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REACTION TIME IN FOCUSED AND IN DIVIDED ATTENTION

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The *S*s listened to dichotic lists of words and responded to animal names by pressing a key. Group 1 performed in a condition of focused attention to one of the messages and in a condition of divided attention, where both messages were relevant. Group 2 performed in focused attention and in a single-message condition. There were many more omissions in divided than in focused attention, and mean reaction time (RT) was prolonged. There was no difference in RT between focused attention and the single-message condition. The occurrence of an animal name in the irrelevant message occasionally caused errors. The results are consistent with an effort theory of attention.

Experimental evidence that has accumulated during the last twenty years demonstrates that it is extremely difficult to divide attention between two concurrent speech messages. Some theories of attention explain this difficulty on the assumption that simultaneous messages can only be analyzed serially. This idea is shared by filter theory (Broadbent, 1958, 1971; Treisman, 1964), which assumes a general limitation on perception, and by analyzer theory (Treisman, 1969; Treisman & Davies, 1973), which assumes that processing is necessarily serial within each analyzer system, although it may occur in parallel in different systems.

Other authors maintain that parallel processing of concurrent inputs is generally possible. Views differ, however, on the question of whether such parallel processes impose demands on a mechanism of limited capacity. Some theorists have implied that there is no limitation on parallel perceptual processing, and that the difficulty of dividing attention arises at the level of response organization and storage in permanent memory (Deutsch & Deutsch, 1963; Keele, 1973; Norman, 1968; Posner & Boies, 1971). According to an alternative theory (Kahneman, 1973), perceptual processes require effort and compete for a limited capacity. In this view, parallel processing of concurrent inputs is possible, but at a distinct cost in speed and effectiveness.

Much evidence that is relevant to these theories is already available. Thus, the assumption that perceptual processes are parallel and effortless implies that it should be easy to watch for a particular target word, or class of words, in two concurrent messages. Contrary to this position, it has been shown that when *S* shadows one of two messages that are simultaneously presented to his two ears, he finds it easy to detect a target word embedded in the shadowed message, but not in the other (Treisman & Geffen, 1967; Treisman & Riley, 1969). On the other hand, there is also evidence against filter theory. Thus, it has been shown that some parallel processing occurs even in a situation where *S* intentionally focuses attention on one of the concurrent messages (Corteen & Wood, 1972; Greenwald, 1970; Lewis, 1970). A study by Treisman (1970, Experiment 5) provides particularly strong evidence for parallel processing. She measured reaction time (RT) for the decision of whether an item is a digit or a letter. Reaction time was reduced by informing *S* in advance of which digit he should watch for, and the reduction was the same (115 msec.), regardless of whether *S* performed a digit–letter discrimination on one item or on a pair of simultaneous items. This finding suggests that the decision that an item is or is not a digit can be made in parallel for two simultaneous inputs. Simultaneous decisions on two items were slower, however, as might be expected from an effort theory.

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In the experiments reported in this paper, we studied RT for the detection of animal names in a word list under three conditions. For one group of *S*s, different lists of words were presented to the two ears, and *S*s were required either to focus their attention on one ear or to divide attention between the two ears. Another group of *S*s performed in the condition of focused attention and in a condition where a single message was presented to one ear. Different theories of attention entail different predictions for the comparison between the various conditions.

Consider the condition of divided attention. A theory which assumes that parallel processing is automatic, complete, and effortless suggests that performance in divided attention should not differ materially from performance in focused attention. If the activities of processing the two inputs do not interact, there is no reason to expect a slowing of RT or other evidence of interference in divided attention, since the present design never requires more than one response at a time.

In contrast, a filter theory entails a difference between the mean RT in focused and in divided attention. A long RT is expected whenever *S* is not attending to the correct channel at the critical time and only recovers the target word in a subsequent search of buffer storage. A substantial number of omissions is also expected. However, filter theory implies that RT to the target will sometimes be as fast in divided as in focused attention, if *S* happens to be attending the correct channel at the instant the target is presented. Like filter theory, an effort theory implies an impairment of performance in divided attention, but the two theories lead to different predictions concerning the details of the RT distribution. While filter theory assumes that *S* in divided attention is sometimes in the same state as if he were focusing attention, effort theory proposes that the two states are consistently different. Consequently, filter theory entails that some of the responses in divided attention will be as fast as the fastest responses in focused attention. Effort theory entails that there should be no overlap between the two distributions in the range of fast RTs.

Method

Subjects. All *S*s were first-year psychology undergraduates fulfilling a course requirement. All were right-handed and without gross hearing defects. There were 36 *S*s in Group 1 and 8 in Group 2.

