Sustained concentration : passive filtering or active orienting?

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3 Sustained Concentration: Passive Filtering or Active Orienting?

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ABSTRACT

This paper is concerned with the process by which one selects information from a sensory channel. Two possibilities are considered. In one the person sets a filter which then passively delivers information from the selected source to conscious-ness (passive filter). In the second view the person maintains an active set or orientation toward the selected channel. Two sets of experiments are presented. The first shows that any visual signal that occurs at a position eccentric to the line of sight produces a relative slowing on the response times for processing subse-quent signals at that spatial position. This effect lasts approximately 1–2 seconds.

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Thus a consequence of a visual stimulus at a spatial position is to reduce the efficiency of attending to subsequent information at that location.

The second set of experiments shows that each visual stimulus causes an active orienting of attention toward its spatial position. This orienting is said to be active because it is reduced or delayed by requiring the subject to perform a secondary task (counting backwards).

Our studies indicated that the basic passive effect of a visual stimulus is to retard processing of subsequent events at that position. This spatially selective sensory inhibition must be overcome by an active process if efficient concentration is to be maintained.

INTRODUCTION

An enduring problem in psychology is to understand the mechanisms by which we prepare for and select information from a source of sensory or memorial information in the presence of competing events from other sources. Most of the literature in this area has emphasized concentration upon an input or sensory channel. For example, one ear (Broadbent, 1958), one modality (Posner, Nissen, & Klein, 1976) or upon a location in visual space (Posner, 1980). Eventually, however, one hopes that some of the same underlying mechanisms that allow us to concentrate upon a source of sensory information are also necessary to sustain concentration upon an area of semantic memory. If so, studies of selecting information from sensory signals may also tell us something about our ability to maintain concentration while thinking.

Active vs. Passive Processes

A major distinction in cognitive psychology is between mechanisms that are primarily passive and those which involve active or controlled processes (Posner & Snyder, 1975; Shiffrin & Schneider, 1977). A filtering mechanism could be either active or passive, but our discussion of filtering includes the idea that the filter, although set actively, can be maintained independently of the subject's current focus of attention. It would seem important to know whether subjects are able to maintain concentration by a process which passively walls out potentially interfering information without using current processing capacity in maintaining the filter. Such a filter would be quite distinct from preparation and selectivity maintained by active orienting toward the selected source, which remains effective only while the subject was free of other tasks.

The idea of a passive filtering mechanism can be associated with selection at a very early level of the nervous system. Such mechanisms do exist physiologically. For example, Skinner and Yingling (1977) show the existence of a thalamic gate that can control the entry of information from sensory channels to

the cortex. However, there has been little evidence indicating modifications of the sensory message prior to the first cortically generated waves of the event related potential in rapid information processing tasks (see Näätänen, 1982 for a review of this work). Instead, Näätänen argues that selection of a signal on a particular sensory channel produces an indwelling negativity in that channel which joins with the event related potential of that signal to produce negative shifts in the potential as early as 90 millisec after input (see also Hansen & Hillyard, 1980). According to Näätänen's view this negativity is only present while the subject maintains an active (attended) orientation toward the selected channel. Thus, Näätänen's analysis associates selectivity with a cortical process that is maintained actively.

We have been investigating the component processes involved in active orienting of attention to a location in visual space (Posner & Cohen, in press). In our studies orienting can be induced by a centrally located symbolic cue indicating where in space a target is most likely to occur or by a cue that occurs in the neighborhood of the target (Posner, 1980; Posner & Cohen, in press). These investigations have begun to reveal components involved in orienting both at the information processing (Posner, 1980; Posner & Cohen, 1982), and at the neurophysiological level (Posner, Cohen, & Rafal, 1982; Wurtz, Goldberg, & Robinson, 1980). We have shown that a peripheral visual event tends to produce an active orienting of attention, even while the eyes remain fixed. The orienting of attention to the cue can be measured by time-locked improvements in the efficiency of processing information that occurs in the neighborhood of the cue either by latency measures or by accuracy measures. Recently, we have shown that if attention is withdrawn from the cue, for example by summoning it back to fixation by a brightening at the center of the field, there is a subsequent reduction in the efficiency of information processing at the formerly cued position in comparison to other positions in the visual field (Posner & Cohen, in press).

