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Inhibitory Component of Externally Controlled Covert Orienting in Visual Space

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Four experiments are reported that investigate an inhibitory effect associated with externally controlled orienting and first identified by Posner and Cohen (1980, 1984). The effect takes the form of an inability to respond quickly to a stimulus appearing in the same location in the visual periphery as a previous one that produced covert orienting. Several characteristics of the effect are revealed that eliminate possible explanations in terms of response inhibition, masking, and sensory habituation. The inhibitory component of orienting occurs whether or not the first stimulus requires a response (Experiment 1), lasts at least a second (Experiments 1, 2, and 3), affects not only the originally stimulated location but also nearby locations (Experiment 2), is determined by environmental coordinates (Experiment 3), and occurs both in the periphery and at the fovea (Experiment 4). It is concluded that inhibition may act together with an early facilitatory component (Posner & Cohen, 1984) in directing the attention and eye movement systems in order to maintain efficient spatial sampling.

Posner (1980) described visual orienting as the aligning of peripheral or central mechanisms with a source of sensory input. The present article is concerned with externally controlled covert orienting, that is, the realignment of attention (but not the eyes) as the result of an external stimulus event. Using a detection-threshold paradigm, Remington (1980) demonstrated that a stimulus in the periphery can trigger both a saccade and a shift of attention. He concluded that "to some degree" the attentional movement automatically follows the presentation of a significant peripheral stimulus. A similar observation was made by Flowers, Polansky, and Kerl (1981), who noted that certain familiar visual stimuli "automatically" direct attention to particular locations within a display. In a study designed to compare internally and externally controlled covert orienting, Jonides (1981) concluded that a peripheral cue "effectively captures attention because it exploits a predisposition of the visual system to be especially sensitive to salient discontinuities off the fovea" (pp. 200–201).

Recent investigations have been concerned with the *consequences* of externally controlled orienting. Posner and Cohen (1980, 1984) presented subjects with three boxes, one on the left, one at the center, and one on the right of an oscilloscope screen. Subjects were required to fixate on the central box throughout the experiment. A trial began with the brightening of one of the peripheral boxes, chosen randomly, for 150 ms (the cue). Targets occurred at 0, 50, 100, 200, 300, or 500 ms following the onset of the cue. These were dots appearing well above threshold, usually inside the central box (probability = .6) but also inside either peripheral box (probability = .2). A small number of trials were catch trials when no target occurred. A simple detection response of a single manual key press to the appearance of the target was required. Trials when eye movements occurred were deleted from the analysis. Their results showed that targets occurring inside the cued peripheral

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box were responded to faster than those inside the opposite box for the cue onset-target onset intervals of 0, 50, and 100 ms. For the intervals of 300 and 500 ms, however, this was reversed so that targets were responded to slower when they appeared inside the cued box than inside the opposite box. Responses to targets appearing in the center were faster throughout both because of the benefit of foveal processing and the greater probability of targets in the central box. Posner and Cohen argued that the initial advantage to the cued side was due to the summoning of attention by the cue. This effect was termed *facilitation*. However, this early advantage to the cued side was replaced by a subsequent *inhibition* after attention had presumably returned to the center (because of the fixation requirements and the greater probability of targets there).

They concluded that visual stimulation in the periphery first summons attention and later inhibits the processing of further information from that location in visual space. Thus there appears to be a reciprocal relation between attention and sensory processes. They suggested that this balance prevents overcommitment of resources to a cued location and is in line with the general tendency of the nervous system to use opposed mechanisms to maintain equilibrium.

There are a number of possible explanations for the inhibitory effect observed in externally controlled covert orienting. First, it might be the result of forward masking from the cue, in particular, metacontrast (see, for example, Averbach & Coriell, 1961), which refers to a particular type where the masking stimulus does not overlap spatially with the target. However, Cohen (1981) provided several reasons why this fails to explain the inhibitory effect. For example, inhibition is present at 500 ms following the onset of the cue, which is well outside the range of forward masking effects, and indeed facilitation is found at the time when masking normally occurs (0–100 ms). Also, metacontrast has been shown to have no effect on simple reaction time (Fehrer & Raab, 1962; Proctor, Nunn, & Pallos, 1983). It therefore seems unlikely that this mechanism can account for the inhibitory effect.

A more likely candidate for the effect may be a "response inhibition" of the type described by Neill (1977) and Harvey (1980). Harvey investigated possible noninformative effects of cues by using the same stimuli as both cues and targets. Two neon bulbs were mounted, one above and the other below fixation. At the beginning of each trial one of the bulbs, chosen at random, was lit for a short period (the cue) and was followed after an interval by the target. This was the lighting of either the same bulb or the other bulb with equal probability. Thus subjects were required to *avoid responding* to the first light (the cue) but to make a speeded decision regarding the location of the second light (the target). Choice reaction time was slower when the target was the same light as the brief visual cue than when the cue and the target were different lights. This was interpreted as the effect of response inhibition to the cue still being present when the target appeared.