Equipment. A Revox two-channel tape recorder was used to present the stimuli through stereophonic headphones.

Materials. A total of 45 dichotic lists were recorded. Each list consisted of a warning tone, followed—after approximately 2 sec.—by 10 pairs of different words to the two ears, read by the same female speaker at a rate of 2 pairs/sec. All words were bisyllabic Hebrew words with the accent on the second syllable. The duration of each word was 300–400 msec., and the average asynchrony of onset between concurrent words was about 20 msec.

Within each list of 10 pairs of words, there were two names of animals, one in each ear. The animal names were inserted in Serial Positions 5, 6, 7, 8, or 9. The two animal names were never presented simultaneously. On the average, the first animal name was presented in Position 6, and the second in Position 8. Only 20 names of animals were used. Each name was presented once to the right ear and once to the left ear in each half of the experiment. The other words in the lists were of high frequency, matching the average frequency of the animal names (Mehlman, Rosen, & Shaked, 1960).

Design and procedure. There were three experimental conditions, described below.

1. Divided attention: The *S* was instructed to listen to the words on both ears, to press a response key as soon as he heard the name of an animal, and afterward to report the name that he had heard. Only the first animal name in the message was responded to. No opportunity was given to correct errors, and no feedback was given on RT or errors.

2. Focused attention: The *S* was told before each trial which message (right or left) was relevant for that trial. In half of the series, an animal name occurred in the irrelevant list prior to the presentation of the target.

3. Single-message: A single message was presented to one ear. The *S* was told before each trial which ear was relevant, but he was not informed of whether an irrelevant message would be presented to the other ear.

The 36 *S*s in Group 1 performed in the conditions of divided and focused attention. The 8 *S*s in Group 2 performed in the conditions of focused attention and single message.

Both groups had 5 practice trials and 40 experimental trials. The experimental trials were divided equally between the two task conditions, which appeared in quasi-random order. In the condi-

TABLE 1

Error Rates in Groups 1 and 2

Condition[a]	Type of error		
	Omission	False alarm	Response to incorrect channel
Group 1			
Divided	23.1	3.0	—
Focused (1)	2.8	1.4	—
Focused (2)	4.4	3.0	2.5
Focused (total)	3.6	2.2	1.3
Group 2			
Single message	5.0	—	—
Focused (1)	5.0	—	—
Focused (2)	11.3	—	—
Focused (total)	8.1	—	—

Note. Error rate percentages are computed from the number of trials in each condition.
[a] In the focused (1) condition, the target was the first animal name on either message. In the focused (2) condition, the target was preceded by an animal name on the irrelevant message.

tions of focused attention and single message, the relevant message was presented with equal frequency to each ear. Four different sequences of instructions were used for Group 1, so that each recorded message was presented for divided attention to half of the *S*s and for focused attention to the others, with a further subdivision to ensure that the left-ear message and the right-ear message were relevant for an equal number of *S*s. Similar precautions were taken for Group 2, so that each message was relevant equally often in the conditions of focused attention and single message.

Measurement of reaction time. The warning tone that preceded each message started the reaction timer, which was stopped by *S*'s key press. The time between the warning tone and the beginning of the target word was precalibrated to an accuracy of about 10 msec. by feeding the output of the tape recorder to a high-speed pen writer. The values of RT were adjusted to the beginning of the target word.

Results

Group 1. Table 1 presents the frequency of various types of errors under the different experimental conditions. It is apparent that omissions were far more frequent in divided attention than in focused attention, t (35) = 13.27, $p < .01$. In focused attention, there were more omissions when the target was preceded by an animal name on the irrelevant ear than when it was not, t (35) = 2.55, $p < .05$. There were no significant differences between conditions in the incidence of errors of identification or false alarms. All such errors preceded the occurrence of an animal name in either series. There was no significant effect of the ear to which the target was presented.

The mean reaction time of correct responses was 605 msec. (SD = 85 msec.) in focused attention, and 741 msec. (SD = 85 msec.) in divided attention, t (35) = 11.89, $p < .001$. All but 2 of the 36 *S*s had a longer RT in divided attention. In the focused attention condition, mean RT was 597 msec. when the target was preceded by an animal name on the irrelevant ear, and 616 msec. when the target was the first animal name to appear in either message, t = 1.99, *ns*. Additional analyses indicated that mean RT did not vary with the serial position of the target in the list, and that there was no significant difference between latencies of response to targets presented to the right or to the left ear.

