not compatible with good performance in responding to color words. Not only was detection performance of secondary ear targets poor, it was inversely related to performance in the primary task; the attempt to detect more secondary ear targets by dividing attention more evenly resulted in more color words being missed. The results of Experiment I would at first

glance seem to be inconsistent with those of Ostry et al. (1976).

In discussing their results, Ostry et al. (1976) proposed a model which they referred to as "a single channel processor under time pressure." It is regarded as being single channel in the strong sense (p. 334): "Whatever the information content of the signals, only one may be processed at a time. It is not, however, restricted as to the moments at which it can switch to the other channel ..." The critical feature of Experiment I was that frequent responses to color words were required whereas few responses to animal names were required in Ostry et al. (1976) where only one of every ten words was an animal name. In this regard, the discussion of channel switching by Moray and Fitter (1973, pp. 7-8) is crucial:

If the observer were to shadow the message instead of merely monitoring it, his information load would be considerably greater. ... there will be almost no time to sample any other sources, and material in such other sources will be missed.

The relation between monitoring and shadowing in such a model will be readily apparent. Monitoring will occupy the attention just as effectively as shadowing, provided that the overall information rate in the incoming message is high, and, perhaps, more important, the variance in the intertarget interval is great, and has a low mean.

The latter requirements were met in Experiment I. Six color words appeared randomly between positions 4 and 18 so the mean interval between color words was less than two words. This interval ranged from as low as zero (consecu-

tive color words) to as high as five. As the words were presented at a fast rate, the subject had to continually be prepared to respond and thus pay close attention to the primary message. It is thus not surprising that many secondary message targets were missed and this result is not inconsistent with the finding of equal detection performance in the divided and selective conditions of Ostry et al. (1976).

The reader may have picked up a common thread running through the models of Moray (Moray & Fitter, 1973; Ostry et al., 1976) and Shiffrin (1976). The concept of switching attention is an important aspect of both models. For Moray, switching means sampling from one input and then from the other in a manner reminiscent of Broadbent's (1958) filter theory. The notion of Ostry et al. (1976) of a single channel processor under time pressure suggests that the switching might be described as 'early.' For Shiffrin (1976), switching is 'late' as it proceeds via a controlled search of short-term memory following automatic processing. In both cases, switching is made difficult or impossible when continuous rapid decisions about items constantly arriving on one channel are required. When such is the case, targets on another channel will be missed as the high information load on the primary channel prevents switching of attention.

In the discussion of Shiffrin's (1976) model,

evidence was presented which argued against using controlled search as an explanation for the attentional effects observed in the present experiments. That same evidence is similarly applicable to an early switching model. It is important to recognize, though, that the adoption of Kahneman's (1973) effort theory does not make invalid the point made by Shiffrin (1976) and Moray and Fitter (1973) that attentional deficits will surface when frequent quick decisions are required. Both of the latter approaches stipulate that such decisions interfere with switching. The problem for an effort theory is to determine how different task demands affect the division of total processing capacity. The requirement to press a button in response to frequently presented color words required that a relatively large share of the processing capacity be allocated to the ear containing the color words. This does not mean that a subject could not divide his attention evenly between the ears in a target detection task under less demanding circumstances.

For Kahneman (1973) and Norman and Bobrow (1975), attentional strategies are not switching strategies. They are allocation strategies for the continuous flow of processing capacity or resource. Still, the processing of a given input can be interrupted (Sorkin & Pohlman, 1973) by a stimulus which causes an involuntary switch of attention to a competing input source. Thus, Kahneman

(1973) specifically discusses interference effects caused by a rapid redirection of attention.

The subjects in Experiment III did not have to respond to the color words. They just waited for the appearance of the target word (while performing the secondary number task). Nonetheless, detection performance was better in the Pre-knowledge condition (selective attention) than in the No-knowledge condition (divided attention). Although consistent with the findings of Treisman and Davies (1973) and Ninio and Kahneman (1974), this result does seem inconsistent with the results of Ostry et al. (1976). Again, a close examination of specific task requirements is warranted.

In Experiment I, an active focusing strategy was required in the primary task. A more passive strategy was likely used by the subjects of Ostry et al. (1976) in the divided condition. The subjects listened to very long lists of items and had to occasionally respond to the presence of an animal name on either ear. In such a situation, a relaxed waiting strategy seems more appropriate than a tense active strategy. However, the presence of a target on one ear is likely to interfere with the detection of a simultaneous target on the other ear due to the special significance of a target item and the overt response associated with it. In the recognition studies of Kahneman (1975), such interference was not

found since all items were of equal importance and no overt responses were required.