The third possibility is that inhibition may be related to habituation. Singer, Zihl, and Poppel (1977) found that visual detection thresholds increase by up to 1 log unit when targets are repeatedly presented in the visual periphery. They concluded that "these local changes in detection threshold reflect shifts in visual attention" (p. 188). Frome, MacLeod, Buck, and Williams (1981) also noted changes in threshold for repeated presentations of peripheral flashes that could not be due simply to retinal light adaptation. They referred to the effect as "habituation to repetitive stimulation" because the loss of sensory excitability exhibited seven out of the nine characteristics of behavioral habituation listed by Thompson and Spencer (1966).

The present experiments were designed to examine the adequacy of these possible explanations for the inhibitory effect within the broader aim of defining some of its essential characteristics. In Experiments 1 and 2 we explore the temporal and spatial extent of inhibition. In Experiment 3, we examine the question of its coordinates (retinal or environmental). Finally, in Experiment 4 we compare the inhibitory effect at the fovea and in the periphery.

Experiment 1

An additional analysis conducted on the results of two experiments based on Posner and Cohen's (1984) study described above (see Ex-

periment 1 of Maylor and Hockey, 1984) revealed the following effect. Reaction time to a target appearing in the same location as on the previous trial was longer than to a target appearing in the opposite location. Thus it is suggested that orienting to a target results in inhibition to respond to the next target if it appears in the same location. In a cue–target paradigm, the subject is required to avoid responding to the cue but to make a speeded detection response to the target. As described above, Harvey (1980) argued that the inhibitory effect is due to response inhibition to the cue that is still present when the target appears. However, if inhibition can result from an event that required a response (that is, a target), Harvey's explanation in terms of response inhibition, which relies on the cue–target distinction, can be discounted. In Experiment 1 of Maylor and Hockey (1984) the average delay between one target and the next was 750 ms, so there is preliminary evidence that the inhibitory effect lasts some considerable time. Experiment 1 was designed to investigate the time course of inhibition using a continuous target–target paradigm rather than the cue–target paradigm employed by Posner and Cohen (1984).

Method

Subjects. The subjects in the present experiments were unpaid volunteers and were undergraduates, postgraduates, and staff at the Universities of Durham and Nottingham (including the authors). All reported normal or corrected-to-normal vision. For Experiment 1, each of 6 subjects participated in a single experimental session lasting approximately 10 min.

Apparatus and stimuli. Timing, presentation of stimuli, and the recording of responses were controlled by an IBM 1130 computer. The computer generated the visual display through two digital-analogue-converters (DACs) applying voltages to the X and Y amplifiers of a Tektronix 602 display oscilloscope (P-31 phosphor). A Morse key connected to the digital input was used to measure reaction time to the nearest millisecond. A chin rest was placed in front of the oscilloscope so that the subject's eyes were level with and 30 cm from the center of the screen.

A permanent central fixation point was provided by a small black spot (1 mm diameter) on the oscilloscope. The stimuli were small squares of four dots subtending approximately 0.1° visual angle appearing well above threshold 4.2° above, below, to the left or to the right of the fixation point.

Design and procedure. Each subject participated in two blocks of trials. A block began with instructions on the screen: "N. B. Keep eyes on fixation point throughout block." To begin, the subject pressed the single key, and after 5 s the first target appeared. At the end of a block (approximately 2 min), the screen went blank until the next block was ready, which was signaled by the return of the fixation instructions. When the subject was ready to continue, a key press started the second block. The subject's task was to respond as quickly as possible by pressing the key when a target appeared, which was equally likely to be in any one of the four locations. Each target remained on the screen until the subject responded. There was a response–stimulus (R–S) interval of 300, 400, 500, or 900 ms before the onset of the next target, and these were randomized. Within a block of 240 trials, there were 60 of each R–S interval.

The subject was informed of the targets' locations and probabilities and was told that the targets would occur at random intervals following each response. In addition, the subject was encouraged to avoid responding when there was no target on the screen.

Results

The data were analyzed in the following way. For each R–S interval, the trials were split into three types: same, adjacent, and opposite. These refer to the spatial relation between the locations of the current and the previous target. For example, a left target that followed a right target was coded as *opposite*, whereas it was coded as *adjacent* if it followed a target above fixation. The first trial of each block was deleted from the analysis because it was not, of course, preceded by a target. Trials following anticipation errors (defined as responses before or during the first 100 ms of target presentation) were also deleted. Because each target was equally likely to occur, there were twice as many *adjacent* trials as either *same* or *opposite* trials.