We view these time-locked phasic changes of facilitation and inhibition produced by cues as elementary components of the process of visual orienting. Our current view of the significance of facilitation and inhibition in the selection of visual information is as follows. The facilitation effect is designed to operate within a fixation. It marks an area of the visual field for attention. It serves as a process which prepares the subject for further examination of that area of the visual input. In many cases, this facilitation will be followed by an eye movement directed toward the area of interest. We have found (Cohen, 1981; Posner & Cohen, in press) that facilitation will move with the eye (as if mapped in retinotopic coordinates) in laboratory situations where there is no information of interest presented at the foveal location. However, we believe that in real world situations attention usually reorients to the fovea with each eye movement, thus keeping coordinated the center of acute vision with the direction of attention. If the subjects should move their eyes to a new position, the previously facilitated area will become inhibited and thus have less capacity to draw the eyes back

toward it. This inhibition presumably represents one of the many neural systems inclined to favor novel stimulation over stimulation that is repeated.

In our work attention can be drawn to the target area by a peripheral cue, or a central symbolic cue may cause the subject to choose to orient toward a particular location. While we recognize that orienting may be based on either symbolic or peripheral cues, if the mechanism is a central attentional one, there should be some effect of dividing attention on the efficiency of orienting. Such an effect would provide an operational basis for the term "active". Jonides (1981) argued that central cues and peripheral cues are different in that central cues are used actively by the subject as a basis for orienting attention while the peripheral cues pull attention automatically to their spatial position. In support of this view peripheral cues can be shown to work even when the probability of a target is kept low. In operational terms Jonides (1981) found interference with the efficiency and speed of using a central cue from a concurrent memory load but no such interference for a peripheral cue. In this paper we use divided attention to separate the more active components of the selectivity from the more passive components.

Organization of Chapter

This chapter involves an examination of active and passive processes in orienting attention by use of central and peripheral cues. The goal is to aid our understanding of active and passive processes in selectivity as a step toward a model of sustained concentration.

The first series of experiments uses a central cue followed by a series of from 10 to 20 peripheral target events to which subjects responded. The location of the target is in accord with the contingencies set by the cue. The basic idea is to test the view that an active process is necessary to orient attention but selectivity is maintained passively once oriented. We use a divided attention task in order to determine whether the selectivity toward the cued position can be maintained passively.

The second set of experiments also used divided attention techniques but this time to explore the active and passive portions of orienting to peripheral cues. In this set of experiments we orient subjects by a peripheral cue and return attention to fixation. Either following the peripheral cue or following the return of attention to fixation, we present a target event to which the subject must respond. These trials take place either with focused attention or when the subject is engaged in a secondary task.

CENTRALLY CUED MINIBLOCKS

Method

Experiments I and II involve presentation of a cue at the start of each block of N trials. The cue is either a plus sign or an arrow pointing to the left or right of

fixation. One third of the blocks use each form of cue. Two seconds after the cue the first of a series of targets (10 targers in Experiment I and 12–20 targets in Experiment II) occurs 5 degrees to the left or right of fixation. In Experiment I, the targets occur approximately 2000 millisec apart. In Experiment II the times between the response to one target and the occurrence of the next were varied randomly between 300, 500, 700, or 1000 millisec. The target is a bright dot that remains on until a response is made. Eye position is monitored by EOG electrodes to determine that fixation is maintained. The subject's task is to press a single key whenever a dot occurs. When the cue is an arrow, 80% of the target events occur on the side indicated by the arrow and 20% on the other side. When the cue is a neutral warning signal, the target events occur equally often on either side of fixation. On half the blocks, at the same time as the cue, a three-digit number is presented to subjects. Subjects count backwards by threes from the three-digit number during the entire time that targets are presented in that block. The experimenter monitored the subject's counting to ensure that counting backwards continued during the block.

Experiment I involved 10 subjects running for 2 days each. Experiment II involved 12 subjects running for 2 days each. On each day subjects had 10 blocks with each type of cue under focused and 10 under divided attention conditions.

Results

For each subject a median R.T. over blocks was calculated for each position within a block for each of the three validity conditions (neutral, valid and invalid) separately for focused and divided attention. We then took the mean of each successive pair of trials (first and second, third and fourth, and so forth) for each subject and combined the subjects' means into an overall mean for the condition. These values are used in the analysis and shown in the figures.

Figures 3.1 and 3.2 provide the results for each experiment. In both experiments there is a small but significant effect of cue type (valid, invalid, and neutral) in the focused attention condition. In Experiment I the invalid cue lies significantly above both neutral and valid cues which are themselves not different. In Experiment II, the valid cue lies significantly below the invalid cue and there is a tendency for the difference between valid and invalid to disappear with successive trials.