It is plausible that the attentional strategy used by subjects in the selective conditions of Experiment III, Ninio and Kahneman (1974), and Treisman and Davies (1973) was different than that used in the selective condition of Ostry et al. (1976). For the former experiments, list length ranged from 10 to 20 pairs of items and lasted from 5 to 12 sec. The subject listened for the target item, pressed a button, and the trial was over. The active strategy of focusing on one ear is certainly appropriate. Doing so resulted in improved performance relative to that found in the divided conditions. The situation is somewhat different for the subjects of Ostry et al. (1976). These subjects heard a continuous series of 200 paired items which lasted almost two minutes (100 sec). The trials were not discrete as the subjects continued to listen for more targets after each response. While maintained selective focusing is possible for relatively short periods of time (e.g., 20 sec), it may not be for long periods of time.¹¹ As evidenced by the secondary

¹¹This discussion is relevant for monitoring situations in which frequent overt responses are not required. Subjects can focus on one message for the purpose of shadowing for an extended period of time. Continuous overt responses are required and this activity demands considerable processing capacity.

task rates in Experiment III, the process of focusing on one of two dichotic messages results in an increase in expended processing capacity relative to a single message condition. It may be difficult to concentrate this additional processing capacity in one ear for an extended period of time for the purpose of detecting occasional targets. If so, then the subjects in Ostry et al. (1976) may have adopted similar passive strategies in the divided and selective conditions.

Kahneman (1973) discusses the important concepts of time-pressure and momentary effort. He notes (p. 25) that "the momentary effort exerted in running the 60-yard dash is greater than the effort exerted in walking two miles at a comfortable pace, although the total expenditure of energy is surely greater in the second task." This analogy is relevant to the present situation. When required to detect targets in rapidly presented stimuli, subjects are under time-pressure inasmuch as continuous decisions are required even though continuous responses are not. There is an additional time-pressure element in Ninio and Kahneman (1974), Treisman and Davies (1973), and Experiment III. Success on a given discrete trial was dependent on the detection of one target which was present in a relatively short list lasting only 10 or 20 sec. It is likely that the subject would concentrate considerable capacity in the selected ear to ensure success on each

trial; momentary effort is high. This type of time-pressure was not present in Ostry et al. (1976). Each subject had repeated opportunities to detect targets during a 100 sec period. Good performance was not dependent on the detection of any particular target. Because of the difficulty in maintaining a high level of concentrated effort, the subjects may have adopted a more passive strategy similar to that used in the divided condition. Thus, at any given time, the momentary effort invested in the selected ear would not be as great in Ostry et al. (1976) as in the discrete trial experiments. Consequently, detection performance in the selective condition would not improve relative to the divided condition. Looked at in the context of the entire experimental situation, a focusing strategy in the discrete trial situation which results in perfect detection performance might not be more efficient (Kahneman, 1973) than a passive strategy used in the continuous trial design where performance is not as high.

The preceding analysis suggests that detection performance in the divided and selective conditions of Ostry et al. (1976) were equal because performance in the selective condition was not especially high. An alternative interpretation might be that the highly practiced subjects were able to raise the level of performance in the divided condition to that in the selective

condition. The data reported by Ostry et al. (1976) support the former interpretation. For those instances in which no target appeared on or a response made to the opposite channel (ear), d' was found to be 2.09 and 2.01 for the divided and selective conditions, respectively. In Experiment III of the present study, about 96% of the Pre-knowledge targets were detected. This 'hit rate' would have to be accompanied by a false detection rate of 40% for a d' value of 2.01 to be achieved. In fact, there were no false detections in the Pre-knowledge condition. In a focused dichotic condition, Ninio and Kahneman (1974) reported a hit rate of 97.2% accompanied by a false detection rate of only 1.4%; this translates into a d' value of 4.11. The performance scores reported by Ostry et al. (1976) are, by comparison, not at all impressive. This is especially so since the subjects were practiced. Equal performance in the two conditions was not due to high performance levels in the divided condition.

It is clear that explanations of attentional effects must take into account relevant temporal parameters. Thus the conclusions of Lewis (1970) concerning automatic processing were modified by Treisman et al. (1974) who studied the temporal aspects of the task. It is unlikely that subjects would employ the same attentional strategy when listening to a single pair of words or syllables (Brown, 1970; Shiffrin et al., 1974), several pairs of

words presented in 10 to 20 sec (Experiment III, Ninio & Kahneman, 1974; Treisman & Davies, 1973), and 200 pairs of words presented in a 100 sec period (Ostry et al., 1976).

