Estimating the area of peripheral vision employed for map search

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This paper describes a simple method for roughly estimating the area of peripheral vision 'used when searching on a map. As well as being of some theoretical interest, the method suggests a minimum size for maps to be used for perception research. When searching for colour and texture area symbols on a land use map the area of useful peripheral vision (AUPV) is estimated to have a diameter of between 6 and 12 degrees of visual angle. This is also the estimate for typographic codes on the same map.

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If someone is asked to find a red circle drawn on a map, he or she will make a series of eye movements, with most fixations falling on features which are coloured red (Williams, 1967). At each fixation that person must make two decisions: Is the observed symbol the target and, if not, where is the next symbol to be fixated? The first question is answered from central vision but the second must employ peripheral vision. The task is essentially the same, whether we are looking for a mail box in a street, for a road sign, for a familiar face, or for a feature on a map. However, searching for a target in a printed list is rather different since here we have a predetermined search path.

In any search task where there is no predetermined path to follow, peripheral vision must play an important role in selecting the next stimulus to fixate. This stimulus will resemble the target in some way. The more selective peripheral vision becomes when selecting possible targets, the fewer will be the number of eye fixations, and the faster the search.

Because of the importance of peripheral vision, it is of interest to ask what size of visual field area will provide useful peripheral information in a typical search task. The size of area must, of course, depend on the type of task. In locating a light in a darkened room, there is little doubt that the entire visual field is available but in searching for features on a map, the area of useful peripheral vision must be far less.

One way to measure the angle of vision being used is to present symbols tachistoscopically (1) at different distances from the fixation point, and to ask the subject to report what can be seen. Yet there are several reasons why this method could give a misleading answer. In a search task, decisions are made very rapidly, whereas the tachistoscopic task gives the subject a relatively long (if not unlimited) time to process and report an observation. Secondly, the tachistoscopic task does not show which dimensions of a stimulus will be used in selecting the next item to fixate. For example, from a tachistoscopic presentation, the subject may be able to say a little about the size, the shape and the colour of a stimulus, but it is unlikely that all of these peripheral cues are used in the search task. It is also possible that other less verbal dimensions are being used. Thirdly, in searching, it may not always be necessary to use peripheral information to the full. If a map has a large number of symbols which closely resemble the target, it may be possible to detect one of these at 20 degrees from the fovea, but if the symbols occur frequently, there will always be one closer symbol which is observed first. Therefore, the area actually being used does not extend as far as 20 degrees.

Clearly, the area of useful peripheral vision must be measured while subjects are actually searching. One possibility is to record eye movements, but there is no simple method for deducing the size of visual field from eye movement records.

One other possibility was investigated by a pilot study. Subjects were asked to search for targets on a map, which they viewed through a box which restricted the area of map visible. The box had circular apertures of different sizes corresponding to different visual angles. Subjects could move the box as they searched, moving the aperture over any part of the map they wished.

The average speed in finding a target is affected by the size of the aperture and the *area of useful peripheral vision* (AUPV), which was assumed to be roughly circular. If the aperture is larger than the AUPV, peripheral information is unimpaired but, if the aperture is smaller, some potential targets will be missed and the average search time will be increased. As Figure 1 shows, it is not necessary to assume that the aperture and the AUPV are concentric.

As the size of the aperture is increased, the search time should decrease, until the aperture is the same size as the AUPV, when search times should remain constant. This prediction is illustrated in Figure 2.

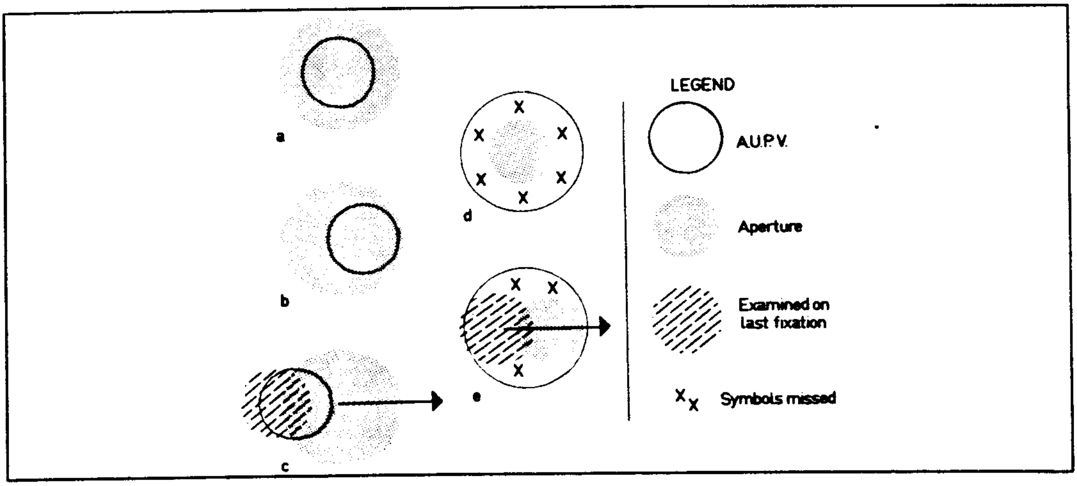

Figure 1. When the circular aperture is larger than the area of useful peripheral vision (AUPV) the search task is not impaired (a, b). The subject may not necessarily centre the aperture on his visual field. In case (c), the subject is scanning the map in the direction of the arrow and the heavily shaded area has already been examined.