The overall results are like those obtained in previous work with blocked trials (Posner, Snyder, & Davidson, 1980) in which there is little benefit of a valid trial over a neutral or invalid one. Experiment II shows slightly more benefit but the effects are extremely small and tend to disappear over trials. The results clearly show that the subjects do not become increasingly effective in maintaining selectivity over successive trials. Indeed, in both experiments there seems to be reduced selectivity in the later trials.
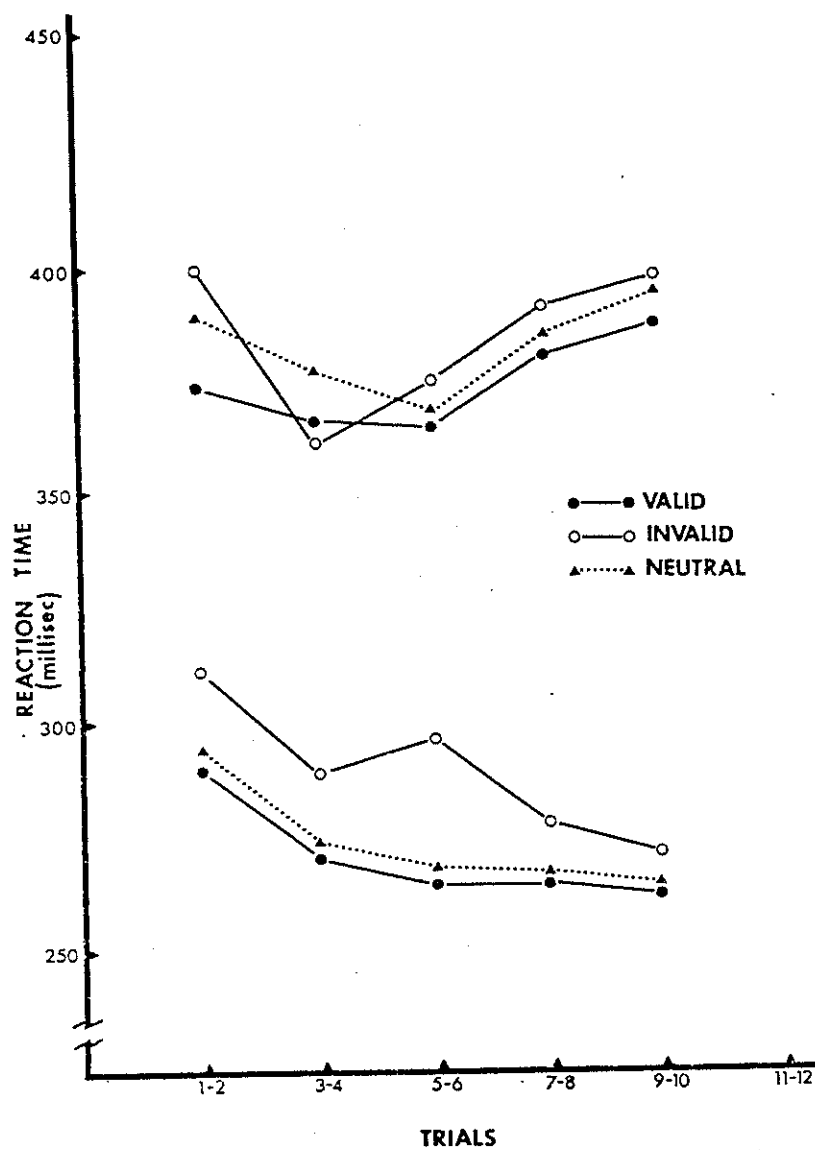
FIG. 3.1.   Reaction times for successive pairs of trials averaged over blocks of a like condition for valid, invalid, and neutral trials. Upper three curves are for divided attention blocks and lower three curves are from focused attention blocks. Data from Experiment I only.
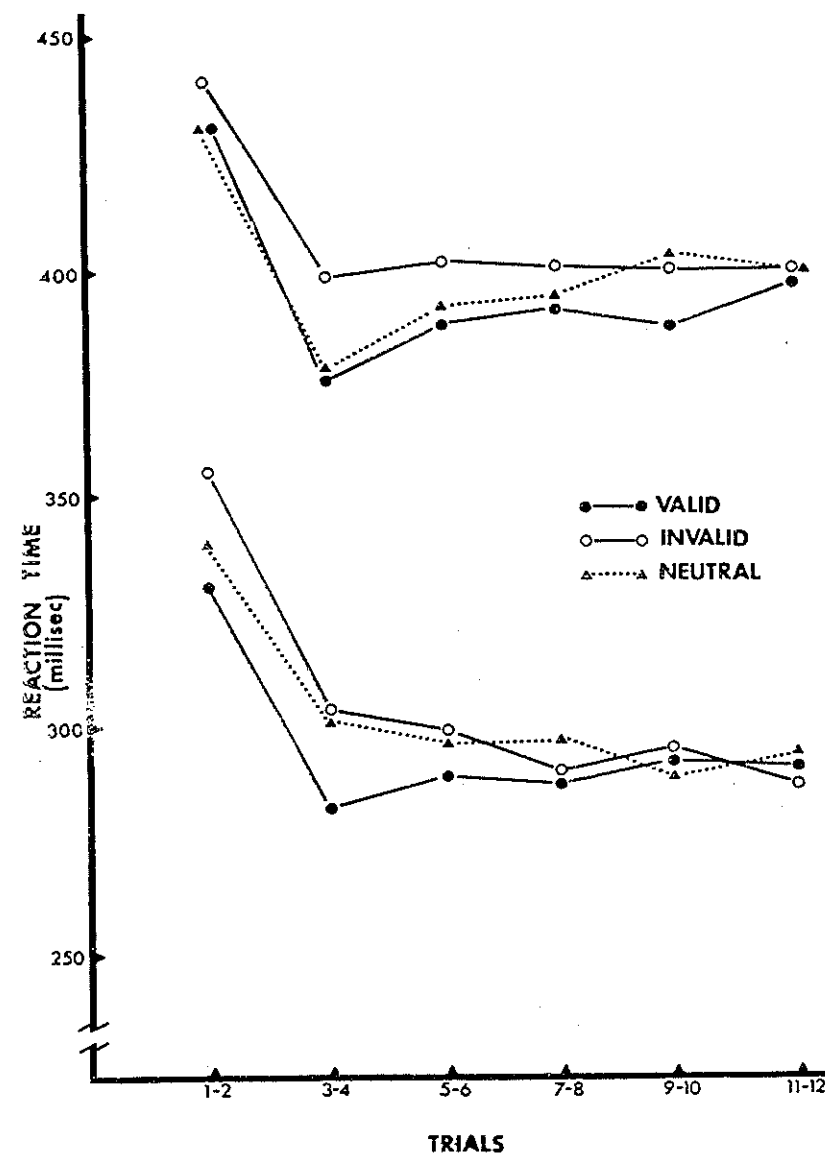
FIG. 3.2.   Reaction times for successive pairs of trials averaged over blocks of a like condition for valid, invalid, and neutral trials. Upper three curves are for divided attention blocks and lower three curves are for focused attention blocks. Data from Experiment II only.

