Bulletin of the Psychonomic Society
1991, 29 (3), 206-208

The effect of presentation time on the size of the visual lobe

A. F. SANDERS and R. BRÜCK
Free University, Amsterdam, The Netherlands

Presentation time has been poorly controlled in studies on the visual lobe, due to the common opinion that a target exerts bottom-up control over the visual system with the effect that data limits are rapidly reached. The visual lobes of 4 subjects were determined with presentation times ranging between 150 and 450 msec and with a self-paced presentation time. The results showed a significant increase in lobe size as presentation time increased. The lobe size at 450 msec was about equally large as at the self-paced condition, suggesting that a data limit may be reached at that value. This result refutes a simple bottom-up sensory explanation of the lobe. Instead, it suggests a contribution of central processing, either bottom-up or top-down, which extends over time. The implications of this result for the role of the lobe while fixating during free search remain to be determined.

The visual lobe, or conspicuity area, is usually defined as the eccentricity contour at which a target can be detected or recognized with a certain probability under conditions of a brief presentation, spatial uncertainty, and a fixated eye (Engel, 1977). The common finding is an elliptically shaped field, with the longer meridian extending in the horizontal plane (e.g., Courtney & Chan, 1986). The actual size of the lobe varies considerably as a function of a score of display factors, among which target demands—detection versus recognition—and the nature of the background in which the target is embedded are most prominent (Brown & Monk, 1975; Edwards & Goolkasian, 1974). The visual lobe plays an important role in visual search models that assume that, while searching for a target in free search, the subject analyzes the contents of the lobe during successive fixations. Search is assumed to end with a rapid fixation as soon as the target has been located during a fixation (e.g., Engel, 1977; Jacobs, 1987). Indeed, it has been repeatedly found that interindividual differences in the size of the lobe are inversely related to search time in tasks like card sorting (Bellamy & Courtney, 1981).

A neglected factor in research on the visual lobe concerns the possible effects of *presentation time*. In some studies, the duration has been about 250 msec, so as to match the modal fixation duration in free search (Bellamy, 1984; Courtney & Chan, 1985). However, in other studies, presentation time has been as short as 75 msec (Engel, 1971) and as long as 750 msec (Johnston, 1965) or even 1,500 msec (Erickson, 1964). Sometimes, it has not been reported at all (Leachtenauer, 1978), or it has been extended until subjects respond (Hughes & Cole, 1986). The dominant feeling has been that the size of the lobe is insensitive to fixation duration: A target exerts bottom-up control over the visual system with the effect that it is either seen or not seen, irrespective of presentation time. There may be peripheral temporal summation, but the effects of that factor should not exceed a presentation time of 100 msec. Insensitivity of the lobe to presentation time would be in line with studies reporting effects of target/background discriminability on length and number of saccades rather than on fixation duration (e.g., Scinto, Pillalamarri, & Karsh, 1986). Yet, Scinto et al. (1986) also report an increase in fixation duration as search continues, suggesting a more "careful" inspection and, perhaps, a larger lobe. Again, in other settings, such as line reading, fixation duration has been found to double because of poor target/background similarity (Jacobs, 1987). In fact, the eyes did not move before the necessary operations had been completed, which increased as a function of signal complexity. Thus, effects of discriminability on fixation duration could indicate a central buildup of sensory encoding as a function of time, beyond the effect of retinal summation (e.g., Jacobs, 1986). Alternatively, effects on fixation duration could follow from research on covert orienting, suggesting a time-consuming scan of a spotlight or an optimal setting of a zoom lens during a fixation (e.g., Eriksen & Yeh, 1985). Both possibilities predict an increase in the size of the lobe until an asymptote—a data limit—has been reached. In particular, the orienting hypothesis suggests at least an active strategic top-down contribution to the lobe, which could well extend to search of homogeneous fields, where bottom-up random models of ocular scanning behavior still dominate the research scene.

These considerations stimulated an experiment in which the effect of presentation time on the size of the lobe was systematically investigated.

Correspondence should be addressed to A. F. Sanders, Faculteit der Psychologie en Pedagogische Wetenschappen, De Boelelaan 1111, 1081 HV Amsterdam, The Netherlands.

METHOD

Procedure

The experiment was carried out in a dimly illuminated, sound-attenuated cubicle (Amplifon). A subject was seated in an adjustable chair at a distance of 150 cm from a rectangular projection screen (70×59 cm), the midpoint of which was at eye level. Stimuli were projected on the screen through back projection. The subject's head rested on a chin/forehead rest so as to ensure a constant distance and to minimize head movements. A fixation mark was located in the middle of the projection area.

A stimulus consisted of a circular shaped scatter of 1,000 randomly placed "x"s serving as homogeneous visual background for the target, which was either an uppercase or a lowercase letter "c." The diameter of the stimulus circle was 57 cm, subtending a binocular visual angle of 22°. A single "x" subtended a visual angle of 0.4°×0.23°; the distance between adjacent elements varied between 0.2° and 1°. The stimulus had a fixation point (1° diameter) that superimposed the fixation mark. Stimuli had a luminance of 7 lx on a background of 5 lx.