When the circular aperture is smaller than the AUPV the search task is impaired because possible targets at X will be missed (d). In a scan across the map, subjects may deliberately offset the aperture to make greatest use of peripheral vision on areas of map which have not been examined, but as (e) shows, possible targets are still missed.

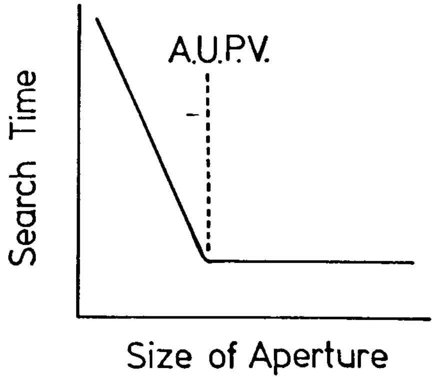

Figure 2. The predicted relationship between search time and size of aperture.

In order to test the method, data were collected from subjects searching for two types of target on a map.

METHOD

Map

An area measuring 315 by 475mm was cut from the United Kingdom 1:25 000 Land Use map of Merthyr Tydfil. This map displays colours to distinguish major types of land use (eg arable, transport, industry) subdivided by texture patterns (eg arable split into cereals, roots, fodder). The legend of the map was removed, but parts of the legend were used to illustrate targets. The map and examples of targets were attached to a light table and illuminated from behind. The experiment was conducted in a dimly lit room.

Apparatus

The search box was placed over the map. Subjects looked through a hole cut in the top of the box, using both eyes. The viewing distance was 34cm and the circular apertures in the bottom of the box gave diameters of either 6, 12, 25 or 52 degrees of visual angle. The box could be slid across the surface of the map to examine any area.

Subjects and design

Eight men and eight women who were university students with normal colour vision acted as subjects. Two men and two women were randomly assigned to each of the four conditions—6, 12, 25 or 52 degrees.

Procedure

Subjects were familiarised with the apparatus and with land use maps. On each search there was an unlimited time for the subject to examine the target example. As soon as the subject looked into the search box a stopwatch was started. Subjects were looking for any instance of the specified target and, as soon as they found one, they pressed a button to operate a buzzer. The experimenter stopped the stopwatch and, on a sample of trials, asked the subject to name something near the target as a check.

After a practice search there were eight searches in which subjects sought land areas designated by colour and texture, for example, *extractive industry* shown by red cross-hatching. This was followed by eight searches for letter codes distinguishing types of rough land, for example, *M, NVF, FN.* These were shown in bold black lettering about 1.7mm high. When searching for areas, subjects were told the meaning of the symbol and this may have occasionally helped them. They were not told the meaning of the letter codes as the information was considered too technical to be of use.

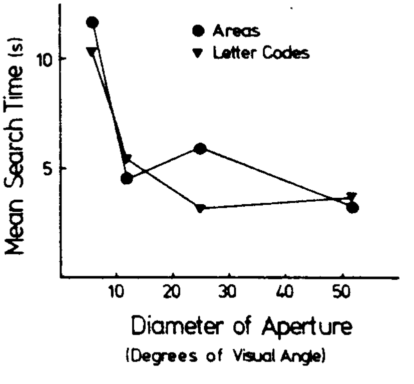

Figure 3. Mean search times as a function of size of aperture.

Results

Search times varied considerably according to the route followed in searching the map. For each subject, median times were calculated for the two types of target. Means of these medians are shown in Figure 3. A one-way analysis of variance showed a significant effect of aperture size on searching for letter codes ($F=11.2$, $df=3, 12$, $p<.001$), but the effect on searching for areas was less reliable ($F=3.2$, $df=3, 12$, $.05 < .1$; equivalent to $p < .05$ on a one tail test).

Discussion

The data presented in Figure 3 are in agreement with the prediction shown in Figure 2. For both tasks there is a sharp drop in search time between 6 and 12 degrees, but little difference between the remaining conditions. This suggests that for these conditions the area of useful peripheral vision has a diameter lying between 6 and 12 degress of visual angle.

Clearly, the method is capable of giving only rough estimates of the visual field area being used. A larger number of subjects and a greater number of visual angles would no doubt improve the estimate a little, but the techniques cannot yield any real precision.

Nevertheless, a rough estimate is still of some interest. Experiments on map legibility frequently test small areas of maps because these are cheaper than larger sheets but, if too small an area of map is used, it may give misleading results, since it prevents the use of peripheral vision in an accustomed way. A useful guideline is to ensure that the map subtends a considerably larger angle than the area of useful peripheral vision. In the case of this pilot experiment the diameter of the AUPV is conservatively estimated as 12 degrees. Doubling this, a test map should perhaps have a shorter dimension subtending at least 24 degrees, or about 12cm at a typical viewing distance. Such measurements depend, of course, upon the type of map and the type of search target.

Acknowledgements

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Footnote

1. A tachistoscope can be used to present a map or similar display for a precise length of time. An exposure of about 0.15 seconds is long enough to see some detail but short enough to prevent more than one eye fixation. If the observer is asked to stare at a fixation point before the exposure, it is possible to test the detail which can be discerned at different distances from central vision.

Reference

Williams, L.G. (1967) The effects of target specification on objects fixated during visual search. *Acta psychologica,* 27, 355-360.