TABLE 3.1

	Same Loc.	Diff. Loc.
Exper. 1		
Neutral	283	275
Valid	276	270
Invalid	305	296
Exper. 2		
Neutral	316	284
Valid	297	279
Invalid	312	297

Mean reaction time (millisec) on trial N when the probe is in the same location as on trial N-1 and when it is in the opposite location as a function of condition (neutral, valid, or invalid).

The most striking results of the experiment are shown in Table 3.1. In both experiments, when the successive targets occur on the same side, the reaction times are systematically longer than when they occur on the opposite sides across all cuing conditions. These effects are very tiny in Experiment I in which the interval between targets was 2000 millisec but they are quite pronounced in Experiment 2 (32 millisec for the neutral trials). These differences between same side and opposite side are highly significant. It is of particular interest that, even when a subject is cued to attend to a side, if two successive targets occur from that side, the second target is slowed with respect to the first.

Table 3.2 shows that this negative sequential dependency effect tends to decrease with interval. In Experiment II, response to stimulus intervals of 300, 500, 700, and 1000 millisecs were used. In both the valid and neutral conditions (in which there are a substantial number of trials at all intervals) it is clear that the

TABLE 3.2

R–S Interval	300	500	700	1000
Trial Type				
Valid	36	19	5	12
Invalid	26	9	40	16
Neutral	46	39	31	15
Neutral Repetitions	376	314	297	294
Neutral Alternations	330	275	266	279

Upper portion of the table indicates the mean difference in RT (millisec) between trials when the target is on the same side as the previous trial (repetitions) and when it is on the opposite side (alternations) as a function of response to stimulus interval and trial type. The lower portion shows the mean RTs for neutral trial types for repetitions and alternations. All data from Experiment II.

TABLE 3.3

Successive Same Side Trials	Neutral	Valid	Inhibition Effect
0	283	279	0
1	329	322	45
2	311	301	26
3	298	285	10

Mean reaction time for same side trials and size of the inhibition effect (same side RTs-opposite side RTs) as a function of the number of same side probes that occur in a row. Data are from Experiment II and include only valid and neutral conditions.

size of the inhibition tends to decrease as the response to stimulus interval increases[2].

