CRAIG, James Richard, 1944-
SELECTIVE ATTENTION AND IMMEDIATE
MEMORY IN DICHOTIC LISTENING.

Iowa State University, Ph.D., 1969
Psychology, experimental

SELECTIVE ATTENTION AND IMMEDIATE MEMORY

IN DICHOTIC LISTENING

by

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A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Psychology

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

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Signature was redacted for privacy.

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Ames, Iowa

1969

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INTRODUCTION

One of the core problems of psychology for late nineteenth and early twentieth century psychologists was that of attention (Bakan, 1966). Even though most psychologists of the time agreed on the importance of the concept there were considerable differences of opinion as to how attention would be treated. For example, the structuralist camp as exemplified by Titchener equated attention with clearness of sensation. The basic problem of accounting for the selection of certain stimuli in consciousness was accomplished by the use of the attention concept which in turn was reduced to sensory clearness (Marx and Hillix, 1963). Functionalists such as William James on the other hand believed attention to be an active process whose function was selection. That is, the active organism directs its attention to specific stimuli and, thereby, determines the nature of its experience (James, 1890). Only those things people notice was thought to influence their psychological functioning (James, 1890).

The subsequent theoretical approaches which followed structuralism and functionalism tended to either ignore the concept of attention or to relegate it to a position of insignificant concern. The supporters of behaviorism, gestalt psychology, psychoanalysis, and S-R learning theory for a variety of reasons were not concerned with the problem of attention (Bakan, 1966). Recent developments, however, suggest that attention is once again being considered a primary problem for investigation in psychology (Bakan, 1966). More and more the organism is being seen as an active seeker and selector of information; as an active <u>per</u>ceiver rather than as a passive <u>re</u>ceiver. The organism has only a limited information handling capacity and, therefore, must select stimuli he is going to focus on from among the many available. These selection processes are currently being viewed as constituting attention (Bakan, 1966). However, the exact nature of the limitation and of the underlying processes of selection has been the subject of considerable argument (e.g., Treisman and Geffin, 1967; Deutsch and Deutsch, 1967; Treisman, 1967; Lindsay, 1967; Treisman, 1969).

One approach to the investigation of the problem of selective attention has been through the use of the dichotic listening (DL) technique--listening to two simultaneously arriving messages independently presented to the two ears. Broadbent (1957, 1958) was one of the first to incorporate the existing DL and other data regarding attention and memory into a theoretical model. Broadbent's model of the human perceptual system proposes a system of limited capacity where information can be processed into memory in but one sensory channel (e.g., one ear at a time). Because of this limitation, a selective operation in the form of a "filter" mechanism is performed upon all messages (input information) in the system.

The selective or "filter" operation takes the form of selecting a sensory channel based on the characteristics of the input information. (For example, the filter may be biased towards a given ear because of "inherent" perferences or habit factors.) The information in the selected channel is passed into what Broadbent calls a "perceptual" or "p" system. The incoming information in the other channel is blocked before reaching the central processing or "p" system. It is held at a stage prior to processing in a temporary, short-term store or "s" system. Information stored in the "s" system is said to "leave the system" (to undergo autonomous decay) if it is held in that store too long before it is processed. In short, information arriving in one channel is immediately processed by the "p" system. The information in the other channel is blocked peripherally and shunted into the "s" system to be processed when the "p" system is free, providing the information is still available.

The proposed filter operation has since been revised through the work of Treisman (1960, 1964, 1969) and supported by the findings of Broadbent and Gregory (1963). The Treisman revision suggests that the mechanism for selective attention is an attenuation process rather than a peripheral blocking of the irrelevant messages and that a hierarchy of tests is carried out on inputs entering all channels whether they are selected for conscious attention or not. That is, the same pattern-recognition processes work on both relevant and irrelevant (as defined by E) information--although the "raw data" on which the processes operate are degraded in the latter case. The decision criteria are the same for both channels, but the "strength" of the incoming information signals is lower in the secondary channel. The attentuated input signals in the secondary channel fail to "pass" tests relatively low in the decision hierarchy because of the "degraded" nature of the signals and, thus, the information goes unrecognized.

The data supporting Broadbent's model (1957, 1958) and Treisman's revision (1960, 1964, 1967) have come largely from DL studies of shadowing--repeating information aloud as it arrives in one channel while "ignoring" information arriving in the other channel or different information arriving in the same channel. Cherry (1953) found that Ss have difficulty in shadowing one of two dichotically presented passages but could relatively easily "reject" the unwanted passage. When Ss were asked afterwards what they had heard in the "rejected" or ignored channel, they could say little about it except that sounds of some type had been presented. Moray (1959) attempted to investigate more closely this finding by testing an S's ability to recall information presented to the ignored channel. Ss were asked to shadow a selection of prose while a list of words was presented to the other ear.

Thirty seconds after termination of the presentation, the Ss were unable to recognize the list that had been presented to the ignored channel.

Treisman (1964) in an investigation of shadowing efficiency presented to one ear a one minute selection of prose which was to be shadowed (the primary channel). She presented 0, 1, or 2 different irrelevant selections either to the other ear alone (the secondary channel) or to both ears simultaneously. She found that shadowing performance was largely determined by the number of channels to be rejected (whether the two irrelevant messages were separate or mixed on one channel) rather than simply the difficulty or ease in separating the selections. She also found that different types of stimuli presented to the secondary channel (prose, numbers, Czechoslovakian, or random English words) had no significant effect on shadowing performance. Treisman concluded that this confirmed her earlier findings (1960) that Ss remain almost completely unaware of the content of the secondary channel in dichotic listening. Thus, in a review of the general findings in the area, Egeth (1967) reached the conclusion that the ignored message has little, if any, behavioral effect.

It must be noted, however, that the Ss in the studies cited above were not told prior to the presentation of the information that the input to the secondary channel would be of any importance or that they would later be asked questions about the input. Also, the test for memory was usually delayed for a definite period of time of up to 30 seconds after presentation. Such a delay would not be an adequate test for short-term memory of the secondary channel information.

Considerable support for the attenuation hypothesis of selective attention in DL was found by Broadbent and Gregory (1963) based on a signal detection analysis. Briefly, the basic idea behind this type of analysis is that an individual's performance is a function not only of his sensitivity but also dependent on his relative willingness to make particular responses (Green and Swets, 1966). The distributions of responses when a signal is present or absent are theorized to take the form of overlapping normal distributions of equal variance. It is further assumed that S is able to convert a priori probabilities of occurrence of signal and of noise as well as the costs and values of specific responses to a monotonic scale. Given these assumptions it is possible to compute two independent measures. One measure, called sensitivity or d', is the distance between the means of the signal and noise distributions, m_s-m_n, divided by the common standard deviation (Green and Swets, 1966). The second measure, called response bias or Beta, indicates where on the monotonic scale the criterion point has been placed relative to the point where the signal and noise distributions intersect (Green and Swets, 1966). Thus, the response bias measure yeilds an index as to where the S stops saying "no" and begins responding "yes".

