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Spatial determinants of the distribution of attention

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A simple reaction time technique was used to investigate the distribution of attention at different eccentricities. Subjects were asked to shift their attention to a cued spatial location and respond to a subsequently presented target light. Although the target was often flashed at the cued location, targets were sometimes presented at other eccentricities. By examining the reaction time to the target as a function of the distance of the target from the cue and the eccentricity of the cue, the distribution of attention at different eccentricities could be determined. Reaction time generally increased with distance, and a smaller effect of the attention manipulation was found with peripheral cues.

Spatial attention or selection refers to the ability to attend to a particular region of space. Researchers have been concerned with understanding the basic mechanisms and properties of spatial selection and the role of selection as a functional component of other tasks (LaBerge, 1983; Posner, 1980). An important goal of the former approach is to identify structural factors that put constraints on the spatial distribution of attention. Posner, Snyder, and Davidson (1980), for example, have shown that it is particularly difficult to split attention to two separate spatial regions. This paper is concerned with the effects of spatial distance and eccentricity on attention allocation. Reaction time (RT) techniques are used to determine how the attention allocated to a location changes as its distance from the focus of attention increases.

Several researchers have examined the effect of distance on the spatial distribution of attention. Gatti and Egeth (1978) and Kahneman and Chajczyk (1983) report that Stroop interference decreases as one increases the spatial separation between a foveal color patch and a peripheral color word. One interpretation of this effect is that as distance increases, the peripheral location is more efficiently filtered, preventing interference from the color word. As both Gatti and Egeth and Kahneman and Chajczyk note, however, the decrease in interference from the peripheral color word could be due to progressive changes in acuity rather than an increased ability to filter that location. Goolkasian (1981) reports that a congruent or incongruent foveal color word facilitated or interfered, respectively, with a vocal response to a foveal Stroop color patch. Only facilitative effects of the foveal color word were found when the color patch was located at 7°. In a second experiment, she examined the effects of a congruent or incongruent foveal word ("right," "left," "up," or "down") on the identification of the orientation of a peripheral letter. Facilitative effects from a foveal congruent word (foveal word "left," peripheral letter facing left) were found only when the peripheral letter was located at 7° and 15°, whereas no effects of the foveal word were found for a 25° letter location. Goolkasian's results suggest that the spatial distance between a target and distractor influences the effect of that distractor on reaction time to the target. Since the location of the distractor was held constant (at the fovea), her results cannot be attributed to changes in the discriminability of the distractor. Eriksen and Hoffman (1972, 1973) also used a distractor technique to determine the spread of attention about a cued location. They found the largest distractor interference for target-distractor distances within 1°, but also reported (Eriksen & Hoffman, 1973) smaller residual interference at two greater distances, the amount depending on distance. Since they presented circular displays, distance was not confounded with acuity. However, their task was acuity limited, restricting the range of eccentricities that could be examined.

The present experiments measured distance effects over a range of eccentricities using a simple RT technique that does not involve acuity limitations. The method rests on the well-documented finding (Posner, 1980) that a response to an event in a location is faster if attention is focused on that location. In Experiments 1, 2, and 3, subjects were cued to attend to either a foveal or a peripheral light. Although subsequent RT targets generally appeared at the cued eccentricity, probe targets at specified distances from the cued location were occasionally presented. The effect of the distance of the target from the focus of attention could thus be measured for both a foveal and peripheral focus.

As stated, the method has a problem. Changes in RT as the target event moves from the focus of attention may

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be due to changes in the eccentricity of the target rather than to the effect of the distance variable (Rains, 1963). Two controls were introduced to eliminate this problem. First, lights at all eccentricities were equated in perceived brightness. This control was expected only to moderate the large changes in RT that occur with changes in eccentricity. The second, more crucial control was to introduce "pure" conditions in which RT to an eccentricity was measured when the subject was actually attending to that eccentricity. The distance effect was then measured by subtracting RT to an eccentricity when that location was being attended to (the pure condition) from the RT to that same eccentricity when a location some distance away was being attended to (called a mixed condition).[1]

EXPERIMENT 1

Method

Subjects

Twenty-one subjects were recruited from introductory psychology classes at Penn State University. One subject, who made errors on 33% of the catch trials, was eliminated from the experiment.