Figure 1 presents the mean percentage of RT's falling in successive intervals of 50 msec. above and below the mean RT of each *S* in the conditions of focused and divided attention. The two distributions are quite similar, although the distribution of RTs for divided attention is slightly more variable and more skewed than the distribution of RTs under focused attention. The greater variability of RT in divided attention is a consistent result: The mean standard deviation within the data of individual *S*s was 186 msec. in this condition, which compares to 145 msec. for focused attention, t (35) = 3.72, $p < .01$.

As indicated in the introduction, the critical test between filter theory and effort theory involves the frequency of very fast reactions in divided attention. The close similarity of the distributions in Figure 1 (after adjustment for a mean difference of 136 msec.) indicates that there is very little overlap between unadjusted distributions in the range of fast RTs. Detailed analysis of individual distributions confirms this impression. For each individual, we computed the percentage of responses in divided attention that fell within the range defined by the three fastest responses in focused attention. On the average, this range con-

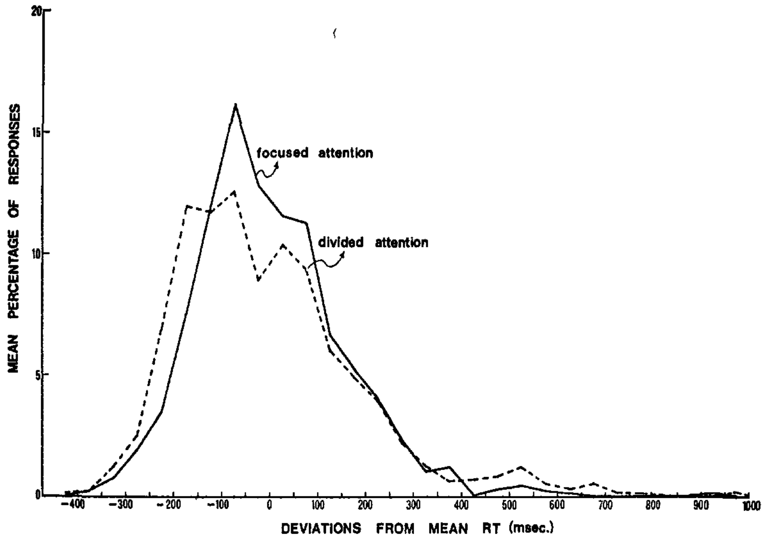

FIGURE 1. Distribution of latencies of correct responses, adjusted to the individual means under the two experimental conditions in Group 1.

tained 14% of the RT distribution in focused attention, but only 3.4% of the RT distribution in divided attention. For 25 of 36 *S*s, there were no responses in divided attention that were as fast as any of the three fastest responses in focused attention. In addition, we compared the means of the three fastest responses in the two conditions. The difference between the means was 121 msec., which is almost as large as the difference between the means of the total distributions.

Group 2. The error rates for this group are shown in Table 1. Five of the eight *S*s made more errors in focused attention than in the single-message condition, one made more errors in the single-message condition, and two made the same number of errors in both conditions. The mean correct reaction time in both conditions was 480 msec., and the standard deviations were 58 msec. in the focused attention condition and 45 msec. in the single-message condition. We have found no explanation for the difference between Groups 1 and 2 in their RT with focused attention. The two groups were run at different times, but the experimental conditions were similar.

DISCUSSION

The pattern of errors in both Groups 1 and 2 suggests that a relevant item is sometimes detected even when it appears in the rejected message in focused attention: An animal name in that message elicited a response on 3% of trials and prevented the response to a subsequent relevant target on perhaps 4%–6% of trials. When a target did elicit a correct response, however, that response was undelayed: Neither the presence of an irrelevant message nor the occurrence of an animal name on that message had a significant effect on RT. Thus, focusing attention was effective but not perfect in the present experiment.

The critical results of this study were obtained in the condition of divided attention. These results are not compatible with filter theory or with a theory which assumes that the processing of concurrent inputs occurs in parallel and without interference (Keele, 1973).

According to filter theory, an alert listener can be in one of four states when a target word arrives, say, on his right ear: he may be attending to the right ear or to the left ear, or he may be in transit from one channel to the other. The probability of detecting the target and the reaction time to a detected target will both vary, depending on the listener's state when the target is presented.