The position of the target varied in direction (north, east, south, and west) and eccentricity, but was always on either a virtual horizontal or a vertical line through the fixation point. Twelve different eccentricities were used with a minimum of 1.5 cm (0.6°) for the (lowercase) "c" and a minimum of 8 cm (3°) for the (uppercase) "C," and a maximum of 19.5 cm (7.4°) for "c" and a maximum of 26.5 cm (10.1°) for "C." Since a target always replaced an "x," the step-width from minimal to maximal eccentricity varied in the same way as the mutual distance of the background "x." A target was never positioned at the margin of the circle to avoid differences in lateral inhibition. For either target, there were 12 alternative locations in each of the four directions, making a total of 48 stimuli (12×4) for both the "c" and the "C."

A trial started with a 100-msec warning tone (5000 Hz), which indicated that the mark on the screen should be fixated. After a 500-msec warning interval, the stimulus was presented for 150, 300, or 450 msec, or until the subject pressed a response key (self-paced condition). Upon completion of the presentation time, a 50-msec backward mask was presented, consisting of another stimulus without a target. After the stimulus had disappeared, the subjects reported either the direction of the target or a failure of detection. Successive trials were separated by a 2-sec intertrial interval.

The task was to keep the fixation point fixated until completion of the trial. This was controlled on and off line by measuring eventual eye movements with a Debic 84 eye camera positioned directly below the screen in front of the subject. Data were digitally stored for later analysis. The Debic operates on the "point of regard" principle (Young & Sheena, 1975). Samples were taken at a rate of 20 msec and the spatial accuracy was about 1°. The Erts software package (Beringer, 1988) was run on an Olivetti M28 digital computer for timing events within and between trials.

The experiment had eight conditions (four presentation times × two levels of target/background similarity), which were run in separate blocks of trials. A block consisted of either an ascending or a descending series of stimuli—starting, respectively, at the minimal or maximal eccentricity—in which target direction was always randomized. A block always started and ended with a dummy stimulus (i.e., without a target) to counteract response bias. Four separate blocks in both ascending and descending order (48 trials per block) were run in an alternating order for all eight conditions. The order of the eight conditions was counterbalanced. Prior to each condition, the subjects received a practice block in descending order. The experimental session started with 15 min of dark adaptation, a general instruction, and calibration and adjustment of the Debic system.

Subjects

Three female and 2 male students of the Free University served as paid subjects. They were between 22 and 29 years of age and had normal or corrected-to-normal vision.

RESULTS

Trials with eye movements were excluded from analysis. An eye movement was defined as a saccade in the direction of the target with a minimal size of 1° (i.e., the resolution of the Debic). By including trials with eye movements in directions other than the direction of the target, a more conservative estimate of the size of the lobe is obtained. In all blocks, a critical eccentricity was obtained for each of the four directions. In the ascending series, this was the eccentricity in which the target was first detected, provided that this detection was followed by a successive second detection in the same direction. In the descending series, it was the eccentricity in which the target was last detected. The lobe was estimated by taking the mean of the critical eccentricity and the eccentricity of the next outer position. The mean values of the size of the lobe, averaged over subjects, are presented in Table 1 as a function of the experimental conditions.

A within-subject ANOVA was carried out with target size, presentation duration, order of presentation, and target direction as main experimental variables. As expected, target size had a highly significant effect [$F(1,4) = 44.75$, $MS_e = 5551.1, p < .01$]. Mean lobe size was larger for the "C" than for the "c" (7.3° vs. 4.7°). Presentation duration also had a significant effect [$F(3,12) = 18.56$, $MS_e = 60.19, p < .001$]. A post hoc analysis of the individual means showed that the lobe size for the 450-msec condition (6.22°) was larger than that for the 300-msec condition (5.82°) [$F(1,4) = 18.99$, $MS_e = 6.53$, $p < .02$], while the lobe size for the 300-msec condition was larger than that for the 150-msec condition (4.90°) [$F(1,4) = 31.87$, $MS_e = 33.81, p < .001$]. Despite the fact that the mean lobe size was still somewhat larger for the self-paced condition, the lobe size for the 450-msec

Table 1
Mean Lobe Sizes (in degrees)

Direction	Condition: 150 msec	300 msec	450 msec	self-paced
	Uppercase "C"			
North	4.93	6.23	6.83	7.51
South	5.59	6.42	6.61	7.19
West	6.64	7.45	7.97	8.82
East	7.34	8.46	8.94	9.81
	Lowercase "c"			
North	2.63	3.35	4.22	4.94
South	3.74	4.35	4.59	4.88
West	3.81	4.83	4.99	5.65
East	4.54	5.48	5.66	7.08
	Average of "C" and "c"			
North	3.78	4.79	5.53	6.22
South	4.66	5.39	5.60	6.03
West	5.23	6.14	6.48	7.23
East	5.94	6.98	7.30	8.45

and the self-paced conditions did not differ significantly. Order of presentation had no significant effect, which suggests that the ascending or descending series had no systematic effects. Neither the subject's knowledge about the next eccentricity nor response bias to reporting the presence or absence of a target played a role in this study, which might well be due to the fact that direction was always uncertain. As such, direction had a significant effect [$F(3,12) = 28.48$, $MS_e = 69.61$, $p < .001$]. A post hoc analysis of individual means showed that mean lobe size was larger for the eastern direction (7.16°) than for the western direction (6.27°) [$F(1,4) = 28.38$, $MS_e = 32.01$, $p < .001$], and mean lobe size was larger for the western direction than for the southern direction (5.08°); north and south were not significantly different. The only significant interaction was between presentation duration and direction. The lobe became somewhat larger in the northern and eastern than in the southern and western directions (Table 1).