Broadbent and Gregory (1963) presented to one ear (the secondary channel) of Ss short bursts of noise which might or might not have contained a tone. The other ear (the primary channel) received six digits. The Ss reported their degree of confidence that a tone was presented to the secondary channel under the two conditions of either ignoring the numbers or of "shadowing" the numbers while making the judgements about the tone. The results showed that the signal detection response bias measure remained relatively unchanged by division of attention. They did find that the sensitivity measure d' changed when attention was divided. From these findings they concluded that division of attention away from a stimulus produces an effect resembling a reduction in the intensity of a stimulus. The ignored event is not blocked altogether and under suitable conditions may produce a response from an observer--a conclusion generally taken as supporting the Treisman (1960, 1964) interpretation of attenuation of input rather than peripheral blocking.

An alternative view of the selective attention process has been expressed by Deutsch and Deutsch (1963). They hypothesize that incoming messages reach the same perceptual and discriminatory mechanisms whether conscious attention is paid them or not. Such information is then grouped or segregated by these central mechanisms. How such a grouping takes place they do not suggest. However, they do hypothesize that each central structure which is excited by the presentation of a specific quality or attribute to the senses is given a pre-set weighting of importance which varies over time. The central structure or classifying mechanism with the highest weighting will transfer this weighting to the other classifying mechanisms with which it has been grouped. Thus, the information handled by those structures given the greatest weighting will be consciously attended to.

A somewhat more detailed central processing view of selective attention is offered by Norman (1968). His ideas are advanced on the basic premise that selective attention is a partially automatic process. That is, selection among various sources or types of information occurs only after a certain amount of automatic information processing has already taken place. The assumption is made that information activates its image in memory storage without intervening cognitive processes being necessary. Memory is important in the selection process in that it provides information which serves as a model against which incoming sensory information is compared and analyzed. Given these basic assumptions, selection is hypothesized to proceed in the following manner.

Incoming sensory information is first processed in terms of its physical characteristics. The special features of the signal as determined by this processing determines the appropriate addresses in memory of the information relevant to the current input. The relevant representations in memory are then excited by the incoming information.

Simultaneously, higher-level cognitive processes determine which stored representations are most important to current on-going psychological processes. These cognitive processes are collectively labeled pertinence by Norman (1968). Primarily, what is meant by pertinence is the expectations of the organism of future inputs and the particular properties of current information. Pertinence determination proceeds or occurs at the same time information is being analyzed and not after selection has taken place. It activates or labels certain information as being of importance to the organism on the basis of current psychological functioning. What information is selected for further processing by the attention mechanism is determined by which stored representations receive the greatest combination of pertinence and sensory activation. That is, selection of outputs of the storage system is determined by which information receives the highest levels of combined activation. Incoming information which is not selected "fades" or "decays" quite quickly so that only a very sketchy or bare outline is left after a few seconds.

Thus, the difference between the theories offered by Deutsch and Deutsch (1963) and Norman (1968) on the one hand and by Broadbent (1957, 1958) with the Treisman revision (1960, 1964, 1969) on the other is that the selective attention process is hypothesized to be a central decision process rather than a peripheral attenuation process. In signal detection theory terminology Deutsch and Deutsch and Norman would appear to be saying that the selective attention process is not solely one of decreasing sensitivity to sensory input, but rather primarily one of decision processes determining which information is of importance and is to be selected for further processing.

Although several previously cited studies (Cherry, 1953; Moray, 1959; Treisman, 1960, 1964; Egeth, 1967) indicated information presented to the secondary channel in DL was not remembered, other studies have found contradictory results. Mowbray (1964) and Peterson and Kroener (1964) found that when Ss were instructed beforehand to recall information presented to the secondary channel, they could, in fact, do so with a relatively high degree of accuracy. Norman (1969) has also demonstrated Ss do remember material presented to the secondary channel. He required Ss to shadow words presented to one ear at the rate of two words per second and tested the Ss' memory for two-digit numbers presented to the other ear after various periods of time between presentation and recall. He found when Ss were tested immediately after presentation, they did remember some of the digits. When Ss had to continue shadowing for 20 seconds before trying to remember the digits (as was done by Moray (1959) and others), the Ss could remember none of the digits which had been presented.

Furthermore, Lewis (1968) found evidence against the attenuation hypothesis in DL when reaction times to words being shadowed differed as a function of the type of words presented to the secondary channel. He found that the meaningfulness of the different types of words in the secondary channel directly affected reaction times to the words to be shadowed. Thus, he concluded that even when the content of the message presented to the secondary channel cannot be reported by Ss, its meaning does affect Ss' behavior significantly. This finding would suggest that information presented to the secondary channel in DL is not "filtered" or attenuated at a peripheral level.

PROBLEM

The major purpose of this research was to attempt to set up a DL situation where the predictions of the theoretical position of Norman (1969) and Deutsch and Deutsch (1963) were different from those offered by Treisman's revision (1964, 1967) of Broadbent (1957, 1958). This was accomplished by employing a DL selective attention situation very similar to that used by Broadbent and Gregory (1963) but which employed the methods and techniques more commonly used in DL and recognition memory studies.

Specifically, the Broadbent and Gregory (1963) study contained several methodological differences from other work in the area which could possibly have affected the results obtained. First, the type of "shadowing" asked of the Ss was different than that usually employed. Broadbent and Gregory had their Ss "shadow" digits by listening to a string of six and then writing them down. The task appears to have been more of a short-term memory type task than the usual verbal shadowing task (repeating items aloud as they are heard). Furthermore, Broadbent and Gregory do not report the accuracy with which their Ss "shadowed" the digits. Thus, they offer no behavioral evidence of how closely the Ss were attending to and shadowing the primary channel. Another methodological difference was the type of memory or detection task asked of the Ss for information presented to the secondary channel.

Presenting tones against a background of white noise lends itself to the signal detection analysis they used, but it does not coincide with the experimental situation employed in the majority of the DL studies.