It is possible to derive precise predictions from filter theory if we make the simplifying assumption that the time required to switch between channels is negligible, relative to the dwell time on each channel. If S is always attending to one of the two channels, the probability that he is attending to the correct channel when the target is presented is .50. The error data for focused attention show that the probability of responding to a target on an attended channel is .96. Since the omission rate in divided attention is .23, it follows that the probability of responding to a target on an unattended channel is $2(.77 - .50 \times .96)$, or .58. It follows that 62%—or $.96/(.96 + .58)$—of all the responses made in divided attention represent cases in which the correct channel was attended at the critical time. Since this class of responses is undistinguishable from the responses made in focused attention, the probability of a fast response in divided attention should be at least .62 times as high as the probability of an equally fast response in focused attention. In fact, as was shown earlier, the ratio of the probabilities of fast responses in the two conditions is much lower. When the responses in divided attention were compared to the three fastest responses in focused attention, the observed ratio was 3.4/14.0, or .24.

The ratio predicted from filter theory will be lower if it is assumed that switching time is not negligible when compared to dwell time. On this assumption, the listener can be in any one of four states at the critical time, and his response in three of these states will be slower than when he attends to the correct channel. To generate the observed results, however, requires the implausible assumption that well over half of the listener's time is spent switching from one channel to the other. Thus, it appears that filter theory cannot account for the present results.

The results of the present experiment are also incompatible with the version of filter theory proposed by Moray (1969), in which both switching time and dwell time are assumed to be negligible, except that dwell time is prolonged when a significant stimulus is detected on a channel. This theory fails to predict the major difference in RT between the conditions of focused and divided attention which was observed in our results.

The different RT observed in focused and in divided attention also poses a difficulty for theories which assert that simultaneous inputs can be analyzed in perception without interference (Deutsch & Deutsch, 1963; Keele, 1973; Norman, 1968; Posner & Boies, 1971). In the present experiment, the condition of divided attention was clearly more difficult than the condition of focused attention. Since the response requirements of the two conditions are precisely the same, the difficulty in divided attention must arise at an earlier stage of processing, e.g., perceptual analysis, memory retrieval, or decision.

The conclusion that interference arises at these early stages of processing is consistent with a view of attention as a commodity which is available in limited quantity, and which can be allocated with considerable flexibility to a single activity or to several activities in parallel, if this is required by the task (Kahneman, 1973). In this view, the allocation of attention to some stimuli in preference to others increases the likelihood that these stimuli will activate corresponding units in memory and will be recognized. Only "spare" capacity is allocated to stimuli that are designated as irrelevant, and the likelihood that such stimuli will activate recognition units is correspondingly reduced. When a significant item on the irrelevant message is nevertheless recognized, attention is drawn to it, and the processing of the relevant message suffers. In the condition of divided attention, several distinct stimuli are attended at once, and all suffer from the competition for the limited capacity. The results of the present study support the conclusion that parallel processing of concurrent speech inputs is neither impossible, as suggested by some theories, nor compulsory and effortless, as suggested by others.

REFERENCES

Broadbent, D. E. *Perception and communication.* London: Pergamon Press, 1958.

Broadbent, D. E. *Decision and stress.* London: Academic Press, 1971.

Corteen, R. S., & Wood, B. Autonomic responses to shock-associated words in an unattended channel. *Journal of Experimental Psychology,* 1972, **94**, 308–313.

Deutsch, J. A., & Deutsch, D. Attention: Some theoretical considerations. *Psychological Review,* 1963, **70**, 80–90.

Greenwald, A. G. A double stimulation test of ideomotor theory with implications for selective attention. *Journal of Experimental Psychology,* 1970, **84**, 392–398.

Kahneman, D. *Attention and effort.* New York: Prentice-Hall, 1973.

Keele, S. W. *Attention and human performance.* New York: Goodyear, 1973.

Lewis, J. L. Semantic processing of unattended messages using dichotic listening. *Journal of Experimental Psychology*, 1970, **85**, 225–228.

Mehlman, I., Rosen, H. B., & Shaked, Y. *A foundation word list of Hebrew.* Jerusalem: Merkaz Press, 1960.

Moray, N. *Attention: Selective processes in vision and hearing.* London: Hutchinson Educational, 1969.

Norman, D. A. Toward a theory of memory and attention. *Psychological Review*, 1968, **75**, 522–536.

Posner, M. I., & Boies, S. J. Components of attention. *Psychological Review*, 1971, **78**, 391–408.

Treisman, A. M. Selective attention in man. *British Medical Bulletin*, 1964, **20**, 12–16.

Treisman, A. M. Strategies and models of selective attention. *Psychological Review*, 1969, **72**, 282–299.

Treisman, A. M. Perception and recall of simultaneous speech stimuli. In A. F. Sanders (Ed.), *Attention and performance.* Amsterdam: North Holland, 1970.

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., & Riley, J. G. Is selective attention selective perception or selective response? A further test. *Journal of Experimental Psychology*, 1969, **79**, 27–34.

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