The overall anticipation rate was 4%. The median reaction times were subjected to an analysis of variance with block (first and second), R–S interval (300, 400, 500, and 900 ms) and trial type (same, adjacent, and opposite) as fixed-effects factors. There was no effect of block, $F(1, 5) < 1.0$, or any interaction involving it, and so this factor will not be discussed further. The overall means are presented in Figure 1. There were significant effects of R–S interval, $F(3, 15) = 19.52$, $p < .0001$, and trial type, $F(2, 10) = 25.47$, $p < .0005$, and a significant interaction between them, $F(6, 30) = 3.90$, $p < .01$. The effect of R–S interval has been well documented (see, for example, Keele & Boies, 1973). From Figure 1 it can be seen that the trial type effect can be attributed to the slow responses to *same*

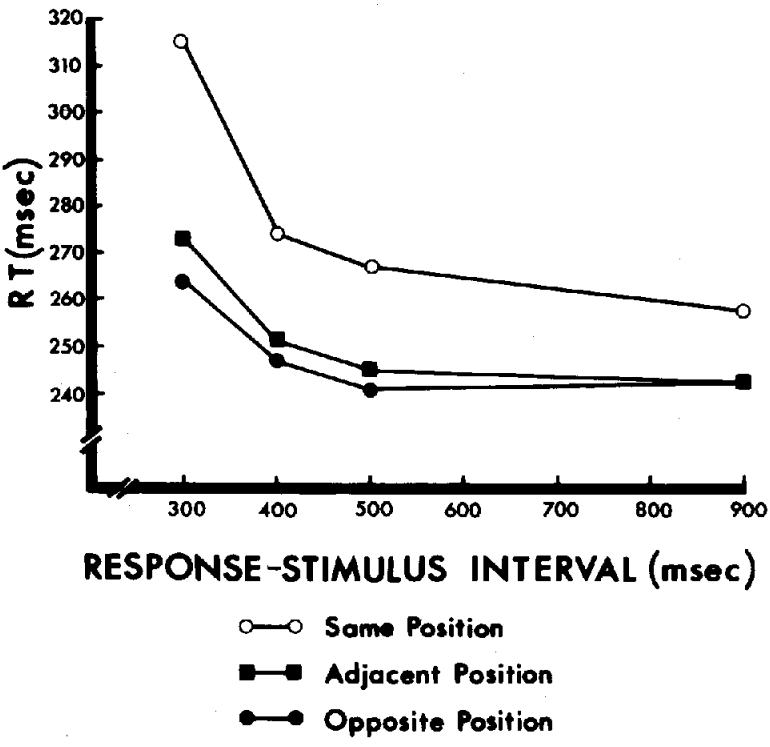

Figure 1. Results of Experiment 1. (RT = reaction time; msec = milliseconds.)

trials compared to *adjacent* and *opposite* ones. The subject is therefore slower to respond to a target that appears in the same location as on the previous trial than in either an adjacent or opposite location. (For the R–S intervals of both 300 and 400 ms, *adjacent* trials were slower than *opposite* trials for 5 of the 6 subjects. The *adjacent–opposite* differences were not consistent for the two longer R–S intervals). The interaction between R–S interval and trial type can be seen from Figure 1 as the result of a decrease in the inhibitory effect over time. Nevertheless, inhibition was still present at 900 ms for all 6 subjects.

There are three conclusions to be drawn from this experiment. First, it is clear that inhibition occurs in a target–target as well as in a cue–target paradigm, providing strong evidence against the response inhibition explanation of Harvey (1980). Second, inhibition lasts for some considerable time so that it is unlikely that any form of visual masking or persistence can account for the effect. Third, the lack of any substantial difference between the *adjacent* and *opposite* types of trial suggests, in agreement with Posner and Cohen (1984), that the inhibitory effect is not due to the realignment of attention toward the opposite location. However, although *adjacent* trials were much faster than *same* trials, they were slightly slower than *opposite* trials, at least for the R–S intervals of 300 and 400 ms. Thus there is some preliminary evidence that reaction time decreases with increasing distance from the previously stimulated location. Experiment 2 was therefore conducted to investigate in more detail the spatial extent of the inhibitory effect.

Experiment 2

A cue–target procedure was employed, both the cues and the targets being light-emitting diodes (LEDs). The effect of the brief presentation of an LED was measured by the simple reaction time to targets appearing at various times and locations following the cue in an attempt to plot the extent of inhibition in time and space.

Method

Subjects. Seven subjects each participated in a single experimental session lasting approximately 30 min.

Apparatus and stimuli. The experiment was controlled by a PDP 11/34 computer using a Cambridge Electronic Design (CED) laboratory interface. Timing was controlled by interrupts from the interface clock running in milliseconds, and a key-operated microswitch generated interrupts using the external event function of the interface. The LEDs were driven by digitial output and mounted in a black stand. A chin rest was again provided and placed so that the eyes were directly in line and level with the central fixation point at a viewing distance of 30 cm.