The picture is made more complete by recent experiments which have measured auditory evoked potentials in selective listening tasks (Hillyard, Hink, Schwent, & Picton, 1973; Schwent, Snyder, & Hillyard, 1976; Hink & Hillyard, 1976). Broadbent (1971) places considerable emphasis on the distinction between selection via physical characteristics, or stimulus set, and selection via category (meaning), or response set. Attentional studies (Hillyard, et al., 1973; Schwent et al. 1976) using tones have provided strong evidence for a distinction between stimulus set and response set based on neuro-physiological correlates. Selective attention by means of stimulus set has been associated with increased amplitude of N_1 waves of the evoked potential (EP); the N_1 component is represented by a negative peak occurring at 80-110 msec following stimulus presentation. These experiments have shown that an enhanced N_1 wave is elicited by all stimuli on an attended channel (ear). An increase in the amplitude of P_3 waves occurs only following targets in the attended message and not following targets in the unattended message or nontargets in the attended message. Thus, the P_3 wave, which is represented by a positive potential elicited at between 250 and 400 msec following

stimulus presentation, has been associated with response set.

Hink and Hillyard (1976) extended the EP findings to dichotic speech messages. The subjects heard prose messages on both ears, one message spoken in a male voice and the other in a female voice. The primary task was to listen to one message in preparation for a quiz on its contents. The secondary task was to "pick up" whatever was possible from the other ear. Embedded in each message were synthesized phonemes which sounded like the vowel "ah" and were matched in frequency to the voice speaking the message. These probe stimuli were not to be responded to and had no special significance from the subject's viewpoint. EP measurements following probe presentation showed the N_1 amplitude to be larger in a given message when that message was primary than when it was secondary. Recall of the material in the primary message was superior to that in the secondary message. In discussing selective listening to dichotic speech messages and to dichotic tone burst sequences, Hink and Hillyard (1976, p. 240) commented:

It is a reasonable presumption, therefore, that the selective N_1 enhancement common to the two tasks is a correlate of the common "stimulus set" or "input selection" process. It is our hypothesis, then, that the N_1 amplitude is an index of an initial stage of selective attention that accords preferential processing to all stimuli belonging to a relevant channel (i.e., having the same pitch/space attributes), irrespective of the nature, complexity, or

specific relevance of the material.

As noted by Hink and Hillyard (1976), those experiments which have not found differences in the detectability of targets on attended and nonattended channels (e.g., Lawson, 1966; Zelnicker et al., 1974) used pure tones as targets which were quite distinct from the speaker's voice. Similarly, different-voiced verbal targets are easily detected on an unattended channel (e.g., Treisman & Riley, 1969; Underwood & Moray, 1971). The Hink and Hillyard (1976) experiment is closely related to Experiment I where the target item was spoken by the same voice as the other items and target detection was poor in the secondary message. The results of the present experiments were interpreted in terms of the allocation of processing capacity which relied on input distinctions made via stimulus set (i.e., ear location) and thus are quite compatible with the EP studies.

C. Concluding Comments

The pattern of results reported in the present paper is consistent with a view of attention which assumes the existence of a limited supply of central processing capacity which can be divided among concurrent activities or tasks. Limitations in task performance will appear when the demands placed on this limited supply exceed the total amount of capacity available. When such limitations

do not arise (i.e., simultaneous processing), it does not necessarily mean that the particular processes under consideration occur automatically and independently of the available processing capacity. Rather, it is more likely that the available processing capacity (or resource) was sufficient to meet the needs of the tasks involved. A proper understanding of the performance levels reached in a dual-task or divided attention experiment is very much dependent upon a thorough appreciation of the nature of the individual tasks and the optional strategies available to the subjects.

Although the present paper has focused on the dichotic listening paradigm, the limited capacity approach (without automatic processing) has much broader applicability. One reason for the popularity of dichotic listening in the study of attention is that it allows for continuous tasks as opposed to the typical single exposure tachistoscopic experiments in vision. Neisser and Becklen (1975) created a continuous visual task which resembles selective listening experiments. Subjects watched two different visual episodes (a hand-slapping game and a ball-throwing game) that were previously videotaped. When presented simultaneously either binocularly (overlapping, each episode presented to each eye) or dichoptically (each episode to separate eyes), subjects were able to respond to critical events in one episode and ignore the other.

They rarely noticed "odd" events in the unattended episode. When required to monitor the events in both episodes performance dropped considerably. These results parallel those found in dichotic listening.

In summary, it is suggested that the current trend toward acceptance of the automatic processing view of perception and attention is unwarranted. The evidence which favors such a view is not at all conclusive. Furthermore, the results obtained in the present dichotic listening experiments argue against automatic processing. Specifically, the results suggest that verbal items do not receive an automatic semantic analysis but rather require an investment of processing capacity. Attempts should be made in future research to measure expended processing capacity in addition to obtaining performance scores. Although this may often be quite difficult to achieve, researchers should not be concerned only with the effectiveness of a particular attentional strategy but also with the efficiency with which that strategy is executed.