Table 3.3 indicates the RTs when either 0, 1, 2, or 3 targets occur on the same side. The 0 trials means that the other side had been stimulated on the previous trial. This forms the baseline in both the neutral and valid conditions to evaluate the effects of repetition. It is clear that the first repetition shows the largest inhibition effect. This is about 45 millisec in both the neutral and valid conditions. If a second successive target occurs on the same side, the inhibition is reduced to 26 millisec and by the third successive same side target it is reduced still further to only 10 millisec.

Conclusions

It seems fair to conclude from these two experiments that selectivity based on a central cue is not established or maintained very well under any of the conditions. The first few trials following a cue show the greatest selectivity but even this is only 10 to 15 millisec. Cost plus benefit is less than a fifth of what occurs in a design in which a central arrow is used as the cue before each successive trial (e.g., Posner, Snyder, & Davidson, 1980). Moreover, there is no tendency for the effect to become larger or more automatic as the block continues.

A major reason for the failure to show strong selectivity is due to the negative sequential dependency (inhibition) that occurs when the same stimulus is presented twice in a row on the same side. Repeated target events occur most often on the valid side since the probability of a stimulus occurring there is .8, whereas

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[2]As can be seen in the bottom two rows of Table 3.2 both repetition and alternations show a general decline in RT with interval. This is a general effect of stimulus to response interval on RT. The decline in the difference between repetitions (same location) and alternations (different location) which we call the spatial inhibition effect is superimposed upon this general decrease in RTs.

most events on the invalid side will follow targets to the opposite side. Negative sequential dependency thus affects reaction time primarily on the cued side where target probabilities are high. Thus they work against finding faster RTs on the cued side.

These negative sequential dependencies are similar to the inhibitory effects of a peripheral cue reported by Posner and Cohen (1982). In the Posner and Cohen experiments, the first stimulus to occur is the peripheral cue followed by a target either in the same location as the cue or on the opposite side. If the attention of the subject is redirected from the cued location to the central fixation position, one finds the side previously stimulated by the cue to be inhibited with respect to the other side by about 20 to 30 millisec in different conditions. This compares favorably with the size of the inhibitory effect due to repeated stimulation reported in the cued conditions of our blocked experiment.

An important question addressed both by our data and by Posner & Cohen (in press) is the relation of inhibition to the orienting of attention. It is striking in the current blocked experiment that the size of the inhibitory effect appears to be roughly similar irrespective of whether the central cue is valid, neutral, or invalid, varying instead with the number of times that location had been previously stimulated. This fits with the argument that Posner and Cohen have made that the effect is not closely related to attention. Maylor (1982) has argued that orienting of attention is a necessary condition for obtaining the inhibition effect. The current results do not rule out orienting of attention as playing a role in producing inhibition but they do not provide any strong evidence of interaction between things that affect attention (e.g., dual tasks, cues) and the size of the inhibition effect.

Another important point is that the inhibition effect seems to be reduced but not eliminated as one varies the time between successive trials from 300 to 1000 millisec (if Exp. I is included effects are still present at 2000 millisec). Posner and Cohen, in press) have suggested that the effect lasts about two seconds or approximately the time for 2–3 eye movements. The current data fit with their estimate.

It is also important to note that there is no evidence that the inhibition effect builds up after the first repetition. Indeed in this study it clearly declines. In these experiments the small block length produced a clear confounding between successive repetitions and position within the block. Long strings of repetition were clearly unlikely, given the constraint that each block had to conform exactly to the cue contingencies. These factors suggest that strings of three or more repetitions might have been salient and thus attracted attention from the subjects which would counteract the inhibition effect. Maylor (1982) studied long blocks of purely random trials and found very similar inhibition results to those reported here. It seems that inhibition effects do not build up with successive events but reach a maximum after one repetition.

These experiments suggest that sustained attention with blocks of trials involve the same inhibitory and facilitatory effects that have been reported in the cued trial-by-trial experiments by Posner and Cohen (in press). The facilitatory effect results from the cue informing the subject where in space the stimulus will occur. However, whatever facilitation might be obtained by active orienting to a spatial position is to some extent counteracted by an inhibitory effect that occurs when two stimuli in close temporal proximity come from the same position in space.