A finding growing out of the methodological orientation of most DL studies has been what is called ear asymmetry. Specifically, researchers have found when _S_s are dichotically presented pairs of items (either digits or words), the information presented to the right ear is remembered better than that presented to the left for right-handed _S_s (Satz, Achenbach, Pattishall, and Fennell, 1965; Bryden, 1964; Kimura, 1961; Borkowski, Spreen, and Stutz, 1965; Bartz, Satz, Fennell, and Lally, 1967). Although ear asymmetry is usually interpreted in terms of certain physiological attributes (Roberts, 1964; Satz, Achenbach, Pattishall, and Fennell, 1965), recent evidence (Johnson, 1967) suggests ear asymmetry may be the result of a habit factor since it appears to disappear with practice. Nonetheless, ear asymmetry is a factor that should be controlled for in DL experimentation. Since Broadbent and Gregory (1963) failed to do so, the present study controlled for possible differences in ears by giving _S_s a considerable amount of practice in the task and by counterbalancing among the _S_s which ear was shadowed first in the experimental manipulations.

Therefore, this experiment employed a DL situation which was more in line with techniques and procedures used in other DL studies. Instead of Ss listening to a string of items, remembering them, and then writing them down, the more usual shadowing technique of having Ss repeat items aloud as they are presented was used. Also, the stimulus materials were all from the spoken English language. The method used to test for detection and memory for items presented to the secondary ear was a recognition procedure. After the presentation of a series of items, a test item was given and S was to decide whether or not that particular item had just been presented. The use of this method of testing for memory allowed the use of the signal detection theory measures which separates each S's responses into a sensitivity component and a response bias component.

Another question of interest was the effect that verbal shadowing has on the performance observed in DL shadowing studies. Perhaps verbal shadowing (repeating items aloud as they are heard) may constitute two listening tasks for the S instead of one. The S must not only monitor and repeat aloud information presented to one ear, but he must also generate and listen to his own reproductions of that information. Possibly, using another type of shadowing task may yield somewhat different findings. Therefore, a "motor" shadowing task was devised wherein the S was asked to shadow the information in one channel by moving the appropriately labeled toggle switch on a display panel in front of him. Although the motor shadowing task also required monitoring of reproduction performance by the Ss to assure the desired response has been made, the monitoring task does not involve a "second" listening task.

If the Broadbent and Gregory (1963) data were to be replicated, it was expected that the signal detection sensitivity measure would show more sensitivity when Ss were asked to both shadow and do the recognition task. The signal detection response bias measure was not expected to change if the Broadbent and Gregory data were applicable. If the Norman (1969) and Deutsch and Deutsch (1963) theoretical position was to be supported, the opposite findings were expected. Sensitivity was not expected to change whether shadowing or not. But, response bias was expected to change with shadowing conditions. No prediction of the results of the comparison between motor and verbal shadowing was made.

METHOD

Subjects

Six Iowa State University undergraduate volunteers were paid for serving as Ss. Each S was right-handed and reported no history of hearing defects. Handedness was determined both by verbal report of each S and by E observing which hand was used to write by each S.

Stimulus materials

The Ss were dichotically presented six pairs of items. The first five items presented to one ear were all letters and were chosen randomly without replacement from the following set of letters--B, C, F, G, H, K, M, Q, R, and S. The letters were chosen from the Conrad (1964) norms to attempt to keep acoustic confusions at a minimum. The first five items presented to the other ear were all color names randomly chosen without replacement from a set of ten--BEIGE, BLUE, BROWN, GREEN, GOLD, GREY, ORANGE, PINK, RED, and TAN. The last items presented to each ear were recognition test items from the opposite class of stimuli.

The trials were dichotically recorded by first marking a recording tape with a clearly visible mark at what would be one second intervals. The recorder was operated at the speed of 3 and 3/4 inches per second so a group of six marks were made at intervals of 3 and 3/4 inches on the recording tape. A gap of 22 and 1/2 inches (six seconds) was left between each group of six marks. Then, one channel of the tape was recorded by speaking an item when one of the marks on the recording tape passed a fixed point on the recorder. The other channel was also recorded using the same procedure. The items were checked for simultaneity of presentation by playing the recording and observing the VU meters for both channels of the recorder. If the indicating needles of the VU meters appeared to E to move simultaneously with the onset of items in each channel, the trial was used as originally recorded. If the indicating needles of the VU meters appeared to move at different times, the trial was re-recorded until simultaneity was observed. Four tape recordings were made using this procedure. After one recording was recorded and checked, a duplicate recording was recorded off of the marked tape. The marked tape was then erased and used to make another recording.

Design

Six pairs of items were presented dichotically at the rate of one pair per second. Immediately following the fifth pair of items, a pair of test items was presented. The last item presented to the ear to be shadowed was the test item for that particular experimental trial and of the opposite stimulus type. For example, if S were shadowing letters the last item presented to that ear would be a color name. S would then respond indicating whether this (last) color name had appeared previously in the list presented to the opposite ear. The Ss were instructed to ignore the last item presented to the ear to be monitored. Constructing the tapes by recording two test items for each trial cut in half the number of tapes needed. The type of item to be shadowed was counter-balanced among the trials so that half of the time Ss were shadowing letters and monitoring color names while the other half of the time they were shadowing color names and monitoring letters.

Three types of shadowing conditions were employed. Under one set of conditions (verbal shadowing), Ss were instructed to verbally shadow aloud items presented to one ear and to monitor the items presented to the other. In a second set of conditions the Ss were asked not to shadow at all, but only to monitor one ear and make the recognition decision (the no shadowing condition). For the third task, the motor shadowing task, Ss were seated in front of a display panel which contained a row of ten toggle switches. Above each toggle switch were two labels: a letter and a color name. Both were typed in capital pica type characters. The letters and color names were both arranged in alphabetical order from left to right. To indicate a particular item had been heard, the S switched a SPDT toggle switch to its opposite position.

Moving the switch turned on a small light visible only to E and indicated that that particular item had been shadowed. E then moved a second SPDT toggle switch on his side of the panel which switched off the light thereby making that particular circuit ready for the next trial.

In addition to the shadowing task, the Ss were to monitor the items presented to the opposite ear. Recognition for items presented to the monitored ear was tested by presenting one item (a test item) and asking the Ss to decide whether or not that particular item had been heard. In order to obtain the signal detection measures of sensitivity and response bias Ss were asked to make a "yes-no" response as to whether or not a test item had been presented and to simultaneously give a certainty rating of their response. This was accomplished by having the Ss respond using a 1 to 99 rating scale where: 1 to 49 meant "no" the test item had not been presented with progressively less confidence, 50 was a "don't know" response, and 51 to 99 indicated "yes" the test item had been presented with progressively increasing confidence. A six second inter-trial interval was allowed for Ss to record their rating response with more time given if needed by stopping the tape recorder.