The LEDs were 3 mm diameter, thus subtending approximately 0.6° visual angle depending upon eccentricity. Fourteen red LEDs were used as cues and targets while a yellow one acted as the central fixation point. The stimulus positions are shown in the upper panel of Figure 2.

Design and procedure. Subjects participated in three blocks of trials and were required to fixate on the central yellow LED throughout. Each block contained 140 trials that were divided in the following way. For 70 of the trials the cue was the presentation for 300 ms of the LED directly to the left of fixation (labeled *cue* in Figure 2). The cue was the LED directly to the right for the remaining 70 trials. For each cue, the target appeared five times in each of the 14 positions (including that of the cue). These five trials were further divided into one of a stimulus onset asynchrony (SOA) of 700 ms, two of 900 ms, and two of 1,300 ms. (Obviously, an equal division was not possible; however, there was no reason to expect the particular ratio chosen to have any significant effect on the results of interest). The order of trials was randomized for every block.

The timing is summarized in the lower panel of Figure 2. Each trial began with the brief presentation (300 ms) of the cue. (We chose 300 ms because it was approximately the average reaction time in Experiment 1, and therefore the duration of the stimuli responsible for the inhibition was similar in the two experiments.) This was followed after the SOA by the target (one of the 14 LEDs). This remained on until the simple detection response of a single key press had been made. There was an intertrial interval that was randomly chosen from the range 1,500 to 2,500 ms.

The subject was instructed to respond only to the target and to use the brief cue as a warning signal that a target was about to appear. He or she was told that the cue was always either the middle left or middle right LED but that the target could be any one of the 14 LEDs, with equal probability. Consequently, the cue and the target appeared in the same location on a small proportion of trials. However, the distinction between the cue and the target was clearly understood by all subjects. The long intertrial interval ensured that the subject was able to follow the cue–target pattern throughout a block even when mistakes were made. When the key was pressed during the SOA and up to 100 ms after the onset of the target, that trial was immediately aborted, an anticipation error was recorded, and the trial was deleted from the analysis.

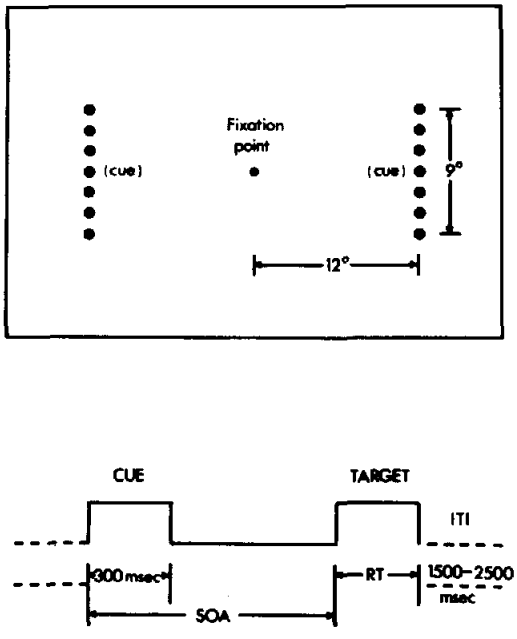

Figure 2. Stimulus positions and timing in Experiment 2. (SOA = stimulus onset asynchrony; ITI = intertrial interval; RT = reaction time; msec = milliseconds.)

Results

The overall anticipation rate was 2.5%. For each subject the data from the three experimental blocks were combined, and overall medians for the 24 conditions (3 SOAs × 8 trial types) were calculated. The type of trial was determined by the distance between the cue and the target (see Figure 3). Thus trials where the target appeared on the same side of the visual field were labeled S1–S4, and for targets on the opposite side O1–O4. Because of the combination of trials above and below the horizontal midline, there were twice as many trials of Types 2–4 than Type 1 for both S and O.

An analysis of variance was performed on the median reaction times with SOA (700, 900, and 1,300 ms) and trial type (S1, S2, S3, S4, O1, O2, O3, and O4) as fixed-effects factors. There were highly significant effects of SOA, $F(2, 12) = 21.08$, $p < .0005$, and trial type, $F(7, 42) = 15.62$, $p < .00001$, with an interaction between them, $F(14, 84) = 3.67$, $p < .0005$. The overall results from the 7 subjects are shown in Figure 3. It can be seen that S1 trials are much slower than the four *opposite* trials (O1–4), which was expected from the results of the previous experiment. Trial Types

S2, S3, and S4 are all slower than *opposite* ones (O1–4), and generally reaction time decreases with increasing distance between the cue and the target. However, it can be seen from Figure 3 that the relation is not linear. The reaction times for Trial Types S2–4 are all faster than would be expected if inhibition was proportional to the cue–target distance. Thus the inhibitory effect falls off quite sharply as the target appears further away from the cue.

