It is argued that the best way to evaluate map typography is to measure the time taken to find names on a map. Eye movement recording demonstrates that this search time depends on two independent factors: the number of names fixated with the eyes and the mean fixation time. Changes in map design usually affect only one of these factors. For example, typographic coding can reduce the average number of fixations but an increase in point size reduces mean fixation time. This discussion leads to some recommendations on type legibility.

Searching for Names on Maps*

Richard J. Phillips, Elizabeth Noyes and R. J. Audley
Department of Psychology, University College London

This paper summarises and discusses some experiments which investigate the effects of map typography on the speed of searching for place names. There is an extensive literature on map typography which makes recommendations on type styles and the placing of type. But, with the exception of two papers (Bartz, 1970; Foster and Kirkland, 1971), no experimental evidence is offered to support these recommendations. There are also a large number of experimental studies on the typography of books, newspapers, forms, tables and other printed matter, but it is questionable whether these results should be generalised to maps.

To study map typography in an objective, scientific manner it is necessary to measure the effect of different styles on the map reader's performance. This entails choosing a representative map reading task and measuring people's speed, or accuracy, or a combination of the two. Amachree, Bloemer and Walter (1977) simply asked people which typefaces they preferred but this tells us nothing about how people will perform when actually using a map (see Poulton, 1977).

It seems likely that measuring the time taken to find a name on a map will be a good way of evaluating map typography. On maps which contain a large number of names, such as city street maps, searching for a name can take a considerable time. On other maps we are less conscious of searching for names, but almost every kind of map reading must first require us to locate those places we are interested in. A factor analytic study by Christner and Ray (1961) demonstrates that search is an important part of many map reading tasks, such as scanning, locating and counting. Search seems a good task for evaluative purposes because it involves both peripheral and central vision whereas tasks such as normal reading put much less demand on peripheral vision.

* Based on a paper read at the 9th International Cartographic Conference, University of Maryland, U.S.A., 1978.

An alternative to search is a transcription task where people are asked to copy names quickly and accurately. Although map readers sometimes need to do this, it seems a less representative task than searching. There are certainly more complex ways in which typography affects map reading—an example is given in *Figure 1*—but these do not suggest a suitable task for research. Like Bartz (1969), we conclude that measuring search speed is the best way to evaluate map typography.

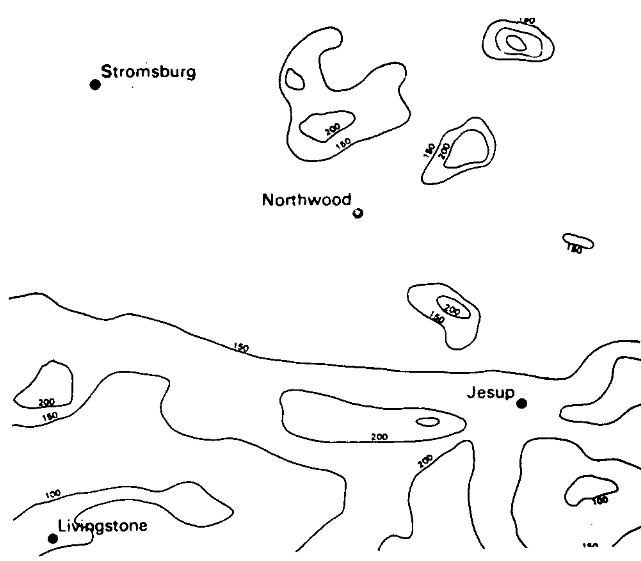

Figure 1. What is the nearest town to Northwood? In one experiment, more than three quarters of the subjects answered 'Stromsburg' although 'Jesup' is closer by 10 *per cent*. The mistake is partly due to the placing of the type and illustrates one way in which type can interact with other information on a map. On the original maps the contour lines were brown. (For further details see Phillips, De Lucia and Skelton, 1975; Audley, Bickmore and Phillips, 1974; Audley and Phillips, 1979.)

People's speed in finding names has been measured in some recent experiments both on specially constructed experimental maps (Phillips, Noyes and Audley, 1977) and on some published maps (Phillips and Noyes, 1977). Other experiments have studied people's eye movements while they search for names (Noyes, 1978; Phillips, 1979). In presenting a summary of these results it is helpful to start by considering how the presentation of type on a map affects the eye movements made while searching, and how these in turn affect the total search time. It will be shown that search time depends largely on two independent factors: the number of names which need to be fixated with the eyes and the average time taken making each eye fixation. The effects of map design on these two factors will be discussed.