The probability of occurrence of the test item in the ear to be monitored was .50 with each of the five serial positions being tested an equal number of times. The trials consisted of 14 tests for each of the five serial positions of the items to be monitored when the test item was present; seven trials were composed of color names to be monitored and seven made up of letters. Seventy trials were recorded when the test item was not presented to the ear to be monitored. Thus, 140 experimental trials were used and the presence or absence of the test items in the monitored ear was randomly ordered among the 140 trials. Four such sets of 140 trials were recorded. One set was used exclusively for practicing the Ss in the various tasks. The three other sets of 140 trials were used for the experimental trials--one for each of the three different shadowing conditions. Each of the three tapes were randomly assigned to two Ss in each of the shadowing conditions so that the particular arrangement of stimuli on the separate tapes was not confounded with shadowing conditions.

Each S shadowed with one ear once through the set of 140 trials and then shadowed the other ear through the same 140 trials after a three to five minute break. Whether the right or left ear was shadowed first was counterbalanced among the six Ss as well as among the three sets of experimental trials.

Thus, the design was a within factorial design across six Ss: 3 (type of shadowing: verbal, motor, or no shadowing) X 2 (ears: shadowing the right or the left ear) X 2 (stimulus materials: shadowing letters or color names) X

5 (serial position: serial positions 1 through 5) X 2 (present or absent: whether the test item was or was not presented to the ear being monitored) X 7 (number of observations per cell).

Procedure

The tape recordings were recorded and played on a Wollensak 5730 stereo tape recorder and were presented to each S via Koss Pro-4 headphones.

The basic task of the Ss was to shadow the items presented to one ear and to monitor the items presented to the other. The last item presented to the shadowed ear was the test item for the monitored ear on each trial. Each S was to decide whether or not that particular item had just been presented to the monitored ear and to simultaneously give a certainty rating of his response. Each S received 2 one-hour practice sessions of verbal shadowing and 1 one-hour practice session in the motor shadowing task. One set of 140 trials was used exclusively for all practice sessions.

The Ss were instructed to shadow as well as they possibly could and were told their pay would be determined by their shadowing performance. That is, they were told their wage would be based on a 95% correct shadowing rate and, that if their shadowing performance dropped below 95%, their wage would decrease proportionately. However, only data from trials where Ss made no mistakes in shadowing were, in fact, included in the analysis. Therefore, when errors in shadowing were made, extra trials randomly selected from another tape were given until a full set of the appropriate 140 trials was obtained. (Most Ss were shadowing so accurately that only a few extra trials were needed.)

One experimental session consisted of 280 trials in two blocks of 140 trials each. Each block of 140 was separated by a rest interval of three to five minutes. The S shadowed the first block of trials with one ear and the second block with the other. Each S participated in three practice sessions (two for verbal shadowing and one for motor shadowing) and three experimental sessions (one for each of the shadowing conditions).

Scoring and analysis

Shadowing performance was scored by E by marking trials where errors were made. Omissions, mispronounciations, and shadowing words out of order were considered to constitute errors in shadowing.

The Ss' rating responses were transformed to control for the tendency of individuals to make finer discriminations between successive points towards the middle of the scale than towards the extremes. The transformation used was the arc sine $\sqrt{P}$ transformation which has the effect of homogenizing the scale. The proportions necessary to use the transformation were obtained by simply dividing each rating obtained from the 99 point scale by 100.

Average percentages of correct recognitions were also computed for several of the manipulations. This was defined as the combined average percentage of saying "yes" when the test item had been presented and of saying "no" when the test item had not been presented.

A 3 (type of shadowing) X 2 (ears) X 2 (type of stimulus materials) X 5 (serial position) analysis of variance was conducted separately for when the test item was present and when it was absent for each S. A signal detection type of analysis was also conducted so as to separate each S's responses into a sensitivity and a response bias component. This will be described in detail later.

RESULTS

The results of the analyses of variance are summarized in Table 1. Examination of Table 2 which summarizes the

Table 1. Summary of analyses of variance for each S

ANALYSIS OF VARIANCE FOR S_1 - TEST ITEM PRESENT

Source	df	MS	F	p
A (type of shadowing)	2	2.062	24.498	<.01
B (ears)	1	0.001	.006	
C (stimulus materials)	1	2.324	27.614	<.01
D (serial position)	4	.101	1.198	
AB	2	.311	3.698	
AC	2	.443	5.262	<.01
AD	8	.226	2.681	
BC	1	.016	.193	
BD	4	.109	1.289	
CD	4	.073	.864	
ABC	2	.772	9.167	<.01
ABD	8	.148	1.757	
ACD	8	.076	.898	
BCD	4	.014	.170	
Error	368	.084		
TOTAL	419			

ANALYSIS OF VARIANCE FOR S_1 - TEST ITEM ABSENT

Source	df	MS	F	p
A	2	9.467	214.362	<.01
B	1	.012	.261	
C	1	.026	.594	
D	4	.035	.784	
AB	2	.053	1.200	
AC	2	.074	1.681	
AD	8	.028	.628	
BC	1	.013	.286	
BD	4	.029	.664	
CD	4	.024	.543	
ABC	2	.032	.716	
ABD	8	.036	.815	

Table 1 (Continued)

Source	df	MS	F	p
ACD	8	.022	.499	
BCD	4	.035	.784	
Error	368	.044		
TOTAL	419			

ANALYSIS OF VARIANCE FOR S_2 - TEST ITEM PRESENT

Source	df	MS	F	p
A (type of shadowing)	2	2.731	25.660	<.01
B (ears)	1	.132	1.238	
C (stimulus materials)	1	.061	.576	
D (serial position)	4	2.164	20.333	<.01
AB	2	.466	4.382	
AC	2	.066	.619	
AD	8	.425	3.994	
BC	1	.016	.148	
BD	4	.084	.786	
CD	4	.073	.690	
ABC	2	.059	.557	
ABD	8	.104	.980	
ACD	8	.205	1.925	
BCD	4	.218	2.048	
Error	368	.106		
TOTAL	419			

ANALYSIS OF VARIANCE FOR S_2 - TEST ITEM ABSENT

Source	df	MS	F	p
A	2	10.746	133.451	<.01
B	1	.032	.400	
C	1	2.014	25.008	<.01
D	4	.026	.325	
AB	2	.478	5.938	<.01
AC	2	.160	1.991	
AD	8	.080	.996	
BC	1	.0002	.003	
BD	4	.022	.279	
CD	4	.036	.442	
ABC	2	.009	.113	
ABD	8	.042	.520	
ACD	8	.037	.465	
BCD	4	.078	.974	
Error	368	.081		
TOTAL	419			

Table 1 (Continued)