Experiment 3

One of the possible explanations for the inhibitory effect proposed in the introduction was sensory habituation (Singer, Zihl, & Poppel, 1977; Frome, MacLeod, Buck, & Williams, 1981). A dichoptic viewing procedure was used by Maylor (1983) to determine whether or not the inhibitory effect is mediated by monocular pathways only. The results demonstrated that inhibition shows complete interocular transfer, thus discounting sensory habituation at the retinal level as an explanation. However, it still would be possible to attribute the effect to habituation at a higher level. Experiment 3 was designed to investigate this by using a cue–target procedure whereby the cue and target share the same location in visual space but not the same pathway (at any level). This was achieved by the insertion of a saccade after the cue but before the target. Thus the question of interest is whether the locus of inhibition is determined by retinal or environmental coordinates.

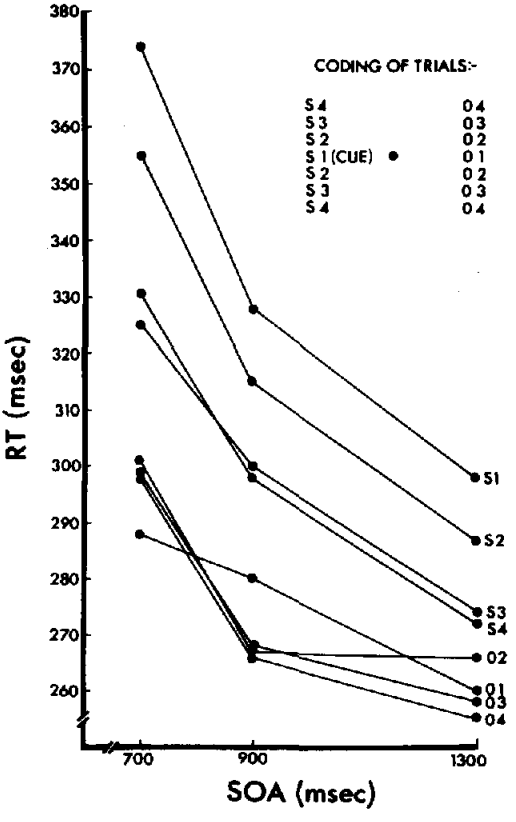

Figure 3. Results of Experiment 2. (SOA = stimulus onset asynchrony; RT = reaction time; msec = milliseconds.)

An experiment by Posner and Cohen (1984) ("Right-Angle Experiment") demonstrated that inhibition produced by externally controlled *overt* orienting is mapped in environmental coordinates. Thus, the response to a target appearing in a previously fixated cued location is slower than to one appearing elsewhere. In the present experiment, the consequences of *covert* orienting were investigated. The subject was required to move his or her eyes in between the occurrence of the cue and the target, although, unlike Posner and Cohen's study, the cued location was never fixated. If the inhibitory effect is environmental, then an eye movement should leave the originally stimulated location in space most affected. However, if inhibition is determined by retinal coordinates, then only the target that shares its retinal location with the cue will be inhibited.

Method

Subjects. Five subjects each participated in a single experimental session of approximately 30 min.

Apparatus and stimuli. The PDP computer as described for Experiment 2 was used to control the experiment. The stimuli were four red LEDs placed in the positions illustrated in the upper part of Figure 4. The two fixation points (1 and 2) were small white circles of approximately 0.5° diameter.

Design and procedure. Each subject carried out three blocks of trials. The subject began each block by pressing the single key, and after a pause of 2 s the first trial was presented. At the end of a block (approximtely 5 min), the subject was allowed to rest and then start the next block, again by pressing the key.

The 140 trials in each block comprised 56 trials of 900-ms SOA and 84 trials of 1,300-ms SOA. Longer SOAs were chosen in order to ensure that the subject had sufficient time to carry out the required eye movement after the occurrence of the cue and before the presentation of the target.

The timing of the trials is summarized in the lower part of Figure 4. A cue–target procedure was used. At the be-

ginning of each trial, the subject fixated on the upper fixation point (1). The cue was the presentation of either the upper-left or the upper-right LED (with equal probability). The *offset* of the cue was the signal for the subject to move his or her eyes to the lower fixation point (2) to wait for the target. This could occur in any one of the four locations (which were equally likely), the subject's task being to press the single key as quickly as possible after the onset of the target. It should be noted that the position of the second fixation point was such that the four targets were equidistant from fixation. Following the response, there was an intertrial interval that was randomly chosen from the range 1,500–2,500 ms before the onset of the next cue. During this interval, the subject was required to move his or her eyes back to the original fixation point (1). This procedure enabled a comparison to be made between targets that share retinal coordinates with the cue and those that share environmental coordinates. For example, following the top-left location as the cue, a comparison can be made between the reaction time to a top–left target (that is, at the same position in the environment), with reaction time to a bottom-left target (at the same position on the retina). It was stressed that the cue was merely a temporal warning signal and that it was noninformative in terms of the location of the target. Anticipations were recorded when the subject pressed the key during the SOA and up to 100 ms after the onset of the target. The response terminated the trial.