Apparatus

All experiments were conducted on a PDP-11/34 minicomputer. Target and cue lights consisted of red and green LEDs mounted on a metal band curved to assume the shape of a hemisphere. Each LED subtended a visual angle of .3°.

Procedure

Brightness adjustment. On Day 1, each subject adjusted the intensity of all target lights so that they would appear equally bright. A dim fixation point and a .5° reference light set at 1.0 cd/m² were presented. A light at the next eccentricity was then turned on. The subject, maintaining fixation, adjusted the luminance of this second light using a potentiometer until it matched the brightness of the reference light. The light was then extinguished and the next light was presented and matched. This adjustment procedure was carried out for lights at all the eccentricities used in the experiment. The eccentricities in Experiment 1 formed two groups corresponding to the foveal and peripheral focus of attention. The four lights in the first group were located at .5°, 3.5°, 7.5°, and 12.5°; the lights in the second group were located at 9.5°, 12.5°, 16.5°, and 21.5°. All lights were presented in the nasal field, and subjects viewed the display monocularly with the left eye. The purpose of this brightness-matching control was to eliminate large differences in RT to lights at different eccentricities. The major control of changes in RT with eccentricity was the pure condition discussed in the next section.

Pure condition. Each trial began with the onset of a fixation point (amber LED). One second later, a cue was presented instructing the subject to attend to a light at a particular eccentricity. On each trial of a pure block, the cued eccentricity was either a fixed light from Group 1 or a fixed light from Group 2 (for example, on each trial of a block, the subject might be cued at either 3.5° or 16.5°). The two lights paired in a particular block were chosen randomly. The cue was an LED that appeared slightly above the target location. To prevent any differential adaptation due to the cue light, noncue lights were also presented at the noncued locations for the group of the cue, but these lights were positioned below the target location. These extra lights lagged the initial cue light by 1 sec so that subjects would have no difficulty identifying the cued location. The subjects were told to attend, without moving their eyes, to the cued location. One second following the onset of the noncue lights, both the cue and noncue lights were extinguished. After a 300-500-msec variable ISI, the target light was presented. In these pure trials, the target light always appeared at the cued location. Following an ITI of 1,500 msec, the fixation light reappeared. Each block consisted of 50 trials, 22 at each cue location, and 6 catch trials in which a cue but no target light was presented. Each eccentricity was tested in two separate pure blocks.

Mixed condition. The sequence of events was the same as in the pure condition. Each trial was initiated by the onset of a fixation point. One second later, the cue light was presented, followed in another second by the onset of the noncue lights. The cued location was either .5° or 9.5°, the first location in Groups 1 and 2 defined above. The cue and noncue lights were extinguished 1 sec following the onset of the noncue lights and after a variable 300-500-msec ISI, the target light was presented. The target light appeared at the cued location on 77% of the trials. On the other trials, it appeared at one of the other locations in the group of the cue. Thus, if the cued location was .5°, the target light would appear at 3.5°, 7.5°, or 12.5°; if the cued location was 9.5°, the target light would appear at 12.5°, 16.5°, or 21.5°. Each block consisted of 186 trials, 122 trials in which the target appeared at the cued location, 36 in which the target was presented to a noncued location, and 28 catch trials.

Order of Sessions

Before all sessions, subjects dark-adapted for 10 min. On Day 1, the subjects performed the brightness adjustment and were given 60 practice trials in the mixed condition. They were then given one mixed block and one pure block. The subjects were informed of the difference between pure and mixed blocks and always knew which type of block was being presented. On each of Days 2 and 3, they were given two mixed blocks and three pure blocks. The order of pure blocks over days was counterbalanced across subjects.