ANALYSIS OF VARIANCE FOR S_3 - TEST ITEM PRESENT

Source	df	MS	F	p
A (type of shadowing)	2	3.654	24.803	<.01
B (ears)	1	.020	.134	
C (stimulus materials)	1	2.227	15.118	<.01
D (serial position)	4	1.152	7.820	<.01
AB	2	.436	2.960	
AC	2	.119	.808	
AD	8	.225	1.525	
BC	1	.083	.566	
BD	4	.163	1.110	
CD	4	.410	2.781	
ABC	2	.318	2.159	
ABD	8	.084	.569	
ACD	8	.-18	.800	
BCD	4	.334	2.266	
Error	368	.147		
TOTAL	419			

ANALYSIS OF VARIANCE FOR S_3 - TEST ITEM ABSENT

Source	df	MS	F	p
A	2	6.234	36.882	<.01
B	1	.232	1.374	
C	1	.054	.318	
D	4	.059	.351	
AB	2	1.155	6.832	<.01
AC	2	.900	5.323	<.01
AD	8	.032	.192	
BC	1	.479	2.832	
BD	4	.017	.101	
CD	4	.017	.100	
ABC	2	.074	.435	
ABD	8	.069	.408	
ACD	8	.084	.497	
BCD	4	.052	.306	
Error	368	.169		
TOTAL	419			

Table 1 (Continued)

Source	df	MS	F	p
A (type of shadowing)	2	4.027	36.269	<.01
B (ears)	1	.106	.955	
C (stimulus materials)	1	.850	7.653	<.01
D (serial position)	4	1.115	10.038	<.01
AB	2	.181	1.634	
AC	2	.096	.867	
AD	8	.746	6.718	<.01
BC	1	.071	.636	
BD	4	.093	.841	
CD	4	.072	.649	
ABC	2	.610	5.490	<.01
ABD	8	.056	.504	
ACD	8	.116	1.048	
BCD	4	.078	.702	
Error	368	.111		
TOTAL	419			

ANALYSIS OF VARIANCE FOR S_4 - TEST ITEM ABSENT

Source	df	MS	F	p
A	2	8.352	81.977	<.01
B	1	.889	8.723	<.01
C	1	.878	8.615	<.01
D	4	.062	.608	
AB	2	.033	.327	
AC	2	.319	3.132	
AD	8	.058	.569	
BC	1	.007	.064	
BD	4	.028	.270	
CD	4	.128	1.252	
ABC	2	.006	.064	
ABD	8	.053	.521	
ACD	8	.100	.979	
BCD	4	.172	1.689	
Error	368	.102		
TOTAL	419			

Table 1 (Continued)

ANALYSIS OF VARIANCE FOR S_5 - TEST ITEM PRESENT

Source	df	MS	F	p
A (type of shadowing)	2	1.216	22.577	<.01
B (ears)	1	.848	15.754	<.01
C (stimulus materials)	1	.483	8.973	<.01
D (serial position)	4	1.786	33.181	<.01
AB	2	.195	3.616	
AC	2	.001	.023	
AD	8	.105	1.942	
BC	1	.029	.548	
BD	4	.012	.224	
CD	4	.019	.355	
ABC	2	.105	1.955	
ABD	8	.095	1.769	
ACD	8	.073	1.359	
BCD	4	.073	1.351	
Error	368			
TOTAL	419			

ANALYSIS OF VARIANCE FOR S_5 - TEST ITEM ABSENT

Source	df	MS	F	p
A	2	2.084	78.040	<.01
B	1	.110	4.136	
C	1	.137	5.139	<.01
D	4	.008	.296	
AB	2	.101	3.778	
AC	2	.009	.322	
AD	8	.028	1.034	
BC	1	.219	8.196	<.01
BD	4	.018	.677	
CD	4	.080	2.978	
ABC	2	.014	.523	
ABD	8	.007	.275	
ACD	8	.025	.926	
BCD	4	.042	1.586	
Error	368	.027		
TOTAL	419			

Table 1 (Continued)

ANALYSIS OF VARIANCE FOR S_6 TEST ITEM PRESENT

Source	df	MS	F	p
A (type of shadowing)	2	9.220	139.386	<.01
B (ears)	1	.307	4.641	
C (stimulus materials)	1	1.524	23.034	<.01
D (serial position)	4	1.798	27.174	<.01
AB	2	.067	1.020	
AC	2	.166	2.512	
AD	8	.194	2.935	
BC	1	.006	.087	
BD	4	.060	.914	
CD	4	.008	.120	
ABC	2	.016	.692	
ABD	8	.223	3.375	
ACD	8	.042	.638	
BCD	4	.067	1.020	
Error	368	.066		
TOTAL	419			

ANALYSIS OF VARIANCE FOR S_6 TEST ITEM ABSENT

Source	df	MS	F	p
A	2	6.243	118.156	<.01
B	1	.192	3.627	
C	1	.010	.181	
D	4	.082	1.543	
AB	2	.173	3.275	
AC	2	.018	.349	
AD	8	.062	1.164	
BC	1	.001	.012	
BD	4	.018	.342	
CD	4	.025	.427	
ABC	2	.024	.464	
ABD	8	.042	.792	
ACD	8	.016	.312	
BCD	4	.039	.737	
Error	368	.053		
TOTAL	419			

Table 2. The error mean squares and standard deviations for each S for both present and absent conditions

S	TEST ITEM PRESENT		TEST ITEM ABSENT	
	EMS	S	EMS	S
1	.0842	.290	.0442	.210
2	.1064	.326	.0805	.284
3	.1473	.384	.1690	.411
4	.1110	.333	.1019	.319
5	.0538	.232	.0267	.163
6	.0662	.257	.0528	.230

error mean squares of the analyses for each S indicated it would be inadvisable to pool Ss for a combined analysis. These variance estimates showed that Ss varied considerably among themselves in their use of the rating scale. Furthermore, two Ss varied considerably in their use of the scale when the test item was present as compared to when it was absent while others showed smaller differences. The statistic described in Winer (1962) for combining several independent tests of the same hypothesis was used to obtain an over-all probability statement concerning the significance of the various main effects and interactions for test item present and absent. The inference associated with this statistic, may, at times, be different from the usual inference associated with significance tests. For example, the test for relative sensitivity of the two ears will be significant either if each S responds similarly or if the more sensitive ear is conditional on the S.