Results

The overall anticipation rate was 1.1%. The trials were divided into the two SOAs and then further coded according to the relation between the locations of the cue and the target. For example, following a cue in the top-left location, the target could occur in the top-left (*same* trials), bottom-left (*same side* trials), top-right (*opposite* trials), or bottom-right (*diagonally opposite* trials) location.

For each subject, the results from the three blocks of trials were pooled and medians taken. These were put into an analysis of variance with SOA (900 and 1,300 ms) and trial type as fixed effects factors. The means are presented in Figure 5. There were significant effects of SOA, $F(1, 4) = 17.19$, $p < .02$, and trial type,

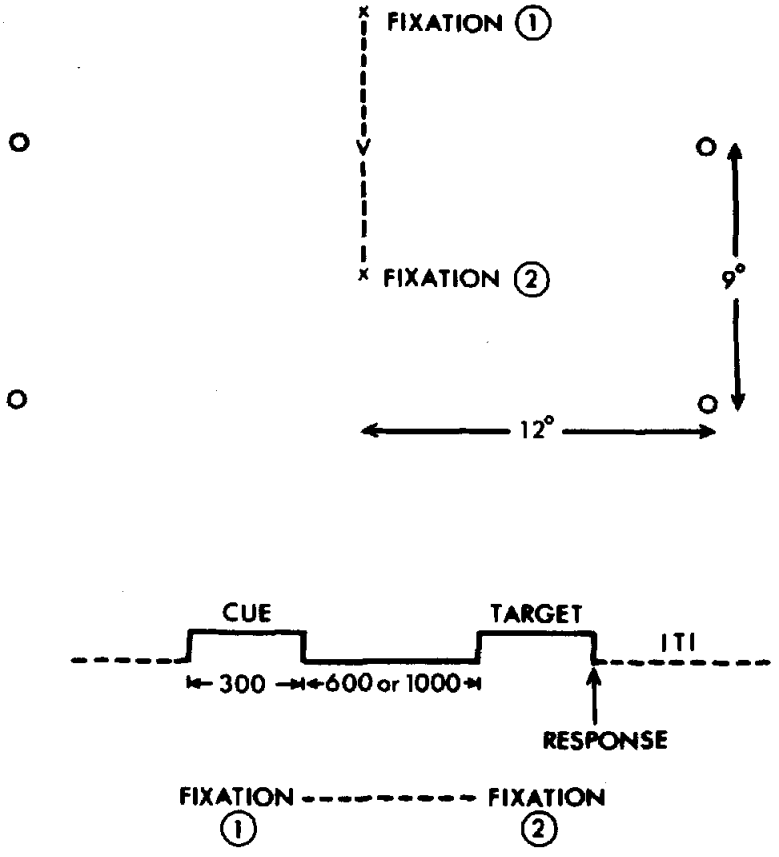

Figure 4. Stimulus positions and timing in Experiment 3. (ITI = intertrial interval.)

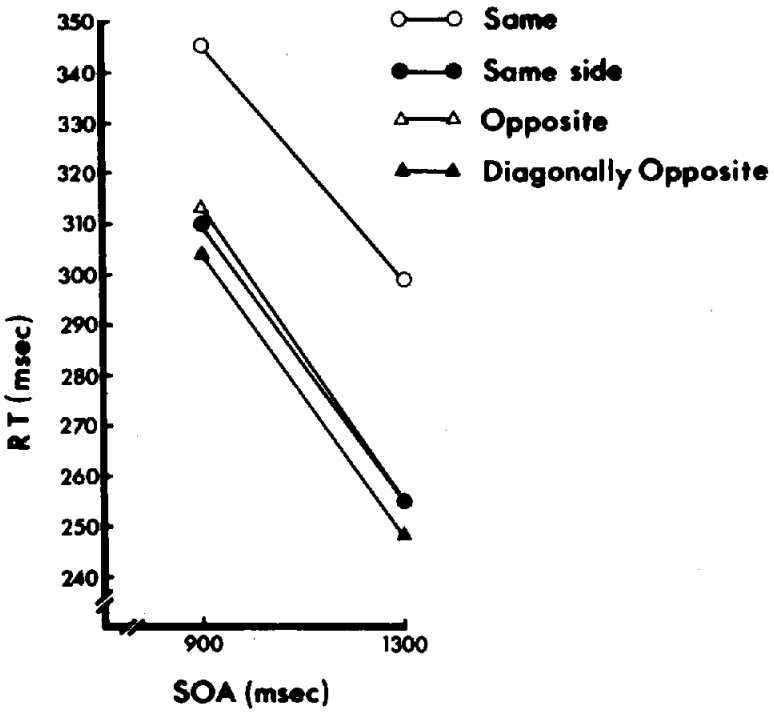

Figure 5. Results of Experiment 3. (SOA = stimulus onset asynchrony; RT = reaction time; msec = milliseconds.)