Results

Median RTs were computed after eliminating latencies less than 100 msec or greater than 1,000 msec.[2] Group means of the medians are displayed in Figure 1 for both the mixed and pure conditions. Reaction time for the pure condition shows a moderate rise with eccentricity, indicating that the brightness adjustment was only partly successful in equating detectability across eccentricity. Figure 2 shows the results of subtracting reaction times in the pure condition from those in the mixed. The abscissa refers to the distance in degrees between the target light and the focus of attention. The value of the subtraction increases in a monotonic fashion for both cue eccentricities, the more peripheral cue yielding a smaller value.

These trends were confirmed in a three-factor analysis of variance on the median reaction times. The factors were condition (mixed and pure), cue location (.5 and 9.5), and distance (0°, 3.0°, 7.0°, and 12.0°). Main effects of condition [$F(1,19) = 26.17$, $p < .001$], location [$F(1,19) = 23.01$, $p < .001$], and distance [$F(3,57) = 58.05$, $p < .001$] and the interactions of condition × location [$F(1,19) = 5.14$, $p < .05$] and condition × distance [$F(3,57) = 7.20$, $p < .001$] were significant. The condition × location interaction indicates that the attention manipulation (mixed vs. pure) had different effects for near and far attentional focus. Thus, the difference between the pure and mixed conditions was greater when the attentional focus

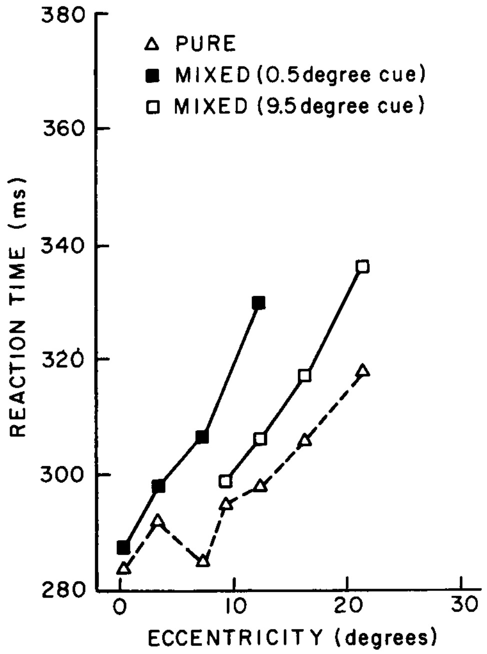

Figure 1. Group reaction time as a function of stimulus eccentricity (Experiment 1).

was near. The condition × distance interaction indicates that the effect of the attention manipulation increased with the distance of the target from the cued location. The difference between the mixed and pure conditions tended to increase as the distance of the target light from the focus of attention increased.

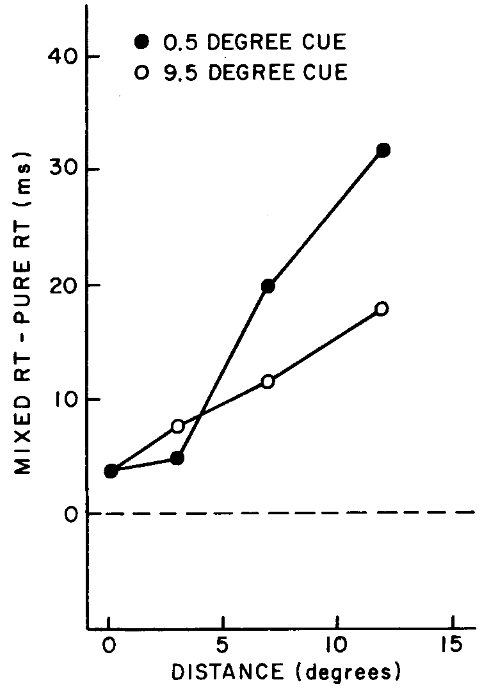

Figure 2. The difference between reaction times in the mixed and pure conditions plotted as a function of the distance between the target light and the cue light.

The effect of distance of the target light from the focus of attention can also be observed by examining the RT for the 12.5° light, which was presented in both the near and far mixed conditions. In the former, the distance is 12° and the RT is 330 msec, whereas in the latter the distance is 3° and the RT is significantly faster at 306 msec [$t(19) = 2.87$, $p < .01$]. In this case, distance is manipulated by keeping the target location constant and varying the cue location, rather than the reverse as in Figure 2.