EYE MOVEMENTS

The eye's photographic plate is the *retina* but unlike a photographic plate, the retina is not uniformly sensitive across its surface. In its middle is the *fovea* which is an area of especially high resolution because of the high density of receptors transmitting information to the brain. When one looks directly at an object the eyes are rotated so that the image of the object falls on, or close to the fovea. The eyes are said to be fixating the object.

When searching for a name on a map, the eye movements are rapid and typically last between 20 and 60 msec. (*N.B.* msec = millisecond, 1000 msec = 1 second.) The eyes' motion blurs the image on the retina so that it is impossible for the eyes to take in any information during this type of eye movement. Between movements, the eyes remain at rest for relatively long periods. These eye fixations typically last between 150 and 600 msec. When searching for a name, nearly all of these fixations fall on names, and only rarely on other map features. *Figure 2* shows that map symbols must resemble names quite closely before they are also fixated.

During a search the eyes fixate a name, move to the next name, fixate this, move again, and so on, until the target name is fixated. Occasionally it is clear from eye movement records that the eyes have overshot their target. When this happens the eyes fixate the target, move to another name where there is a fixation of rather short duration and then return to the target.

It is possible to express in terms of simple arithmetic how the components of this search process make up the total search time:

Total search time = Number of names fixated
× Mean duration of one fixation and one movement
+ Constant

The constant accounts for the fairly short periods at the beginning and the end of a search. The time taken to make an eye movement is usually about a tenth of the fixation time and so is relatively unimportant. The two important factors which influence the total search time are (1) the number of names fixated and (2) the mean fixation time.

The number of names fixated depends largely on *peripheral vision*, that is, vision from areas of the retina which are some distance away from the sensitive fovea. While the eyes are fixating one name, the brain must decide where to place the eyes next on the basis of information available in peripheral vision.

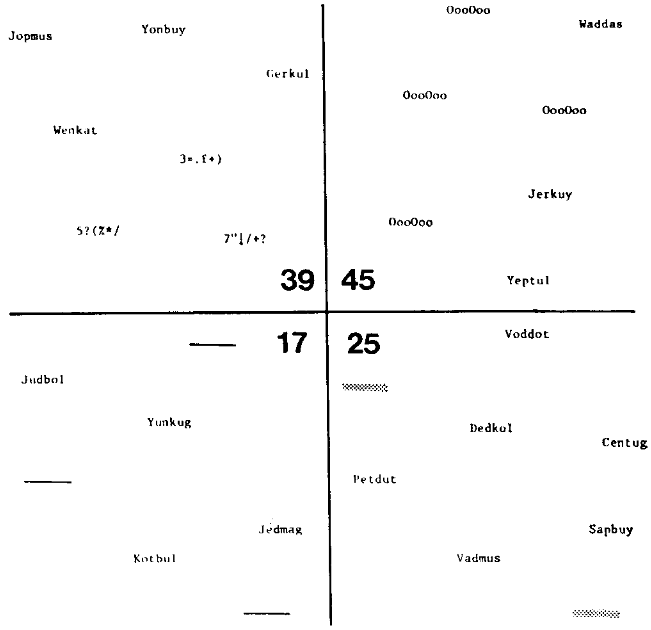

Figure 2. Eye movements were recorded while people searched for names on four types of display each containing ten names and ten other features which were similar to names in their size and weight. The numbers show the percentage of eye fixations which fell on these distracting features. For example, with the display in the lower left, only 17 *per cent* of fixations fell on the straight lines and so the other 83 *per cent* of fixations fell on names. The most distracting features were those made from six letter *Os*, illustrated in the top right. 45 *per cent* of fixations fell on these.

Peripheral vision is of poorer resolution than vision in the region of the fovea. If this were not so, we would not need to move our eyes while searching but could find our target in a single eye fixation. For some kinds of map symbol this is possible. For example, we can sometimes see the position of a large city on a map without moving our eyes to look at it. But in searching for place names the detail of information available from peripheral vision is always too poor to find a name without making eye movements. Clearly, what can and what cannot be discriminated in peripheral vision will have a direct effect on the number of eye fixations needed to find a name.