$F(3, 12) = 8.73$, $p < .005$, but there was no interaction between them ($F < 1.0$). From Figure 5 it can be seen that the trial-type effect can be mainly attributed to the increased reaction time to respond to *same* trials compared to the other three types. Clearly, the inhibitory effect is found only for targets that share *environmental* location with the cue. Thus inhibition associated with both overt (Posner & Cohen, 1984) and covert externally controlled orienting is mapped in environmental coordintes. It is clear that explanations for the effect in terms of habituation of sensory pathways at any level must be discounted.

Experiment 4

Posner and Cohen (1984) concluded that inhibition is observed only when attention is summoned away from the cued location. Two methods were used to ensure that attention returned to the center following peripheral cuing. As described in the introduction, Posner and Cohen (1984) employed a probability manipulation whereby the target was more likely to appear at the center than in the periphery. Cohen (1981) included central cuing in order to summon attention back to fixation. The results of the present Experiments 1–3 appear to argue against Posner and Cohen's (1984) conclusion that "if attention is not drawn away from the cued location, no net inhibition is found" (p. 541), because each exhibited an inhibitory effect without the inclusion of specific measures to attract attention back to fixation after the presentation of each target (see also Maylor, 1983). Nevertheless, it is possible that the requirement to fixate centrally throughout and the fact that the target was equally likely to appear on either side of fixation ensured that the subject's attention did return to the center following the offset of each target. However, Maylor (in press) argued that inhibition can be observed while attention (as inferred from temporal order judgments) is still at the cued location. A direct test of Posner and Cohen's claim would be to compare inhibition at the fovea and in the periphery following both foveal and peripheral cuing. This was the aim of Experiment 4.

Method

Subjects. Six subjects each participated in a single experimental session of approximately 20 min.

Apparatus and stimuli. The experiment was controlled by an LSI 11/23 system, the stimuli being presented on a large Hewlett-Packard screen (P-31 phosphor). Three boxes were displayed throughout the experiment, one 4.2° to the left and another 4.2° to the right of a central box. The cues and targets were identical and were small squares of dots appearing in the middle of the boxes. The subject was seated approximately 65 cm from the screen and provided with a response panel consisting of two buttons labeled "Yes" and "No".

Design and procedure. The subject was instructed to fixate on the central box throughout the experiment. The index finger of the right hand was placed on the button labeled "Yes" while the left hand rested on the subject's lap. A trial began with the presentation of a cue inside one of the three boxes for 300 ms. On experimental trials, this was followed after an interval of 600 ms (SOA = 900 ms) by a target, again inside one of the three boxes. The subject's task was to press the "Yes" button as quickly as possible following the onset of the target. The target disappeared following the response and the next trial continued after an intertrial interval of 1,500 ms. On catch trials, the cue was not followed by a target, and the subject was required to withhold a "Yes" response, and then wait 2 or 3 s before pressing the "No" button with the left hand to signal when ready to continue.

The trials (108) were divided equally between the three cues, left, center, and right. For each of the three cues, the target appeared 8 times in each of the three locations (experimental trials) and did not appear 12 times (catch trials).

Results

A total of three errors was made throughout the experiment. The overall means of the median reaction times for each of five trial types (produced by combining left and right) are presented in Table 1. An analysis of variance with trial type as the fixed effects factor revealed a highly significant effect of trial type, $F(4, 20) = 13.23$, $p < .0001$. Planned comparisons confirmed that in addition to a significant inhibitory effect of 61 ms in the periphery—1 vs. 3, $F(1, 20) = 13.46$, $p < .002$—there was a significant effect of 88 ms at the fovea—2 vs. 4, $F(1, 20) = 28.49$, $p < .00005$. Inhibition was larger at the fovea than in the periphery for 5 of the 6 subjects. The overall difference of 21 ms between reaction time to foveal (2 and 4) and peripheral (1, 3, and 5) targets approached significance, $F(1, 20) = 3.85$, $p < .07$.

It is assumed that when both the cue and the target appear at the fovea, attention must remain there throughout the trial. Thus the present results, in addition to those of Maylor (in press), argue against Posner and Cohen's (1984) suggestion that in order to observe inhibition, attention must be withdrawn from the cued location.

Table 1
Results of Experiment 4

Trial type	Cue–Target	RT (ms)
1	L–L, R–R	404
2	C–C	384
3	C–L, C–R	343
4	L–C, R–C	296
5	L–R, R–L	336

Note. RT = reaction time; L = left; R = right; C = center; ms = milliseconds.