DISCUSSION

Some main results of this study merely confirm earlier results. Thus, the larger lobe for the C than for the c is obviously mandatory. The elliptical shape of the lobe with a bias in the direction of reading is also consistent with the usual findings. The effect of presentation time is less self-evident. The size of the effect was far from negligible and proved to be about equal to that of a potent variable like target size. This means that presentation time is relevant when attempting to predict free-search performance from a psychophysical lobe. The finding that the self-paced condition had about the same lobe size as did the 450-msec condition suggests that, under the present type of noisy field conditions, a data limit is reached at a fixation duration of about half a second. This corresponds well with findings about maximal fixation duration in free search.

Thus, the data clearly refute the hypothesis that the lobe is only sensory determined. From the present data, it is difficult to decide between an explanation in terms of bottom-up accumulation of evidence at a central level of processing and top-down covert search of the visual field. The interaction between the effects of direction and presentation time seems more in line with the last option, but the result is incidental and should not be taken too seriously.

An obvious next step is to find out whether or not, in free search, it pays off to make longer fixation durations, in the sense that a larger and better analyzed lobe is obtained at the cost of a longer fixation duration. Alternatively, it might be more efficient to trade a well-analyzed lobe for more frequent fixations, up to the point where targets may be missed, even when they are within the lobe. Bottom-up models, suggesting random search from exponentionally distributed search times, have usually assumed that, once within the lobe, a target is always detected, but this is far from an obvious assumption (Williams, 1966). The results also raise the more general issue of whether the conclusions from the literature about covert orienting extend to fixations in free search or whether they are limited to conditions with fixated eye.

REFERENCES

Bellamy, L. J. (1984). The application of visual lobe measurement to visual inspection. In A. G. Gale & F. Johnson (Eds.), *Theoretical and applied aspects of eye movement research* (pp.353-361). Amsterdam: North-Holland.

Bellamy, L. J., & Courtney, A. J. (1981). Development of a search task for the measurement of peripheral acuity. *Ergonomics*, **24**, 497-509.

Beringer, J. (1988). ERTS: Experimentelles Run-Time System. Version 2.0. Darmstadt, BRD: Psychologisches Institut, Technische Universität.

Brown, B., & Monk, T. H. (1975). The effect of local target surround and whole background constraint on visual search times. *Human Factors*, **17**, 81-88.

Courtney, A. J., & Chan, H. S. (1985). Simple measures of visual lobe size and search performance. *Ergonomics*, **28**, 1319-1332.

Courtney, A. J., & Chan, H. S. (1986). Visual lobe dimensions and search performance for targets on a competing homogeneous background. *Perception & Psychophysics*, **40**, 39-44.

Edwards, D. C., & Goolkasian, P. A. (1974). Peripheral vision location and kinds of complex processing. *Journal of Experimental Psychology*, **102**, 244-249.

Engel, F. L. (1971). Visual conspicuity, directed attention and retinal locus. *Vision Research*, **11**, 563-576.

Engel, F. L. (1977). Visual conspicuity, visual search and fixation tendencies of the eye. *Vision Research*, **17**, 95-108.

Erickson, R. A. (1964). Relations between visual search time and peripheral visual acuity. *Human Factors*, **6**, 165-178.

Eriksen, C. W., & Yeh, Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception & Performance*, **11**, 583-597.

Hughes, P. K., & Cole, B. L. (1986). Can the conspicuity of objects be predicted from laboratory experiments? *Ergonomics*, **29**, 1097-1111.

Jacobs, A. M. (1986). Eye movement control in visual search: How direct is visual span control? *Perception & Psychophysics*, **39**, 47-58.

Jacobs, A. M. (1987). On localisation and saccadic programming. *Vision Research*, **27**, 1953-1966.

Johnston, D. M. (1965). Search performance as a function of peripheral acuity. *Human Factors*, **7**, 528-535.

Leachtenauer, J. C. (1978). Peripheral acuity and photo interpretation performance. *Human Factors*, **20**, 537-551.

Scinto, L. F. M., Pillalamarri, R., & Karsh, R. (1986). Cognitive strategies for visual search. *Acta Psychologica*, **62**, 263-292.

Williams, L. G. (1966). Target conspicuity and visual search. *Human Factors*, **8**, 80-92.

Young, L. R., & Sheena, D. (1975). Survey of eye movement recording methods. *Behavior Research Methods & Instrumentation*, **7**, 397-429.

(Manuscript received October 27, 1990.)