There are a number of ways of recording eye movements. All the data reported here came from a Polymetric V-1164-3 Eye Movement Recorder linked to a PDP-12 computer. A small bright light is reflected off the surface of the left eye. This *corneal reflection* moves as the eye moves and it is received by a television camera. The same camera records the map and the two can be seen together on a television monitor. When the apparatus has been properly adjusted, the monitor shows a bright spot of light which moves rapidly about the map showing the regions being fixated. The television picture is electronically divided into a grid of 15 by 15 cells, and the computer samples the position of the corneal reflection in this grid every 20 msec in order to provide a permanent record. It should be remarked that eye movement recording is not an easy technique and its usefulness to cartography is limited.

The next two sections discuss those factors which affect, firstly, the number of fixations made while searching for a name and, secondly, the mean fixation time.

FACTORS WHICH AFFECT THE NUMBER OF FIXATIONS

The number of place names which need to be fixated during a search must clearly depend on the search path which the eyes follow and the position of the target name. As people often begin their search near the top of a map, fewer names on average will be fixated in finding targets in the upper half of a map. But as both the position of towns and cities and the search path followed are factors which are outside the map designer's control, these factors are best regarded as having a random effect on the number of names fixated.

Our research suggests that the designer has only two ways of reducing the number of names which need to be fixated: firstly by reducing the number of names in the search area, and secondly by typographic coding.

It is clear that halving the number of names on a map will approximately halve the number of names fixated in finding a particular name. Perhaps less obvious is the fact that the same end can be achieved by reducing the area which needs to be searched. Two London street atlases which are drawn with similar detail and at a similar scale differ considerably in their method of grid referencing. A grid reference from one atlas locates an area of 0.03 km^2 whereas a grid reference from the other locates an area of 0.77 km^2. It is not surprising that search times are almost three times as long on the second atlas when people are asked to find a street knowing the grid reference. A London delivery driver who had to look up ten street names each working day would waste at least six hours a year if he was using the wrong atlas! (For further details see Phillips and Noyes, 1977.)

The second way in which the designer can reduce the number of names fixated is by typographic coding. If names are printed in different point sizes or in different colours, this will substantially reduce the number of fixations if the map reader knows which size or colour he is looking for. This was demonstrated by Bartz (1970) using an experimental map with names set in 5 point and 10 point type. When people did not know the size of names they were looking for, search times were almost twice as long as when they did have this information. Foster and Kirkland (1971) have demonstrated that the same effect occurs for names printed in one of two colours. Typographic coding by point size or by colour can clearly save time in finding a name as long as the code is meaningful to the map reader.

It is not clear from the work of Bartz and of Foster and Kirkland whether typographic coding affects the number of fixations or the mean fixation time. However, some elegant eye movement experiments by L. G. Williams suggests it is almost certainly the former.

Williams (1967) recorded the eye movements of subjects searching displays containing squares, circles, triangles, crosses and semicircles of different colours and sizes. Subjects made a series of rapid eye fixations, nearly all of which fell on or near one of the shapes. When they knew the colour of their target, over half of their eye fixations fell on stimuli of the correct colour. When they knew the size of the target, there was a weaker tendency to fixate stimuli of the correct size. But when they knew the shape of the target, the frequency of fixating stimuli of the correct shape was only a little above the level expected by chance. In searching, the decision as to where to place the eyes next must be made from information in peripheral vision. Williams' results suggest that colour codes are easy to distinguish in peripheral vision, size codes are more difficult, and shape codes more difficult still.

This agrees well with the data on typographic coding and suggests that people who know the size or colour of a name are faster in finding it simply because they need to make fewer fixations.

Would other kinds of typographic coding work as well? Cartographers frequently employ roman and italic typefaces to code names. If differences in typeface are like the differences in shape studied by Williams, we would expect this kind of coding to be less effective than coding by point size or colour. The only direct evidence on this comes from one of Bartz's experimental maps where names appeared in two typefaces, one bold and one of normal weight. Unlike size coding, knowledge of the typeface of the target name had little effect on people's speed.

Typographic coding is only useful if people have a good chance of guessing the size or colour of a name. Bartz (1970) has shown that without this information it takes longer to search among names in two point sizes than in one size. But this is probably due to differences in mean fixation time rather than in the number of fixations.

Are there other factors which affect the average number of fixations needed to find a name? If we are looking for 'Brighton' do we tend to make more fixations on names with an initial *B* than those with other initials? If we are looking for a name with 12 letters, do we tend to fixate names of about that length? Our eye movement experiments suggest that the answer to all these questions is 'no'.