Analysis of the catch-trial data indicated that errors occurred on 4% and 6% of the catch trials with a central cue and peripheral cue, respectively, in the mixed condition, and on 5% of the trials in the pure condition. The difference in catch-trial errors for a central and peripheral cue was significant [$t(1,19) = 3.27$, $p < .01$].

Discussion

The results indicate that RT is a function of the distance of the target light from the focus of attention. This conclusion holds whether one maintains the focus of attention constant and changes target location (Figure 2) or maintains target location constant and changes the focus of attention. Although the first method controls for changes in retinal sensitivity through the use of the pure condition, it is still the case that different distances are tested at different target eccentricities. The second method allows one to test different distances under conditions in which target eccentricity is constant.[3]

The condition × location interaction indicates that the attentional manipulation had less effect with a peripheral cue than with a central cue. This result can be interpreted in two ways. It may not be possible to selectively attend to the periphery as efficiently as in the fovea. The act of attending in the periphery may expend some capacity. Alternately, if one conceives of spatial attention as a spotlight that illuminates different areas of the visual field, it seems possible that the width of the spotlight, the attentional field size, may vary with its eccentricity. Eriksen and Hoffman (1972) suggested that the focus of attention had a diameter of about 1°, but they did not discuss whether this size might change with eccentricity. Humphreys (1981) has published data that suggests that the attentional field does increase as a function of eccentricity. He found that a distractor increased RT to classify a target when the target was presented at .5° and the distractor was presented at fixation, but not when the eccentricities of target and distractor were reversed. He concluded that the focus of attention could be narrower at fixation than off fixation. Humphreys did not test this conclusion over a wide range of eccentricities (he compared fixation and .5°, perhaps because his task was acuity limited.

The size of the attentional field should be reflected in the slope of the distance function. If the focus of attention is narrow, then simple RT to events that occur a short distance away should be slower than to events at the center of the focus. If the focus is broad, then the increase in RT to events away from the center of the focus should not be as great. The slope of the change in reaction time with distance will thus give an indication of the size of the attentional field. Inspection of Figure 2 suggests that the peripheral cue may have produced a shallower distance function. A trend analysis, however, indicated that the linear components of the central and peripheral distance functions were not significantly different [$F(1,19) = 2.79$, $p = .11$]. It is possible that a significant slope difference might be found if the eccentricity of the peripheral cue was increased.

EXPERIMENT 2

In Experiment 2, the eccentricity of the peripheral cue was extended to test the hypothesis that the slope of the distance function depends upon the eccentricity of the cue.

Method

Twenty subjects were recruited from introductory psychology classes. The procedure and design were identical to those of Experiment 1. Eccentricities in Group 1 were .5°, 3.0°, 6.0°, and 10.0°; those in Group 2 were 21.0°, 23.5°, 26.5°, and 30.5°. Again, the first location in Group 1 corresponds to the near focus of attention, and that in Group 2 to the far focus of attention. Stimuli were also presented in the temporal field instead of the nasal field. The field location was changed so that the stimuli in the experiment would not be approaching the edge of the visible field. The luminance of the target light was decreased to .55 cd/m².

Results and Discussion

The results from the mixed and pure conditions are plotted in Figures 3 and 4. Although distance effects were found with the near cue, little or no effects of distance were present with the far cue. An analysis of variance on the median RTs yielded significant main effects of condition [$F(1,19) = 18.18$, $p < .001$] and distance [$F(3,57) = 5.61$, $p < .01$], significant interactions of condition × location [$F(1,19) = 29.65$, $p < .001$], condition × distance [$F(3,57) = 7.96$, $p < .001$], and distance × location [$F(3,57) = 10.94$, $p < .001$], and a marginal interaction between condition, location, and distance [$F(3,57) = 2.63$, $p = .06$].