APPENDIX A
WORD LISTS

MONAURAL LIST 1

one

two

three

1. beam
2. speed
3. noon
4. bag
5. dome
6. crack
7. white
8. fuel
9. sweat
10. pink
11. bunch
12. green
13. stop
14. switch
15. brown
16. gray
17. gift
18. red
19. drunk
20. cape

MONAURAL LIST 2

- one
two
three
1. wise
 2. match
 3. yarn
 4. blue
 5. clerk
 6. fate
 7. main
 8. bat
 9. fun
 10. brown
 11. breed
 12. touch
 13. red
 14. green
 15. pen
 16. white
 17. drug
 18. black
 19. loop
 20. guest

MONAURAL LIST 3

- one
two
three
1. roll
 2. hang
 3. trim
 4. straw
 5. blue
 6. aid
 7. pin
 8. pink
 9. white
 10. lend
 11. brown
 12. rush
 13. noise
 14. green
 15. dust
 16. trade
 17. gray
 18. knee
 19. fast
 20. trip

MONAURAL LIST 4

one

two

three

1. boost
2. drink
3. phrase
4. self
5. toast
6. soft
7. red
8. black
9. list
10. jeep
11. gray
12. pound
13. brown
14. pull
15. gang
16. pink
17. heat
18. white
19. bad
20. spread

MONAURAL LIST 5

one

two

three

1. brief
2. glass
3. thick
4. rod
5. black
6. link
7. glance
8. harm
9. pink
10. plus
11. blue
12. green
13. rule
14. deal
15. gray
16. brown
17. fight
18. chance
19. blame
20. hide

DICHOTIC LIST 1

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, " - " = Left leads)
	one	
	two	
	three	
1. claim	1. chip	-10
2. win	2. push	-40
3. drain	3. bend	-20
4. gas	4. green	+40
5. camp	5. soap	+55
6. jazz	6. walk	-10
7. foam	7. pink	+25
8. sight	8. root	-65
9. join	9. white	-25
10. bid	10. deed	+10
11. club	11. calm	+20
12. odd	12. sink	+80
13. sign	13. brick	-50
14. drop	14. black	+05
15. bent	15. kid	+55
16. file	16. red	-20
17. cream	17. plant	+20
18. draft	18. brown	+20
19. wash	19. prince	+100
20. hate	20. dirt	+30

DICHOTIC LIST 2

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, " - " = Left leads)
	one	
	two	
	three	
1. dean	1. storm	+130
2. bath	2. curve	-05
3. twist	3. sport	+40
4. dry	4. friend	+35
5. phone	5. throat	-40
6. drill	6. white	-30
7. port	7. press	-70
8. clay	8. ship	+40
9. sick	9. blue	-100
10. nest	10. jaw	-40
11. deck	11. gray	-15
12. save	12. rich	-80
13. square	13. black	-65
14. height	14. green	-50
15. dull	15. chair	+85
16. catch	16. stream	+80
17. teeth	17. red	+40
18. spare	18. bank	-100
19. pick	19. hit	0
20. milk	20. track	-10

DICHOTIC LIST 3

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, " - " = Left leads)
	one	
	two	
	three	
1. proof	1. stiff	+130
2. cap	2. flame	-30
3. sky	3. guilt	-180
4. faith	4. throw	-50
5. burn	5. brown	-20
6. net	6. green	-15
7. shame	7. step	+15
8. smart	8. pole	-70
9. box	9. black	-15
10. nose	10. break	-60
11. dream	11. red	+25
12. tight	12. pure	+30
13. feed	13. gun	+20
14. pass	14. kick	+05
15. coast	15. blue	-35
16. spot	16. store	+20
17. frame	17. white	-15
18. print	18. watch	-30
19. serve	19. trick	-60
20. steam	20. breeze	-110

DICHOTIC LIST 4

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, " - " = Left leads)
	one	
	two	
	three	
1. grant	1. flat	+60
2. film	2. joy	+75
3. wait	3. wrong	0
4. term	4. swift	-130
5. shock	5. rough	-80
6. flag	6. prime	-15
7. firm	7. brown	-30
8. warm	8. pink	-20
9. edge	9. swim	+110
10. scheme	10. drift	-110
11. grave	11. blue	-15
12. test	12. green	-50
13. gain	13. size	+80
14. sweep	14. learn	-120
15. wet	15. white	+25
16. soup	16. cheap	-40
17. skirt	17. lake	-40
18. lane	18. gray	+05
19. fear	19. score	+125
20. clock	20. post	-10

DICHOTIC LIST 5

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, "-" = Left leads)
	one	
	two	
	three	
1. boss	1. slight	+175
2. skill	2. foot	0
3. flow	3. squad	+20
4. boat	4. green	+25
5. arm	5. blast	-10
6. treat	6. pink	-60
7. horn	7. health	+60
8. fame	8. base	-60
9. pitch	9. poor	-10
10. soul	10. black	-85
11. charm	11. brown	-30
12. snow	12. fly	-130
13. tray	13. white	-05
14. lip	14. code	+60
15. spell	15. luck	-80
16. tape	16. red	-05
17. farm	17. coal	0
18. theme	18. ring	+30
19. guide	19. lamp	-10
20. reach	20. path	0