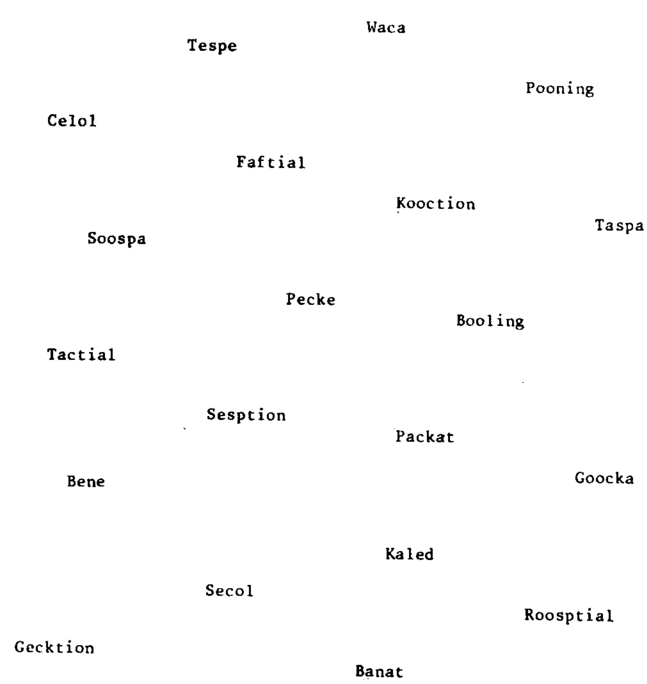

Figure 3. An example of one of the search displays used for eye movement experiments.

Figure 3 illustrates one kind of display used in our experiments. This has 20 names in the same type style. On any search one of these is the target and the other 19 are non-targets. What is the average number of fixations on non-targets before the target name is fixated? If all non-targets are equally likely to be fixated and if the eyes never fixate a name more than once, we would expect that on average half of the non-targets are fixated before the target. Half of 19 is 9.5. But if some non-targets are more likely to be fixated because they resemble the target, we would expect the average to be considerably less than 9.5. In fact, over a large number of searches the average was 9.1. This suggests that when we are searching for a name among names of the same size and typestyle we do not selectively fixate names which resemble the target.

The result is a robust one. As well as these simple displays we have also tested others which are much more like topographic maps, including layer tints, line symbols, a grid, and a more irregular distribution of type (see *Figure 4*). The same result was found.

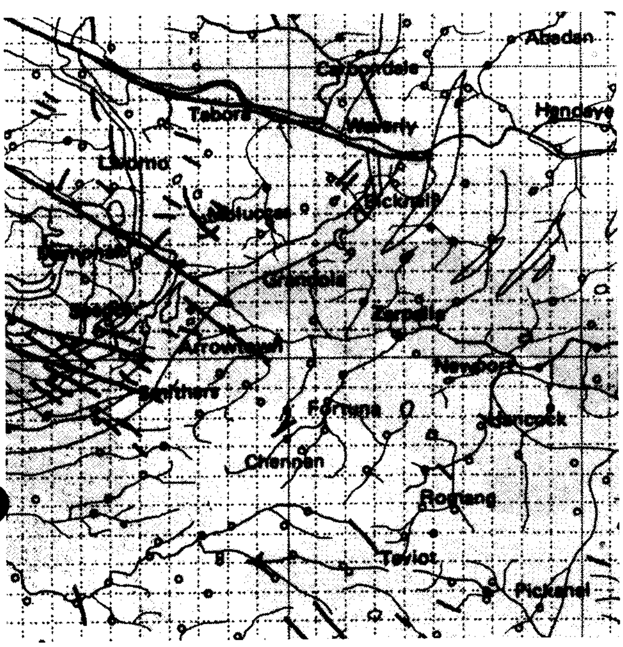

Figure 4. A second kind of display used for eye movement experiments. In the original the layer tints were orange and the line and point symbols were red.

We can now summarise those factors which affect the number of eye fixations which are made in finding a name. The search path followed by the eyes and the position of the target are clearly important, but these are outside the cartographer's control. The average number of fixations increases with the number of names on the map, or in the area of map being searched. Typographic coding by colour or point size can considerably reduce the number of fixations if the map reader knows what size or colour the target will be. Other kinds of typographic coding, for example, roman or italic, are probably less effective.