As in Experiment 1, the significant condition × location interaction indicates that selective attention in the periphery was less effective than in the fovea. The hypothesis that this difference reflects a change in attentional field size was evaluated by examining the slopes of the foveal and peripheral distance functions. A trend analysis revealed that the linear components of the central and peripheral distance functions were significantly different [$F(1,19) = 7.25$, $p < .02$].

Subjects made catch trial errors on 3% and 4% of the trials with a central and peripheral cue in the mixed condition and on 3% of the pure condition trials. The differ-

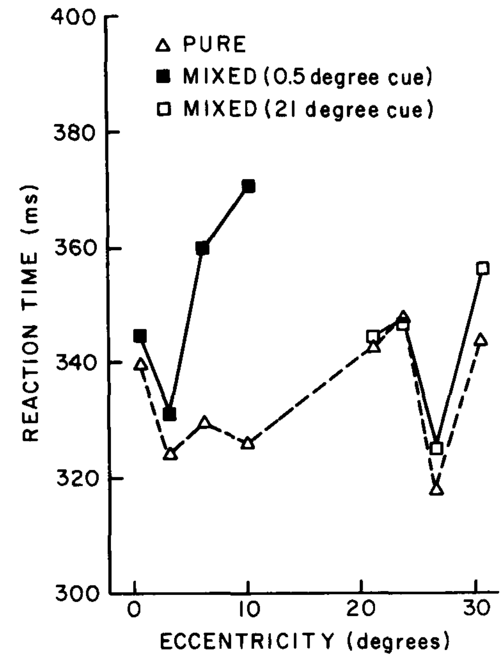

Figure 3. Group reaction time as a function of stimulus eccentricity (Experiment 2).

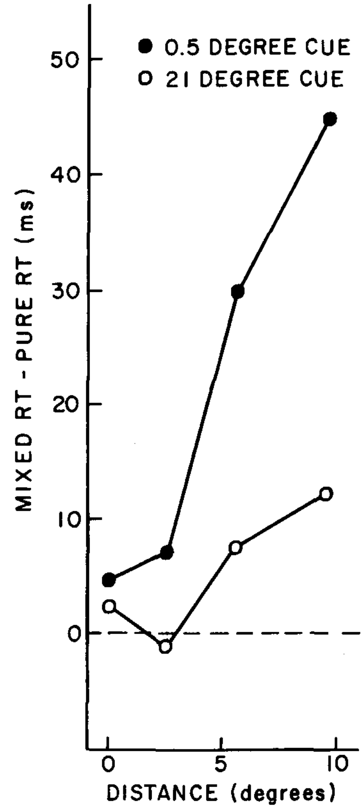

Figure 4. The difference between reaction times in the mixed and pure conditions plotted as a function of the distance between the target light and the cue light (Experiment 2).

ence in catch-trial errors with a central and peripheral cue was not significant [t(19) = 1.1, p > .2].

EXPERIMENT 3

Experiments 1 and 2 provide evidence for distance effects and for a decrease in the efficiency of selection in the periphery. Two objections might be raised, however, to those conclusions.

In both experiments, there was a 300-500-msec interval between the offset of the cue and the onset of the target light. Although this interval is small, one might argue that it introduces some positional uncertainty concerning the proper location of attention. If this uncertainty is greater in the periphery, one might account for the difference between central and peripheral cues. In Experiment 3, we therefore did not extinguish the cue and noncue lights until the subject had responded to the target.

Secondly, we did not monitor eye movements during the first two experiments. Although it is unlikely that eye movements produced the main findings of the first two experiments,[4] we decided to measure eye movements in Experiment 3 as a check.

Method

Sixteen subjects participated in three sessions, each lasting 90 min. Group 1 eccentricities were .5°, 8.5°, and 16.5°, and Group 2 eccentricities were 7.5°, 15.5°, and 23.5°. The main change in procedure from the previous experiments was that the cue and noncue lights were not extinguished until the subject had responded to the target light. To avoid masking or interference between these lights and the target, the vertical separation between them and the target was increased to 2.0°.