DICHOTIC LIST 6

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, " - " = Left leads)
	one	
	two	
	three	
1. swing	2. cop	-45
2. joke	2. rise	+30
3. round	3. chest	-30
4. truck	4. sleep	+45
5. mist	5. black	-60
6. cow	6. green	-15
7. prize	7. cloth	+15
8. tool	8. fill	+35
9. ace	9. bread	+20
10. chain	10. glad	+10
11. pile	11. tough	-15
12. coach	12. pink	0
13. speak	13. tap	-30
14. ranch	14. white	-40
15. hot	15. red	+05
16. troop	16. tile	-20
17. shirt	17. date	-80
18. fist	18. gray	0
19. fleet	19. rock	+30
20. bench	20. paint	+70

DICHOTIC LIST 7

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, " - " = Left leads)
	one	
	two	
	three	
1. grip	1. chill	-10
2. brush	2. prove	-15
3. mold	3. stay	+15
4. brave	4. blue	+10
5. dance	5. dress	+35
6. stove	6. brown	-35
7. grow	7. bark	+10
8. stress	8. nurse	-100
9. bus	9. green	+45
10. hat	10. plate	-90
11. shake	11. white	-80
12. youth	12. vote	+45
13. blood	13. gray	+60
14. coat	14. wax	+15
15. gloom	15. bed	+10
16. chart	16. smell	+80
17. screen	17. red	-40
18. guard	18. sweet	+150
19. graph	19. chase	+85
20. fork	20. stand	+155

DICHOTIC LIST 8

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, "-" = Left leads)
	one	
	two	
	three	
1. thin	1. drag	+95
2. moon	2. build	-25
3. cry	3. pipe	-05
4. tent	4. earth	-50
5. beach	5. brown	-15
6. glow	6. green	+05
7. blank	7. wheel	+25
8. queen	8. folk	0
9. band	9. shoe	+85
10. inch	10. race	+45
11. game	11. knife	+50
12. tail	12. red	-05
13. neat	13. white	+70
14. fresh	14. sun	+110
15. stone	15. black	-70
16. fence	16. page	+50
17. wish	17. gray	+30
18. belt	18. fool	+70
19. gate	19. mud	+20
20. clean	20. bulk	-25

DICHOTIC LIST 9

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, "-" = Left leads)
	one	
	two	
	three	
1. rent	1. myth	+10
2. pond	2. crowd	+45
3. cheek	3. gap	-05
4. card	4. laugh	-05
5. pan	5. white	-45
6. drive	6. cash	-35
7. chin	7. proud	-65
8. slave	8. red	-135
9. twice	9. blue	-60
10. crime	10. chief	-20
11. stock	11. sit	0
12. teach	12. green	+15
13. smooth	13. pale	-70
14. key	14. truth	+30
15. price	15. pink	-35
16. shop	16. loud	-90
17. corn	17. gray	+05
18. taste	18. term	+25
19. fort	19. crop	+25
20. neck	20. wine	+30

DICHOTIC LIST 10

<u>Left Channel</u>	<u>Right Channel</u>	<u>Approximate Asynchrony (msec)</u> ("+" = Right leads, " - " = Left leads)
	one	
	two	
	three	
1. smoke	1. bold	-65
2. pride	2. yard	+20
3. search	3. quote	-110
4. tie	4. mouth	-45
5. crash	5. rain	-80
6. shut	6. fruit	0
7. mad	7. cloud	+60
8. king	8. blue	-45
9. ripe	9. tube	+30
10. park	10. red	-35
11. porch	11. black	+35
12. ask	12. quick	+40
13. trace	13. pen	+05
14. bone	14. gray	+85
15. flash	15. sauce	+70
16. pool	16. white	+65
17. tree	17. cook	+55
18. blind	18. brown	+45
19. threat	19. damp	+55
20. false	20. jump	+05

APPENDIX B
TARGET WORDS FOR EXPERIMENTS I AND II

SET P

"R" indicates Right Channel, "L" indicates Left Channel.
 For Asynchrony, "+" indicates Right Channel leads and "-"
 indicates Left Channel leads.

<u>List #</u>	<u>Position in List</u>	<u>Word</u>	<u>Approximate Asynchrony (msec)</u>
<u>Monaural</u>			
1	9	sweat	
2	12	touch	
3	13	noise	
4	5	toast	
5	7	glance	
<u>Dichotic</u>			
1	12	sink (R)	+80
2	4	friend (R)	+35
3	14	pass (L)	+05
4	5	shock (L)	-80
5	8	fame (L)	-60
6	13	tap (R)	-30
7	12	youth (L)	+45
8	16	page (R)	+50
9	14	truth (R)	+30
10	13	trace (L)	+05

SETS 1 AND 2

"R" indicates Right Channel, "L" indicates Left Channel.
For Asynchrony, "+" indicates Right Channel leads and "-" indicates Left Channel leads.