Using the statistic described above for combining the

Ss' data (Winer, 1962), the type of shadowing task was found to interact with which particular ear was shadowed to significantly affect performance, χ^2 (12) = 23.81, $p<.05$, and χ^2 (12) = 35.15, $p<.01$, for the present and absent conditions respectively. Generally, small differences in recognition performance between the ears were noted under the motor and no shadowing conditions. This is reflected in the average percentage of correct recognitions which is the average percentage of saying "yes" when the test item was present and of saying "no" when the test item was absent. These percentages were 75% and 73% on the motor shadowing task and 92% and 93% under the no shadowing condition for the left and right ears respectively. On the verbal shadowing task recognition performance was higher and the Ss showed somewhat greater confidence in their responses when shadowing the left ear and monitoring the right than vice versa. The average percentage of correct recognitions showed that 76% of the items were correctly recognized when monitoring with the right ear as compared with 70% when monitoring with the left ear.

The main effect of type of shadowing task was significant across Ss, χ^2 (12) = 41.55, $p<.01$, for both present and absent conditions. The Ss generally displayed greater confidence in their responses and a higher average percentage of correct recognitions when they did not have to shadow. There were no large, consistent differences in performance between the verbal and the motor shadowing tasks when summing across ears. Across the shadowing conditions, a small ear asymmetry effect was noted when the test item was absent, χ^2 (12) = 24.22, $p<.05$. Ss tended to exhibit somewhat greater confidence and more accurate recognition performance when shadowing the left ear and monitoring the right ear than in the opposite case when the item was absent.

The type of stimulus materials being shadowed (or monitored) was found to differentially affect performance across Ss, χ^2 (12) = 66.31, $p<.01$, for the present condition and χ^2 (12) = 33.33, $p<.01$, for absent. The average correct recognition percentage was found to be 77% when color names were shadowed and letters were monitored. When letters were shadowed and color names monitored, the average correct recognition percentage was 83%. Also, the Ss tended to display more confidence in their responses by using a greater number of extreme ratings when shadowing letters (monitoring color names) than when shadowing color names (monitoring letters).

The position of the test item (when it was presented) in the series of five items presented to the ear to be monitored definitely affected performance, χ^2 (12) = 69.91, $p<.01$. (In the test item absent analyses ratings were randomly assigned to the various "positions" for purposes of the signal detection analyses to be described later.) The performance of all Ss was found to show both a primacy and a recency effect. Specifically, there was a tendency to use higher ratings for serial position 1 than for serial position 2, a primacy effect. For each serial position succeeding position 2, the ratings were found to gradually increase. A tendency for some Ss to use lower ratings for the last serial position than for serial position 4 was found. The serial position effect was also reflected in the average percentages of correct recognitions (when the item was present only) for each serial position. The percentage of 69% for serial position 1 compared to 66% for position 2 reflects a small primacy effect. The percentages of 78%, 86%, and 84% for serial positions 3, 4, and 5 respectively show an increase in performance with serial position with a small decline in performance on position 5 also being noted.

The second method of analysis proposed was to have been the usual signal detection analysis for recognition data. The assumptions of normal distributions of signal and noise and of equal variances of the distributions are basic to the application of the signal detection analysis incorporating likelihood ratios. However, the assumption of equal variances could not be met by the present data. For two of the Ss there were marked differences in the variances of their ratings when the test item was absent (noise) as compared to when the test item was present (signal). This was determined by looking at the error mean squares of the analyses of variance for each S and comparing these variance estimates for test item present and absent. These variances are shown in Table 2.

Since the distributions of ratings for test item present and absent were not equally variable for all the Ss, an index of sensitivity and of response bias which took these inequalities into account was considered to yield the most appropriate information. The sensitivity measure d' is usually defined as: $\frac{m_s - m_n}{\sigma}$ (Green and Swets, 1966) which is the same as: $\frac{m_s}{\sigma_s} - \frac{m_n}{\sigma_n}$ where $\sigma_s = \sigma_n$. When $\sigma_s \neq \sigma_n$, an index of relative sensitivity can be determined by: $\frac{m_s}{s_s} - \frac{m_n}{s_n}$ where s_s and s_n are estimates of the variance in responses for the signal and noise distributions respectively. By subtracting the two ratios one is effectively determining the area between the cumulative probability distributions of the ratings both when the test item was present and when it was absent. By adding $\frac{m_s}{s_s} + \frac{m_n}{s_n}$, a relative estimate of where along the various rating scale levels the S changed his criteria or biases for responding. These indexes of sensitivity (called d* here) and of response bias (called

$Beta_2$ here) are relative indexes directly based on the variability of rating responses of the Ss. This does not allow direct arithmetic comparisons among Ss across conditions for the indexes, but relative trends or changes in the indexes across experimental manipulations are possible. And, since the indexes are directly related to variability of responding, the absolute size of the measures will change with the variability of the two distributions. Estimating the variance for either distribution across several factors may yield estimates which result in negative d* indexes. However, if enough observations per cell are (had been) available, variance estimates based on each cell would not (have) yield(ed) such negative indexes. Greater sensitivity is reflected in the d* index by larger numbers. Larger numbers with the $Beta_2$ index reflect a greater willingness to respond "yes".

Using the d* and $Beta_2$ measures derived above, the sensitivity and response bias indexes were applied to several of the experimental manipulations. As has been pointed out elsewhere (Raser, 1969) the sensitivity index yielded the same general findings as the analyses of variance previously described. The d* measure showed that for the shadowing task by ears interaction, the sensitivity of the two ears was relatively the same on the motor and no shadowing tasks as is shown in Table 3. Under the verbal shadowing condition considerably more sensitivity was generally noted when Ss were monitoring with the right ear than with the left. Also,

Table 3. The sensitivity measure across Ss for the type of shadowing task (motor, verbal, and no) by ears (left and right) interaction

S	MOTOR		VERBAL		NO	
	L	R	L	R	L	R
1	-.29	-.16	-.05	.20	3.03	2.53
2	.68	.91	1.35	.59	2.98	3.64
3	1.28	.92	1.77	1.43	2.68	3.14
4	1.20	1.19	.26	-.10	2.89	2.27
5	-.76	-.42	1.41	.81	2.40	1.71
6	.83	.90	.81	.99	3.86	4.74
$\bar{d}*$	.49	.56	.92	.65	2.97	3.01

sensitivity generally increased somewhat on the verbal task compared to the motor task. A large increase in sensitivity was found on the no shadowing task as compared to the other shadowing tasks. The d* index also indicated Ss were more sensitive to the monitored ear when shadowing letters and monitoring color names than vice versa.