The validity of the cue in the pure condition was also changed to correspond to that of the mixed condition. In Experiments 1 and 2, the cue validity in the mixed and pure conditions was .77 and 1.0. We thought this difference might be responsible for the slight advantage at the cued position for the pure over the mixed (producing the small costs at the 0° distance). In Experiment 3, the cue validities for both the mixed and pure conditions were set at .8.

Eye movements were monitored using dc electrooculography. The apparatus was calibrated at the beginning of each session for each subject, and this calibration was checked midway through the session. Eye movements were detected by visually inspecting the eye-movement records, using the voltage changes specified by the calibration procedure. Our apparatus was sufficiently precise to reliably indentify eye movements of amplitude 2° or greater.

Results and Discussion

Median latencies were computed after eliminating trials on which eye movements were detected. The group means for the mixed and pure condition are plotted in Figures 5 and 6. Distance effects were found for both a central and a peripheral cue, but the slope of the distance function appears greater with a central cue. An analysis of variance on the median reaction times yielded main effects of condition [F(1,15) = 37.52, p <.001] and distance [F(1,15) = 17.76, p < .001] and interactions of condition × location [F(1,15) = 4.43, p = .05], condition × distance [F(2,30) = 17.28, p <.001], location × distance [F(2,30) = 8.55 p < .01], and condition × location × distance [F(2,30) = 3.84, p < .05].

Subjects made eye movements on 1.0% of the trials, too few to analyze in detail. The subjects made catch-trial

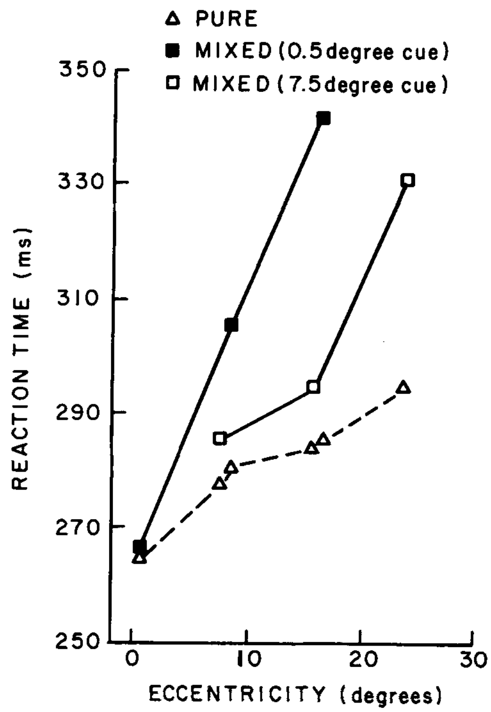

Figure 5. Group reaction time as a function of stimulus eccentricity (Experiment 3).

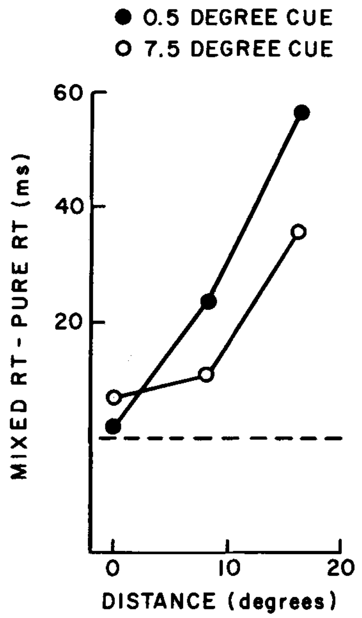

Figure 6. The difference between reaction times in the mixed and pure conditions plotted as a function of the distance between the target light and the cue light (Experiment 3).

errors on 5.0% and 4.9% of the trials with a central and peripheral cue in the mixed condition and on 7.3% of the pure condition trials.

The results replicated the main features of earlier experiments. Significant distance effects were found as well as a decreased efficiency for peripheral cues. The significant condition × location × distance interaction suggests that the distance function for central cues is steeper than for peripheral cues.

GENERAL DISCUSSION

The preceding experiments have examined the manner in which the eccentricity of the focus of attention and distance from the focus of attention define the distribution of spatial attention. In Experiments 1, 2, and 3, reaction time to a target light increased with increases in the distance between the target and the focus of attention. In Experiments 1, 2, and 3, a peripheral focus of attention produced a significantly smaller increase in RT to nonattended stimuli than did a foveal focus (the condition × location interaction).