<u>List #</u>	<u>Position in List</u>	<u>Word</u>		<u>Approximate Asynchrony (msec)</u>
		<u>Set 1</u>	<u>Set 2</u>	
<u>Monaural</u>				
1	5	dome		
2	17	drug		
3	7	pin		
4	15	gang		
5	10	plus		
<u>Monaural</u>				
1	11		bunch	
2	8		bat	
3	16		trade	
4	12		pound	
5	14		deal	
<u>Dichotic</u>				
1	13	brick (R)	sign (L)	-50.
2	10	nest (L)	jaw (R)	-40
3	13	feed (L)	gun (R)	+20
4	17	skirt (L)	lake (R)	-40
5	5	blast (R)	arm (L)	-10
6	10	chain (L)	glad (R)	+10
7	15	bed (R)	gloom (L)	+10
8	10	race (R)	inch (L)	+45
9	4	card (L)	laugh (R)	-05
10	17	cook (R)	tree (L)	+55

APPENDIX C
TARGET WORDS FOR EXPERIMENT III

SET P

"R" indicates Right Channel, "L" indicates Left Channel.

<u>List #</u>	<u>Position in List</u>	<u>Word</u>	
<u>Binaural</u>			
1	11	bunch	
2	15	pen	
3	6	aid	
4	12	pound	
5	17	fight	
<u>Dichotic</u>		<u>Pre-knowledge</u>	<u>No-knowledge</u>
1	11	club (L)	
2	15		phone (L)
3	13	gun (R)	
4	16		cheap (R)
5	5	blast (R)	
6	10		chain (L)
7	15	gloom (L)	
8	11		knife (R)
9	14	truth (R)	
10	17		tree (L)

SET 1

"R" indicates Right Channel, "L" indicates Left Channel.

<u>List #</u>	<u>Position in List</u>	<u>Word</u>
<u>Binaural</u>		
1	13	stop
2	7	main
3	16	trade
4	15	gang
5	10	plus
<u>Dichotic</u>		
		<u>Pre-knowledge</u> <u>No-knowledge</u>
1	13	brick (R)
2	16	catch (L)
3	7	step (R)
4	10	scheme (L)
5	15	spell (L)
6	13	tap (R)
7	16	smell (R)
8	7	blank (L)
9	10	crime (L)
10	15	sauce (R)

SET 2

"R" indicates Right Channel, "L" indicates Left Channel.

<u>List #</u>	<u>Position in List</u>	<u>Word</u>	
<u>Binaural</u>			
1	17	gift	
2	9	fun	
3	10	lend	
4	14	pull	
5	13	rule	
<u>Dichotic</u>			
		<u>Pre-knowledge</u>	<u>No-knowledge</u>
1	17	plant (R)	
2	10		jaw (R)
3	14	pass (L)	
4	13		gain (L)
5	9	pitch (L)	
6	17		date (R)
7	10	plate (R)	
8	14		fresh (L)
9	13	pale (R)	
10	9		ripe (L)

REFERENCES

- Ambler, B., Fisicaro, S. A., & Proctor, R. W. Temporal characteristics of primary-secondary message interference in a dichotic listening task. Memory & Cognition, 1976, 4, 709-716.
- Bowers, K. S., & Brennehan, H. A. Unattended information and hypnotic susceptibility. Paper delivered at the Society for Clinical and Experimental Hypnosis Convention, Montreal, 1974.
- Broadbent, D. E. Perception and communication. London: Pergamon Press, 1958.
- _____. Decision and stress. New York: Academic Press, 1971.
- Brown, J. Recognition and the direction of attention. Acta Psychologica, 1970, 33, 149-157.
- Cherry, E. C. Some experiments on the recognition of speech, with one and two ears. Journal of the Acoustical Society of America, 1953, 25, 975-979.
- Corteen, R. S., & Dunn, D. Shock-associated words in a nonattended message: A test for momentary awareness. Journal of Experimental Psychology, 1974, 102, 1143-1144.
- Corteen, R. S., & Wood, B. Autonomic responses to shock-associated words in an unattended channel. Journal of Experimental Psychology, 1972, 94, 308-313.
- Craik, F. I. M., & Lockhart, R. S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.
- Deutsch, J. A., & Deutsch, D. Attention: Some theoretical considerations. Psychological Review, 1963, 70, 80-90.
- Deutsch, J. A., & Deutsch, D. Comments on "Selective attention: Perception or response?" Quarterly Journal of Experimental Psychology, 1967, 19, 362-363.
- Egeth, H. E. Selective attention. Psychological Bulletin, 1967, 67, 41-57.
- Erdelyi, M. H. A new look at the new look: Perceptual defense and vigilance. Psychological Review, 1974, 81, 1-25.