General Discussion

Experiments 1–4 have revealed several characteristics of the inhibitory effect associated with externally controlled covert orienting. First, it occurs in a target–target paradigm (Experiment 1), thereby enabling us to discount "response inhibition" (Harvey, 1980) as an explanation. The time course of the inhibitory effect (Experiments 1, 2, and 3) eliminates possible masking and persistence phenomena. Inhibition is not restricted to the exact location of the previous event (Experiment 2), is determined by environmental coordinates (Experiment 3), and occurs at the fovea as well as in the periphery (Experiment 4). These results, particularly from Experiment 3, make it unlikely that sensory habituation is responsible for the inhibitory effect.

The results of Experiment 2 are highly consistent with those of Vaughan (1984). He investigated the spatial and temporal extent of the inhibitory effect around previously fixated locations by measuring saccade latency rather than manual reaction time. The subject was asked to track unpredictable step displacements. Thus Vaughans's procedure was similar to that of Experiment 1 in that a series of visual targets was presented, each target requiring a response (that is, a saccade). He found that saccade latency is increased to a previously fixated location with respect to a new location and that the effect persists for at least 1,200 ms following a saccade. Moreover, the increase depends upon the distance between the desti-

nation of the saccade and the previously fixated location in a similar way to Experiment 2 (although it is difficult to make quantitative comparisons between the two experiments as different stimulus eccentricities were used).

In addition, Vaughan's study extends the range of experimental conditions that result in an inhibitory effect. First, inhibition occurs for both simple and choice manual responses to a target appearing more than 300 ms after and in the same or nearby location as a direct cue in the periphery, in the absence of eye movements (Posner & Cohen, 1984; Maylor, in press; Experiment 2). Second, saccade latency is greater to a target from a cued location in the periphery than from an uncued location (Maylor, in press). Third, manual reaction time is inhibited to a target appearing in a previously fixated location, as long as the initial saccade is externally controlled (Cohen, 1981). Finally, saccade latency is greater to a target from a previously fixated location than to one in a new location, all saccades being under external control (Vaughan, 1984).

A comparison between the results of the four present experiments reveals that the size of the inhibitory effect is somewhat variable. The reduced amount of inhibition observed in Experiment 1 can be attributed to the use of a rapid target–target procedure in which a target could occasionally appear in the same location on *more* than two successive trials. Maylor and Hockey (1984) demonstrated that under such conditions, inhibition is large for the first repetition but decreases thereafter. It could be argued that the amount of inhibition is determined by the ranges and probabilities of R–S intervals or SOAs used. By employing the particular distributions of Experiments 1, 2, and 3, the "survivor function" (the probability that a target will occur, given that it has not occurred already) starts with a low probability and rises as a function of time, leading to a general reduction in reaction time with increasing R–S interval of SOA. One possibility is that a stimulus in a particular location *facilitates* the detection of another stimulus in that same location, which then appears to occur earlier in time than one from a different location. As a consequence, the increase in target expectancy over time would have a greater effect on new locations than on old locations.[1] There are at least three reasons why this fails to account for the results. First, both early facilitation (at 100 ms) and late inhibition (at 500 ms) can occur at SOAs where overall reaction time is generally decreasing (Maylor, in press). Second, inhibition was observed in Experiment 4, where the target either appeared 900 ms after the onset of the cue or did not appear at all on a catch trial. Third, Maylor and Hockey (Experiment 3, 1984) demonstrated an inhibitory effect using a choice reaction-time task with a fixed R–S interval of 600 ms. It is assumed that survivor functions are irrelevant in the present Experiment 4 and Experiment 3 of Maylor and Hockey.

It can be concluded that the inhibitory effect is characterized by an inability to respond as quickly (both manually and ocularly) to a target appearing in a recently stimulated location (either by a cue or by another target) as to one appearing in a different location. Inhibition is *dependent* upon externally controlled orienting (Maylor, in press) and a comparison between experiments with 2, 4, and 14 possible target locations reveals that inhibition cannot be explained by a bias *toward* a particular alternative target source; rather it is a bias *against* the present one. In agreement with Posner and Cohen (1984), we find that inhibition appears to act to delay responding to a location that was recently examined (either covertly or overtly) and thus may play an important role in maintaing spatial selectivity.

It is concluded that a single event in the visual periphery may first capture attention, leading to the early facilitatory component as described in the introduction. This brief period of enhanced processing may or may not be accompanied by an eye movement toward the location of the initial stimulus. In both cases, however, there then follows an inhibitory component whereby responses to stimuli at that same location are delayed with respect to new locations. Thus the two components associated with externally controlled orienting appear to combine to produce a spatial mechanism that responds efficiently to novelty in the visual environment.

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[1] I am grateful to an anonymous reviewer for this suggestion.

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