The sensitivity measures for each S over serial positions indicated the same general findings as shown by the analyses of variance as is shown in Table 4. The d* index exhibited a bow-shaped serial position curve for most Ss with some much

Table 4. The sensitivity values (d*) over serial position for each S

serial position	Ss 1	2	3	4	5	6	$\bar{d}$*
1	.76	1.25	1.78	.90	.56	1.56	1.14
2	.87	1.24	1.50	.89	.28	1.42	1.03
3	.83	1.64	1.72	1.16	.93	1.81	1.35
4	.90	2.07	2.20	1.49	1.36	2.54	1.76
5	1.04	3.24	2.15	1.79	1.85	2.59	2.10

more bow shaped than others. Some Ss showed little difference in sensitivity for serial positions 4 and 5 while others showed noticeable differences. Again, the same descriptive account obtained via the analyses of variance. The d* index did reflect one finding that was not evident from the analyses of variance however. Several of the Ss exhibited almost equal sensitivity to the first two serial positions while clear differences in sensitivity were found for other Ss.

The response bias or $Beta_2$ measure did reflect different trends of bias for the ears across the three shadowing conditions as is shown in Table 5. On the motor and the no shadowing tasks Ss generally showed a somewhat greater willingness to say "yes" when shadowing the left ear and monitoring the right. In contrast, under the verbal shadowing condition Ss generally showed a greater willingness to say

Table 5. The response bias measure across Ss for the type of shadowing task (motor, verbal, and no) by ears (left and right) interaction

S	MOTOR		VERBAL		NO	
	L	R	L	R	L	R
1	6.55	7.01	6.73	6.65	5.42	5.22
2	5.59	5.49	5.28	5.59	4.40	4.69
3	4.04	4.86	4.45	4.19	4.30	4.19
4	6.65	5.59	4.19	5.03	7.16	6.07
5	5.42	4.40	4.30	4.51	7.61	6.28
6	5.22	4.69	4.19	4.77	7.91	6.21
$\overline{\text{Beta}}_2$	5.58	5.34	4.86	5.12	6.13	5.44

"yes" when shadowing the right ear and monitoring the left. Across the shadowing conditions mixed changes in response bias were found. Generally, Ss were more willing to say "yes" on the no shadowing task than under the other shadowing conditions. There was some tendency toward Ss saying "yes" more often on the motor task than on the verbal task but the trend was not wholly consistent. Beta_2 changes associated with which type of stimulus material being shadowed were mixed. Almost all Ss showed either no bias or a greater willingness to say "yes" when shadowing letters. Response bias over serial positions generally exhibited a bow-shaped serial position curve in terms of willingness to respond as is shown in Table 6. Some Ss did display a greater willingness to say "yes" on serial position 4 than on serial position 5.

Table 6. The response bias values ($Beta_2$) over serial position for each S

		Ss						
		1	2	3	4	5	6	$\overline{Beta_2}$
serial position	1	6.32	4.77	4.34	4.80	7.48	5.82	5.59
	2	6.05	4.52	3.86	4.73	7.16	5.42	5.29
	3	6.09	5.24	4.30	4.84	7.95	6.53	5.83
	4	6.52	5.55	4.76	4.95	8.46	6.88	6.19
	5	6.34	5.80	4.45	5.53	8.65	6.71	6.25

DISCUSSION

A portion of the Broadbent and Gregory (1963) findings were replicated The signal detection analyses revealed that Ss showed greater sensitivity when they were not shadowing than when they were. However, the response bias index indicated that Ss also changed their response biases when they changed shadowing tasks. The previous findings of Broadbent and Gregory would not lead us to expect this outcome. They found no changes in response bias when Ss shifted from a shadowing to a no shadowing condition. Several procedural differences between the present experiment and the Broadbent and Gregory (1963) study could have produced the failure to replicate their findings entirely. First, it is possible that their detection task was less difficult than the recognition memory task employed here. They used as their attention dividing task the detection of a tone against a white noise background while shadowing and there might have been little reason to change the criterion for responding between the shadowing and no shadowing conditions. Also, Broadbent and Gregory did not report how accurately the Ss shadowed. In the present experiment only those trials where Ss shadowed perfectly were included in the analyses. Lastly, Broadbent and Gregory required their Ss to write down the six digits they had heard (the "shadowing" task) and then to make a detection response. The task here required Ss to actively shadow items immediately upon presentation. Thus, it would appear that the information processing requirements were greater in the present study and that a response bias shift might well be expected as Ss move from the tasks of both shadowing and making recognition judgements to the recognition task alone.

As is true of almost all "critical" prediction experiments, the findings here do not clearly favor one theoretical position over another. The changes in sensitivity replicate the Broadbent and Gregory (1963) findings and lend support to Treisman's notion of attenuation of signals as the governing mechanism of attention. The theoretical position held by Norman (1969) and Deutsch and Deutsch (1963) would predict the observed changes in response bias, but would also seem to predict sensitivity should not change. Thus, an eclectic position regarding the mechanisms and processes of selective attention currently seems most appropriate.

A significant procedural implication for DL studies of selective attention was revealed by the comparison of the verbal and the motor shadowing tasks. Taking into account the novelty and the limited amount of practice on the motor shadowing task, the findings indicate that both the verbal and the motor tasks used here require roughly the same amounts of information processing and monitoring for the Ss. Any type of shadowing task requires the S to process and recognize certain incoming information, produce a reproduction of the information in one form or another, and then to monitor his reproduction to insure it is the one that was intended. In retrospect it seems apparent that if two different shadowing tasks require handling roughly the same amounts of information there would not be great differences in performance observed due to type of shadowing. However, if the task requires shadowing "less" or "easier" information, then differences in performance might be expected to be directly related to the type of shadowing task. The comparison of the present findings with those of Broadbent and Gregory (1963) also suggests the type of shadowing task may directly affect performance. The DL selective attention situation is thus a complex one involving many relevant factors.

Another factor which affected performance was the type of stimulus material which was monitored and tested for recognition. As has been found in other types of short-term memory experiments (e.g., Mackworth, 1964), there were differences in performance dependent on whether letters or color names were monitored. Ss were generally found to be more sensitive and accurate when monitoring color names than when monitoring letters. It is erroneous, however, to attribute this finding to the hypothesis that it was "easier" to perceive and/or remember color names in the monitored channel than it was letters. It is just as possible that Ss could devote somewhat more time to perceiving and remembering color names because shadowing letters did not require as much "work". The particular design used in this study does not allow such inferences because different stimulus materials were always heard in the two ears. A suitable design to resolve this question would be one in which Ss shadowed letters while monitoring either color names or letters and shadowed color names while monitoring either color names or letters. This might allow some hypothesizing as to the processes underlying the findings observed in the present study. That is, whether the finding was due to the type of stimulus material being shadowed or being monitored or both. It is also possible that length of the presentation times of the letters and color names were unequal enough to have produced the differential performance. A recording procedure which insured equal presentation time of the stimuli such as chop-slicing the items (Yntema and Trask, 1963) would control for this possibility.