- Glucksberg, S. & Cowen, G. N. Memory for nonattended auditory material. Cognitive Psychology, 1970, 1, 149-156.
- Griffith, D. The attentional demands of mnemonic control processes. Memory & Cognition, 1976, 4, 103-108.
- Hamilton, P., & Hockey, R. Active selection of items to be remembered: The role of timing. Cognitive Psychology, 1974, 6, 61-83.
- Hillyard, S. A., Hink, R. F., Schwent, V. L., & Picton, T. W. Electrical signs of selective attention in the human brain. Science, 1973, 182, 177-180.
- Hink, R. F., & Hillyard, S. A. Auditory evoked potentials during selective listening to speech messages. Perception & Psychophysics, 1976, 20, 236-242.
- Kahneman, D. Remarks on attention control. Acta Psychologica, 1970, 33 (Attention and Performance III, Ed. A. F. Sanders), 118-131.
- _____. Attention and effort. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1973.
- _____. Effort, recognition and recall in auditory attention. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and Performance V. New York: Academic Press, 1975.
- Kantowitz, B. H. Double stimulation. In B. H. Kantowitz (Ed.), Human Information Processing: Tutorials in Performance and Cognition. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1974.
- Kantowitz, B. H., & Knight, J. L., Jr. On experimenter-limited processes. Psychological Review, 1976, 83, 502-507. (a)
- Kantowitz, B. H. & Knight, J. L., Jr. Testing tapping timesharing, II: Auditory secondary task. Acta Psychologica, 1976, 40, 343-362. (b)
- Katzin, B. E., Corballis, M. C., & Lockhart, R. S. Attentional strategies in dichotic listening. Canadian Journal of Psychology, 1972, 26, 207-218.
- Kerr, B. Processing demands during mental processing. Memory & Cognition, 1973, 1, 401-412.

- Kučera, H., & Francis, W. N. Computational analysis of present-day American English. Providence, R. I.: Brown University Press, 1967.
- Lackner, J. R., & Garrett, M. F. Resolving ambiguity: Effects of biasing context in the unattended ear. Cognition, 1972, 1, 359-372.
- Lawson, E. A. Decisions concerning the rejected channel. Quarterly Journal of Experimental Psychology, 1966, 18, 260-265.
- Lewis, J. L. Semantic processing of unattended messages using dichotic listening. Journal of Experimental Psychology, 1970, 85, 225-228.
- Lindsay, P. H. Comments on "Selective attention: Perception or response?" Quarterly Journal of Experimental Psychology, 1967, 19, 363-364.
- Lyons, J. L. The encoding of ignored information. Memory & Cognition, 1974, 2, 161-168.
- Mackay, D. G. Aspects of the theory of comprehension, memory and attention. Quarterly Journal of Experimental Psychology, 1973, 25, 22-40.
- Massaro, D. W. Perceptual processing in dichotic listening. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 331-339.
- Mewhort, D. J. K. Retrieval tags and order of report in dichotic listening. Canadian Journal of Psychology, 1973, 27, 119-126.
- Moray, N. Attention in dichotic listening: Affective cues and the influence of instructions. Quarterly Journal of Experimental Psychology, 1959, 11, 50-60.
- _____. Attention: Selective processes in vision and hearing. New York: Academic Press, 1970.
- _____. A data base for theories of selective listening. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and Performance V. New York: Academic Press, 1975.
- Moray, N., & Fitter, M. A theory and the measurement of attention: Tutorial review. In S. Kornblum (Ed.), Attention and Performance IV. New York: Academic Press, 1973.

- Moray, N., Fitter, M., Ostry, D., Favreau, D., & Nagy, V. Attention to pure tones. Quarterly Journal of Experimental Psychology, 1976, 28, 271-283.
- Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.
- _____. Cognition and reality: Principles and implications of cognitive psychology. San Francisco: W. H. Freeman and Company, 1976.
- Neisser, U., & Becklen, R. Selective looking: Attending to visually specified events. Cognitive Psychology, 1975, 7, 480-494.
- Ninio, A., & Kahneman, D. Reaction time in focused and in divided attention. Journal of Experimental Psychology, 1974, 103, 394-399.
- Norman, D. A. Towards a theory of memory and attention. Psychological Review, 1968, 75, 522-536.
- _____. Memory while shadowing. Quarterly Journal of Experimental Psychology, 1969, 21, 85-93.
- _____. Memory and attention: An introduction to human information processing. New York: John Wiley & Sons, 1976.
- Norman, D. A., & Bobrow, D. G. On data-limited and resource-limited processes. Cognitive Psychology, 1975, 7, 44-64.
- Ostry, D., Moray, N., & Marks, G. Attention, practice, and semantic targets. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 326-336.
- Pohlman, L. D., & Sorkin, R. D. Simultaneous three-channel signal detection: Performance and criterion as a function of order of report. Perception & Psychophysics, 1976, 20, 179-186.
- Posner, M. I., & Snyder, C. R. R. Attention and cognitive control. In R. L. Solso (ed.), Information Processing and Cognition: The Loyola Symposium. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1975. (a)
- Posner, M. I., & Snyder, C. R. R. Facilitation and inhibition in the processing of signals. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and Performance V. New York: Academic Press, 1975. (b)