The distance effect is consistent with the idea that a gradient of attention extends outward from the center of the attentional focus. This gradient would define the resolution of attention and would appear to extend over a large area, since effects were found as distance increased to 16°. The present technique for measuring the resolution of spatial attention differs from that used in the measurement of conventional acuity, since one can selectively attend to a location in the absence of a stimulus. In the present experiments, subjects respond to a single stimulus in a dark field; they do not have to resolve two external stimuli. Resolution here refers not to the ability of an internal mechanism to distinguish a stimulus in one location from that in another, but to the ability of an internal mechanism to select information from one location rather than another. The distance function can thus be interpreted as a measure of the resolution of the internal mechanism that governs spatial selection or attention.

The second main result of these experiments, the condition × location interaction, suggests some limitations on our ability to attend in the periphery. One possibility, raised by the significant slope difference in Experiments 2 and 3, is that the resolution of spatial attention decreases in the periphery. This characterization implies that effects of selective attention in the periphery can be as large as those in the fovea if the distance between the attentional focus and the unattended target is sufficiently large. It is also possible, however, that there are absolute limits on the efficiency with which attention can be allocated in the periphery.

Both of these considerations might explain why, in the pure condition, RT generally increased with eccentricity even though brightnesses were matched. For example, to the extent that attention is spread over a larger region in the periphery than in the fovea, events at the center of a peripheral focus will be less efficiently processed. Similarly, limits in our ability to attend in the periphery would also lead to increases in the pure condition. It is also possible that these RT differences may be purely sensory in nature. There is no necessary reason why lights that appear equally bright should produce equivalent RTs. RT might be controlled, for example, by transients in the signal whose magnitudes are not strictly correlated with perceived brightness. More generally, structures that determine RT may be sensitive to different properties of a stimulus than those that determine perceived brightness.

The goal of the present experiments was to identify variables that define the spatial distribution of attention.[5] The effects of these variables can be conceptualized by considering the internal representation of the visual field. If one attends to a region of space by selecting the relevant segment of the representation of the visual field, then the characteristics of that representation should influence the properties of selection. The data suggest that selection is influenced by both the topographic nature of the representation and possibly the decrease in the resolution of the representation in the periphery.

The present experiments have determined the distribution of attention in an empty field under a particular task demand. Attentional field sizes can be expected to vary with task demands and the spatial distribution of task-relevant stimuli. Several recent experiments (LaBerge, 1983; Podgorny & Shepard, 1983) have examined RT to spatial probes in structured displays involving different task demands. LaBerge asked subjects to categorize either a five-letter word or the middle letter of a five-letter word or nonword (spanning 1.77°). Subjects also had to classify probe stimuli that appeared in one of the five letter positions. Probe RT did not vary with letter position in the word task, but increased with the distance from the middle letter in the letter task. LaBerge suggests that the size of the attentional field varied with the task demand, being smaller in the letter task than in the word task. The distance effects that LaBerge finds in the letter task are qualitatively similar to those found in the present experiments, in spite of the large methodological differences between the studies. Thus, although the absolute size of the attentional field may vary from study to study, the effects of distance and eccentricity in the present study can be expected to generalize across tasks.

CONCLUSION

The preceding experiments have demonstrated systematic effects of the internal representation of the visual field upon the distribution of spatial attention. This distribution is influenced by both the topographic nature of the representation and possibly the change in the resolution of the representation with eccentricity.

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NOTES

1. Given this subtraction technique, one might question whether brightness matching was necessary. The subtraction always involves two terms in which the target eccentricity is constant. It is the case, however, that as cue-target distance changes, the target eccentricity in the subtraction also changes. To look at effects of cue-target distance, one must therefore assume that two subtractions at different eccentricities (and therefore with lights of different brightnesses) are comparable. In designing our studies, we thought that the validity of the assumption underlying our subtraction method would be increased if discriminability differences for different eccentricities were minimized.