Another important theoretical and procedural finding is related to the ear asymmetry factor. As indicated previously, numerous studies (e.g., Bryden, 1964; Satz, Achenbach, Pattishall, and Fennell, 1965) have reported findings of ear asymmetry in DL studies in that information presented to the right ear is remembered better than that presented to the left. However, these studies typically have used very few trials (usually around 30) presented over short periods of time. A study by Johnson (1967) suggested that ear asymmetry in memory tasks while shadowing may be a habit factor since it disappeared with practice and that previous studies would not have found ear asymmetry had a greater number of trials been employed. Since Ss were given a considerable amount of practice in this experiment, ear asymmetry was not expected to significantly affect performance. However, the d* index did reflect fairly large ear asymmetry in sensitivity of the ears on the verbal shadowing task but not on the motor or no shadowing tasks for most Ss. In addition, ear asymmetry was not always in favor of greater sensitivity for the right ear; some reversals were found. Thus, it appears that sensitivity of the ears is in some manner related to the task requirements of verbal shadowing. Perhaps having to listen to one's own speech to monitor accuracy of shadowing constrains in some way the complex information processing carried out by the individual that relates to physiological factors such as speech lateralization (Kimura, 1961; Satz, Achenbach, Pattishall, and Fennell, 1965). Also, since Ss exhibited differences in response bias for each ear across all shadowing conditions, the findings suggest that a portion of the observed ear asymmetry effect was a function of individual reactions to the tasks and the strategies adopted by the Ss. The factors which underlie ear asymmetry appear to be complex and not entirely clear at this time.

A serial position effect was found. This effect has been found in numerous other short-term memory studies (e.g., Glanzer and Cunitz, 1966; Murdock, 1962; Raser, 1969) using a variety of different presentation procedures and methods of testing for memory. The analyses of variance indicated a bow-shaped serial position effect in terms of ratings for all Ss, with the effect being more pronounced for some than for others. Whatever the reasons for the curve, the finding was consistent and did not interact with other factors. The sensitivity and response bias indexes indicated that the sensitivity to the first two positions was not much different for some Ss. Yet, all Ss showed differences in response bias for the two positions with a greater willingness to say "yes" for position 1. Thus, the primacy effect in this study appears to have been primarily a function of the response biases of the Ss and not due to sensitivity differences.

The analyses of variance also revealed that for some Ss there were small differences in performance for serial positions 4 and 5. The reasons behind the finding are not obvious. The d* measure did indicate a general tendency for greater sensitivity for items presented in position 5 than for items presented in position 4. The $Beta_2$ index showed that when drops in performance occurred response bias also changed. When those Ss showed less of a willingness to respond "yes", ratings dropped.

Perhaps this recency effect finding is related to the manner and timing of the presentation of the test items. The test items were presented in the same rhythm as the other items. If the fifth item was being tested for recognition, some confusion was perhaps created by having the same item appearing twice in succession. Possibly the mere closeness of presentation mislead S into thinking at times he had heard the test item only once when it was presented as the test item. A greater time interval between the test and experimental items or presenting the test items visually would perhaps have eliminated this confusion.

In addition to the substantive implications of this research there is a methodological one which is highly important for the tenability of the above findings. The signal detection analysis has several basic assumptions underlying the use of the procedure which were not met here and seem to be over-looked relatively often in other experiments. Specifically, signal detection theory assumes that the signal and the noise distributions are normally distributed and, more importantly, have equal variances (Swets, Tanner, and Birdsall, 1961). Some departure from these assumptions is tolerable before the analysis becomes inappropriate (Green and Swets, 1966). But, when the variances are considerably different in magnitude, the rationale for the use of the analysis breaks down. Yet, some researchers do not appear to be concerned with whether or not their data meet the assumptions and proceed to use the analysis (e.g., Murdock, 1968). When the underlying assumptions are not met however, the signal detection measures are misleading and little confidence should be placed in them (Green and Swets, 1966).

Several alternatives are available when the assumption of equal variances is not met. One may simply ignore the fact and proceed with the usual analysis. Since some investigators fail to report even comparing the signal and the noise variances, it appears that a few researchers are perhaps unknowingly electing this alternative.

A second approach to determine a sensitivity index is also based on the computation of likelihood ratios as in the usual analysis. A curve called a MOC (memory-operating-characteristic) curve can be traced out by plotting the cumulative probabilities of hits to false alarms for each of various selected intervals of the rating scale. It can be shown that the more the means of the signal and the noise distributions differ, the larger will be the area under the MOC curve (Green and Swets, 1966). The general feeling of signal detection theorists seems to be that an index of response bias (Beta) is not directly computable in the unequal variance situation. Other information such as mean differences in confidence ratings for various treatment conditions must be used to obtain information regarding response bias changes.

A third alternative is to compute the indexes used here. These indexes adapt to unequal variances and should yield the same relative findings as the measures based on likelihood ratios when variances of the signal and the noise distributions are equal or approximately so. A question yet to be answered is how the various methods of computing sensitivity and response bias indexes compare. A study to directly compare the procedures for computing these indexes when variance estimates are available for each experimental manipulation is needed.

As originally planned, the present study was thought to involve a straightforward application of the signal detection analysis. However, the data did not conform to some of the underlying assumptions of signal detection theory as pointed out above. This raises the question of the applicability of the remaining assumptions of the signal detection analysis to recognition memory experiments. Since the recognition memory study requires memory of information first and then a decision regarding the presence of particular input, the recognition situation is at least one step removed from the perceptual detection task that was the foundation for the logic behind the signal detection measures. This experiment and that of Raser (1969) suggest that task requirements can greatly affect the response biases as well as the sensitivity to information. Thus, it is possible that the basic assumption of the response bias and the sensitivity measures does not hold in recognition memory experiments. Perhaps psychologists have been too willing to accept the psychophysical procedure as being directly applicable to memory experiments. A parametric study involving the thorough examination of the various procedures for computing the signal detection measures and the applicability of the analysis is needed.

ACKNOWLEDGMENTS

I would like to thank Dr. Wayne H. Bartz for his continued encouragement, sympathetic ear, and critical evaluation in the initiation and completion of this research. Dr. Leroy Wolins deserves a special thanks for his patient help with the statistical aspects of this research. I would also like to thank Drs. Ronald Peters, D. C. Edwards, and Harold Dilts for serving on my committee. Most of all I want to express my sincere appreciation to my wife, Janet, for her continued and optimistic encouragements and understanding during the writing of this manuscript.

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