PERIPHERAL CUES AND DIVIDED ATTENTION

Jonides (1981) showed that a peripheral cue summons attention to the same extent whether or not the subject had to hold items in memory. He argued from this that the peripheral cue automatically summons attention. We felt that the use of concurrent dual processing task, such as counting backwards, might provide a more sensitive test of the degree of automaticity of the peripheral cue. Moreover, it would also be possible to examine the effect of divided attention on both the facilitatory and inhibitory components. It would seem reasonable to suppose that the divided attention task might interfere more with the facilitation effect, which we believe is due to orienting, than it would with the inhibitory effect, which we think is heavily due to sensory information.

Method

Two experiments were run following basically the same methodology. Both experiments used a cathode ray tube display with three boxes arranged horizontally. A single key press was used for target detection. Eye position was monitored with EOG.

In the focused attention block, subjects performed only the target detection task while in the divided attention blocks, subjects also counted backwards by threes from a fixed three-digit number. Each trial began with a peripheral cue which was brightening of a box 5 degrees to the left or right of fixation. The box brightened for 150 millisec. At 300 millisec, the central box brightened and remained brightened for 150 millisec. Intervals of 100, 300, or 500 millisec between the peripheral cue and the target were used. The 100 millisec target occurred while the peripheral box was still brightened, whereas the 500 millisec target occurred following the offset of the brightening of the central box. The target was a bright square of light that occurred in the center of one of the two peripheral boxes.

Each day consisted of two blocks run in the focused condition and two blocks run in the divided attention condition. Each block consisted of 96 trials randomly

assigned to each of the three cues to target intervals. On half the trials, the target occurred on the cued side and on half it occurred on the uncued side. Experiment III used 10 subjects each run for 2 days. Experiment IV was similar except that 7 subjects were run for only a single session.

Results

Results for Experiment III are shown in terms of the mean of the median reaction times averaged across days and subjects for each target interval in both the divided and focused attention conditions. The focused attention condition replicated the pattern of an early facilitation followed by a later inhibition obtained in earlier experiments. The facilitation effect was about 30 millisec and the inhibition effect about 20 millisec. Both are highly significant statistically. These are similar to results reported previously by Posner and Cohen (1982).

Overall, there is no evidence of a facilitation effect at all in divided attention condition. This finding must be qualified both by the differences between days and the results of the replication experiment. On the second day of Experiment III there was a tendency toward facilitation at 300 millisec. This was not large and does not show up in the overall data of the two days in Fig. 3.3. However, it was consistent across subjects on Day 2 and occurs more strongly in Experiment IV (see Fig. 3.4). In all blocks of Experiment III and in Experiment IV, there is no facilitation effect at 100 millisec in the divided attention condition, but on Day 2 in Experiment III and in Experiment IV there is a significant facilitation at 300 millisec. Thus, overall, it seems safest to conclude that the facilitation effect is at least delayed by the backwards counting task.

Results for the inhibition effect are more equivocal. In Experiment III the overall inhibition effect for the focused condition is 16 millisec and for the divided attention condition, 10 millisec. These effects remain constant over the four blocks of the experiment. However, in Experiment IV where the facilitation effect is at least delayed, there is no evidence of an inhibition effect at 500 millisec.