2. In Experiments 1, 2, and 3, this criterion resulted in the elimination, respectively, of 1.4%, 2.6%, 1.7%, and .97% of the total trials.

3. This comparison illustrates the advantages of measuring the distance effect with a technique in which only one stimulus is presented. The distractor techniques cited in the introduction rely on the ability of an irrelevant stimulus to either inhibit or facilitate the processing of a second target stimulus. As one changes the distance between the two, however, one changes the relative efficiency in the retinal processing of the two stimuli. This is true whether one maintains the location of the target and changes the location of the distractor (Gatti & Egeth, 1978) or the reverse (Goolkasian, 1981). These changes in relative retinal efficiency may influence the size of the distractor effect and thus make it difficult to unambiguously interpret the measured distance functions. Even if one is able to control the relative retinal sensitivity to the distractor and the target, the distractor technique still involves the assumption that any change in performance with target-distractor distance is due to an effect of distance specifically on the spread of attention. It is possible, however, that other nonretinal but still nonattentional factors that underlie the effect of the distractor might also depend on distance.

Circular displays, which control for retinal sensitivity, are not a general solution, since they do not easily allow one to compare the effects of the same distance for foci of attention at different eccentricities. For example, with a cue at 10°, distances of 20° or less can be examined; with a cue at .5°, only distances less than 1° can be examined. Even when the cue-target distance can be equated for two cue eccentricities, other spatial characteristics will vary. For example, if the cue is located at 5°, a target at a 10° distance is located across the midline at a point at the plane of fixation. If the cue is at 20°, a 10° distance positions the target on the same side of the midline in the superior visual field. These conditions do not seem comparable.

4. Although in the past one of us (GLS) has recorded eye movements to insure that subjects do not move their eyes along with their attention, this precaution has proven unnecessary. Subjects are quite able to obey instructions when the task does not involve any acuity demands.

Several features of the data from Experiments 1 and 2 also indicate that subjects did not move their eyes. Even with the brightness matching procedure, RT generally increased with eccentricity. The condition × location interaction of Experiments 1 and 2 is also inexplicable under the assumption that subjects moved their eyes and fixated the cued location. Neither distance effects nor the difference between central and peripheral cues can be explained by eye movements.

5. It has been suggested (Duncan, 1980; Shaw & Shaw, 1977) that subjects in cuing experiments set different criteria for cued and noncued locations. Attending to a location could affect the degree of evidence required to categorize a stimulus as present, not the information or representation upon which the categorization is based. The concern of this paper is not with the manner in which selective attention affects performance, but with the spatial constraints on how selection may occur—constraints that must be satisfied by any theory of selection. Criterion theories state both the manner in which selection affects performance (by affecting criteria) and the constraints on how selection can occur (constraints on how criteria are set). The rules or constraints governing selection in these theories are often those given by statistical decision theory.

It is clear, however, that many of the constraints on how selection occurs are not encompassed by statistical decision theory. Similar results to the cuing paradigm can be found using methods in which attention is automatically drawn to a location by an external stimulus in the absence of a probability manipulation. These capture effects (Jonides, 1981; Posner & Cohen, 1983) cannot be explained by a theory that emphasizes a rational statistical decision process. One would have to assume that the occurrence of a stimulus automatically lowers the criteria for stimuli near that position. Similarly, Posner, et al. (1980) have shown that it is particularly difficult to attend to widely separate spatial regions (i.e., criteria cannot be simultaneously lowered in separate locations).

Consider the results of the present experiments from the standpoint of a criteria-setting theory. The distance effect suggests that a criterion 7° from the cued position is, for some reason, constrained to lie between the criterion set at the cued position and that 12° from the cued position. It would seem that a rational decision maker would set one criterion at .5° and a different criterion at the other low probability location. Similarly, the difference between central and peripheral cues suggests that people cannot set different criteria as effectively in the periphery as in the fovea. One may still choose to describe the effect of selection on performance in terms of criterion changes. But it is clear that the manner in which criteria are set involve many considerations beyond those of statistical decision theory.

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