- Posner, M. I., & Warren, R. E. Traces, concepts, and conscious constructions. In A. W. Melton & E. Martin (Eds.), Coding Processes in Human Memory. Washington, D.C.: V. H. Winston & Sons, 1972.
- Salter, D. Shadowing at one and at two ears. Quarterly Journal of Experimental Psychology, 1973, 25, 549-556.
- Schwent, V. L., Snyder, E., & Hillyard, S. A. Auditory evoked potentials during multichannel selective listening: Role of pitch and localization cues. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 313-325.
- Shaffer, L. H. Multiple attention in continuous verbal tasks. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and Performance V. New York: Academic Press, 1975.
- Shaffer, L. H., & Hardwick, J. Monitoring simultaneous auditory messages. Perception and Psychophysics, 1969, 6, 401-404.
- Shiffrin, R. M. The locus and role of attention in memory systems. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and Performance V. New York: Academic Press, 1975.
- _____. Capacity limitations in information processing, attention, and memory. In W. K. Estes (Ed.), Handbook of Learning and Cognitive Processes, Volume 4: Attention and Memory. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1976.
- Shiffrin, R. M., & Grantham, D. W. Can attention be allocated to sensory modalities? Perception & Psychophysics, 1974, 15, 460-474.
- Shiffrin, R. M., Pisoni, D. B., & Castenada-Mendez, K. Is attention shared between the ears? Cognitive Psychology, 1974, 6, 190-215.
- Sorkin, R. D., & Pohlman, L. D. Some models of observer behavior in two-channel auditory signal detection. Perception & Psychophysics, 1973, 14, 101-109.
- Sorkin, R. D., Pohlman, L. D., & Woods, D. D. Decision interaction between auditory channels. Perception & Psychophysics, 1976, 19, 290-295.

- Spelke, E., Hirst, W., & Neisser, U. Skills of divided attention. Cognition, 1976, 4, 215-230.
- Sullivan, L. Selective attention and secondary analysis: A reconsideration of Broadbent's filter model of selective attention. Quarterly Journal of Experimental Psychology, 1976, 28, 167-178.
- Treisman, A. M. Contextual cues in selective listening. Quarterly Journal of Experimental Psychology, 1960, 12, 242-248.
- _____. Selective attention in man. British Medical Bulletin, 1964, 20, 12-16.
- _____. Reply to "Comments on 'Selective attention: Perception or response?'" Quarterly Journal of Experimental Psychology, 1967, 19, 364-367.
- _____. Strategies and models of selective attention. Psychological Review, 1969, 76, 282-299.
- _____. Perception and recall of simultaneous speech stimuli. Acta Psychologica, 1970, 33 (Attention and Performance III, Ed. A. F. Sanders), 132-148.
- Treisman, A.M., & Davies, A. Divided attention to ear and eye. In S. Kornblum (Ed.), Attention and Performance IV. New York: Academic Press, 1973.
- Treisman, A. M., & Geffen, G. Selective attention: Perception or response? Quarterly Journal of Experimental Psychology, 1967, 19, 1-17.
- Treisman, A. M., & Geffen, G. Selective attention and cerebral dominance in perceiving and responding to speech messages. Quarterly Journal of Experimental Psychology, 1968, 20, 139-150.
- Treisman, A. M., & Riley, J. G. A. Is selective attention selective perception or selective response? A further test. Journal of Experimental Psychology, 1969, 79, 27-34.
- Treisman, A. M., Squire, R., & Green, J. Semantic processing in dichotic listening? A replication. Memory & Cognition, 1974, 2, 641-646.
- Underwood, G. Moray vs. the rest: The effects of extended shadowing practice. Quarterly Journal of Experimental Psychology, 1974, 26, 368-372.

- Underwood, G., & Moray, N. Shadowing and monitoring for selective attention. Quarterly Journal of Experimental Psychology, 1971, 23, 284-295.
- von Wright, J. M., Anderson, K., & Stenman, U. Generalization of conditioned GSRs in dichotic listening. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and Performance V. New York: Academic Press, 1975.
- Wardlaw, K. A., & Kroll, N. A. E. Autonomic responses to shock-associated words in a nonattended message: A failure to replicate. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 357-360.
- Wickens, C. D. The effects of divided attention on information processing in monaural tracking. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 1-13.
- Zelnicker, T., Rattock, J., & Medem, A. Selective listening for tones appearing on a relevant and on an irrelevant input channel. Perception & Psychophysics, 1974, 16, 50-52.