These experiments do not provide an entirely clear picture of the effects of divided attention on facilitation and inhibition. The clearest result of the experiments is the replication of an early facilitation and late inhibition effect in this paradigm. It also seems safe to conclude that there is some reduction of facilitation in divided attention conditions. Facilitation is eliminated in the early blocks of Experiment III, but appears to be only retarded in Experiment IV. It appears impossible to conclude much about whether divided attention affects the inhibition in this paradigm. If one views facilitation as being delayed by the divided attention task, the intervals used for assaying the inhibition effect in undivided attention may not be appropriate for divided attention. If the net RT is the sum of effects of facilitation and inhibition and if the divided attention task delays the former, it may be impossible to assay its effects on inhibition at these intervals
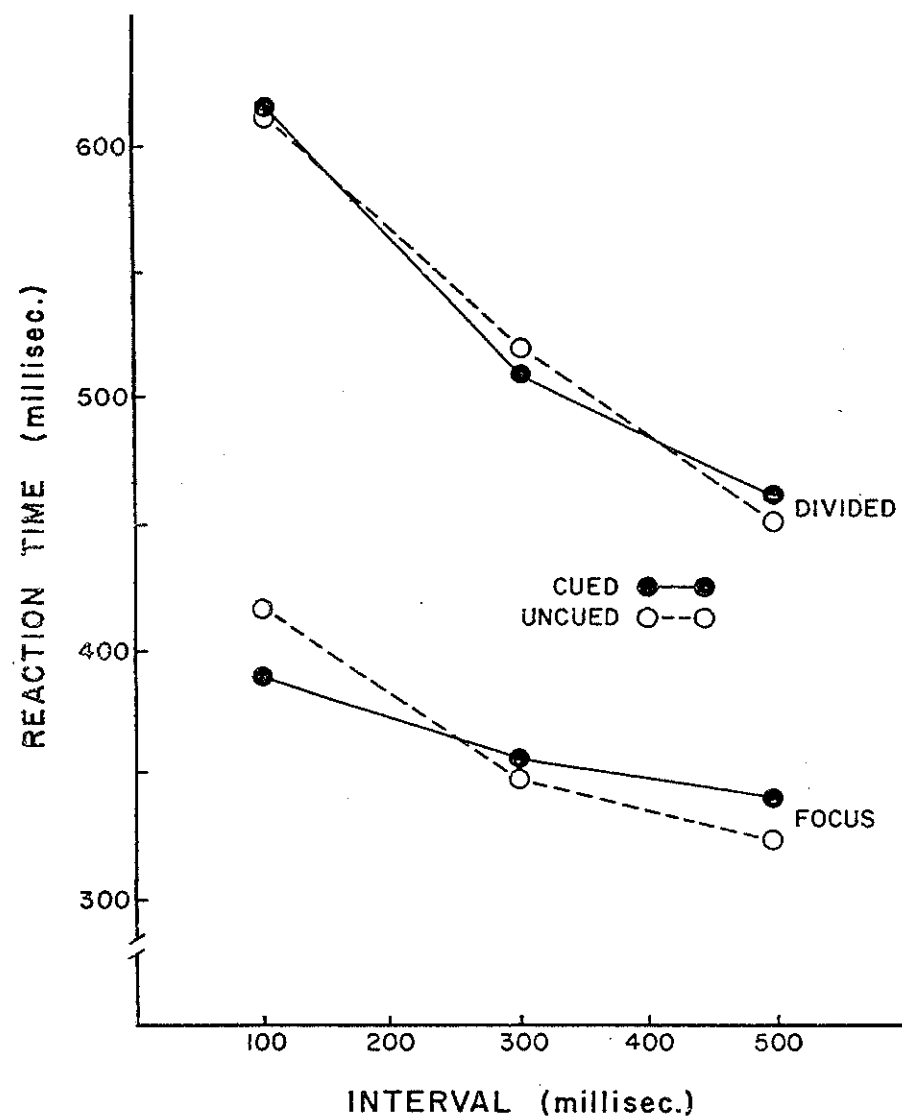
FIG. 3.3.   Mean reaction time for cued and uncued trials in focused and divided attention conditions as a function of time following the peripheral cue. The first interval is when attention has been oriented toward the periphery. The last interval is following a cue designed to draw attention back to the fixation position. Data from Experiment III.
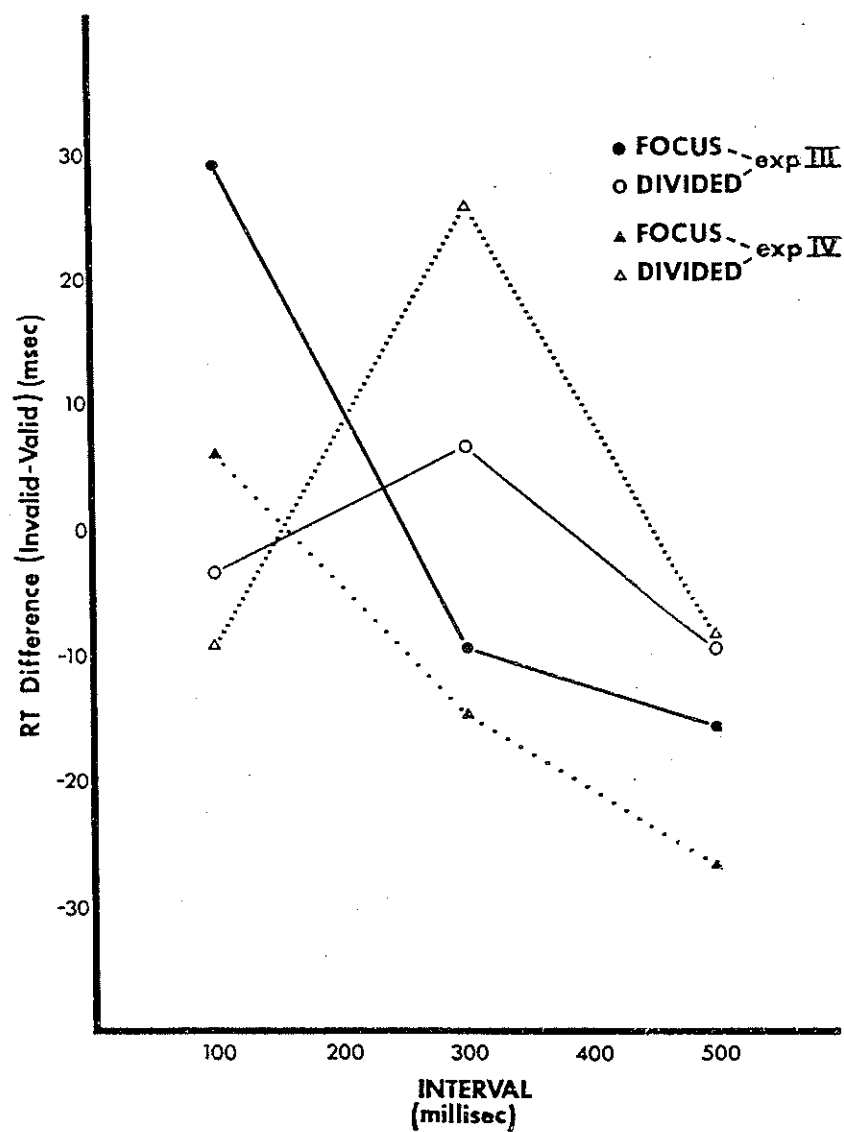
FIG. 3.4.   Amount of facilitation and inhibition found in Experiment III and IV as a function of interval following the cue.

because attention may be delayed in returning to fixation. We know that the inhibition effect lasts a rather long time (up to 2 sec) and it might be possible to obtain a pure measure of the inhibition effect if the time interval for targets is extended beyond those used in the current experiments.

At the very least, these effects seem to suggest a qualification to the conclusions made by Jonides based on his 1981 memory target experiment. In unpublished studies in which a secondary memory task was used, we obtained little evidence of interference with the overall RTs found in the cued spatial orienting task. It appears that memory tasks are not as effective in producing interference as concurrent tasks such as used in Experiments III and IV.

GENERAL CONCLUSIONS

We began this chapter with a brief consideration of two major approaches to the problems of sustained concentration. One position emphasizes a passive filtering of the input information prior to cortical processing. According to this approach, information outside of the attended source is attenuated or filtered at an early stage while attended information is unfiltered. The other position emphasizes active selection of the attended channel by an effortful alignment of attention with signals from the selected source.

There have been two major empirical approaches to the study of sustained attention. One has involved presenting two streams of information with subjects required either to process both (divided attention) or to concentrate on only one (focused attention). The results of this paradigm have shown that focused attention is better than divided only when events on the attended channel must be actively processed, such as in shadowing each event, or when one examines the unattended channel at the moment a target is selected on the attended channel (Duncan, 1980). It is also important that successive events follow quickly, otherwise the evidence of selectivity obtained from behavioral or EEG result often is lost. The second major paradigm for the study of sustained concentration has involved vigilance. Here only a single source of information is presented. Evidence from high event rate vigilance tasks suggest that when information is rapid, there is a loss in sensitivity over time even with only a single channel of input (Parasuraman, 1979). Thus, conditions for maximum selectivity are also conditions where the input from the selected channel tends to be reduced in quality.

These empirical observations tend to fit rather poorly with a concept of early primarily sensory and passive filtering of attended information. If such filtering accounted for selectivity, it would not seem to depend so heavily on active processing of each attended signal as it so frequently does. Nor do our results fit with the ability to form and maintain a passive bias toward the selected channel. Instead we find that the selected and unselected information alike is subject to an

inhibitory influence from prior information at the same spatial location. It appears that the basic sensory effect is to favor a novel or previously quiet channel of stimulation rather than to favor the channel that is more probable or biased for selection. If this account is correct, it leaves the problem of selection for higher level processes that depend upon active orienting to the selected channel. Such an active orienting would be best maintained if the subject is continually processing events and might even be enhanced when the discriminability of events makes it quite difficult to distinguish targets from noise on the attended channel as would happen with high rates of input.

We believe that our results with trial-by-trial cueing (Posner & Cohen, in press) taken together with findings with clinical patients and alert animals have provided a start toward a fundamental understanding of the way in which phasic orienting based on central and peripheral cues is achieved by the nervous system. While the current experiments do not add too much to our understanding of the mechanisms, they do provide evidence that they are involved in a fundamental way in sustained concentration at least to visual signals. If this is the case, we may be able to provide a better basis for an understanding of sustained concentration through basic studies of the properties of visual orienting.

ACKNOWLEDGMENTS

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