FACTORS WHICH AFFECT THE MEAN FIXATION TIME

Although a factor may not affect the number of fixations made before the target is located it may have an effect on the time spent inspecting non-targets. Mean fixation time, that is, the average time the eyes remain at rest on a name, is typically about 300 msec. Therefore we make about three fixations a second. However, a number of factors can affect mean fixation time and the more difficult a name is to process, the longer the fixation time.

Firstly, if a name closely resembles the target name it will take longer for the brain to decide whether it is the target. In one experiment, the mean fixation time for names with a different initial letter from the target was 313 msec, but for names with the same initial letter it increased to 410 msec. There was a similar but weaker effect on the last letter of the names.

Secondly, design factors can affect the difficulty of processing a name. For example, the mean fixation time decreases as the point size of the names increases (Phillips, 1979). An important design factor seems to be the masking effect which some map features have when placed close to names. The strongest effects are from names themselves. One of our experimental displays contained 20 horizontally placed names and 20 vertically placed names. The subjects were told to ignore the vertical names as the target would always be a horizontal one. Fixation times were longer on those horizontal names which had a vertical name close by

(*e.g.* Fleet Harlow or Hoxton Banff)

and the effect was stronger with masking at the beginning of a name than at the end. Other research suggests that any map symbol of roughly the same size and weight as the lettering is likely to increase fixation time if it comes close to the initial letter of a name (Noyes, 1978).

Other design factors may also affect the mean fixation time, although the main evidence for this is indirect as it comes from an experiment which did not record eye movements. Using 256 geography undergraduates as subjects, a factorial design was employed to investigate the effects of type style on the speed of finding names on a map, and the speed and accuracy of copying them (Phillips, Noyes and Audley, 1977). We varied typeface, size, weight and case, as well as the complexity of the map and the pronounceability of the names. *Figure 5* summarises the main results: increasing type size predictably improved performance, but for the search task there was also a strong effect of case. Names set in lower case with an initial capital were almost 10 *per cent* faster than names in capitals, even though the former occupied less space on the map. There was also a little evidence for faster search with names set in Times rather than Univers, but this result was not statistically significant. Taken with the other research it seems plausible that the differences in search speed arise from differences in mean fixation time rather than differences in the number of names fixated.

To sum up, mean fixation time seems to reflect the difficulty of processing a name while it is being fixated.

Fixation times are longer when the letters in a name resemble the target name, but type style and interference from other map features can also have an effect.

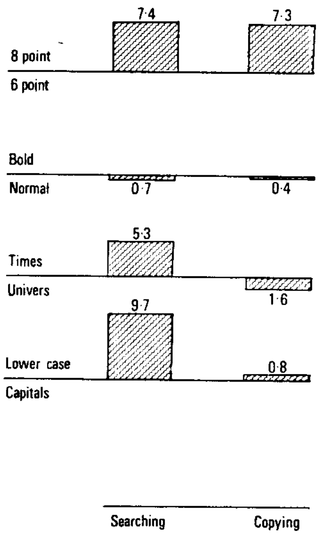

Figure 5. In an experiment to investigate the legibility of type on maps, subjects searched for and copied place names. The figure shows the effect of type style on performance as percentage differences. For example, searching was 7.4 *per cent* faster with 8 point type than with 6 point type.

CONCLUSIONS

For the eye and brain, the process of finding a name can be compared to that of the police finding a culprit who they know is bald and has a scar on his left knee. The police can see at once whether a man is bald, but ascertaining whether he has the scar is clearly more difficult and time consuming. Eliminating those men who are not bald is similar to the process of eliminating those features in the visual field which are so clearly not the target that they do not need to be fixated. This includes map symbols which are not names, and also names of the wrong point size or colour. The more time consuming matter of asking suspects to raise their left trouser leg can be compared to the need to move the eyes to a name in order to fixate it. Most of the names fixated will turn out not to be the target, just as most of the bald men will be exonerated and sent on their way.

Search is largely a process of eliminating information we are not interested in. When searching for a name, irrelevant information can be eliminated in two ways: in peripheral vision and in central vision. An understanding of these two stages tells us how different factors affect the total time needed to find a name on a map and these are summarised in Table 1.

Table 1 distinguishes those factors which are outside the cartographer's control from those which he can affect and so make his map easier to read. In practical terms the bigger reduction in search time can be achieved by reducing the number of fixations. Under some circumstances, appropriate typographic coding or grid referencing can reduce the average search time by half. Changing factors

TABLE 1

This table summarises the main conclusions of this paper. The time taken to find a name on a map is a function of the number of eye fixations and the mean fixation time. The table shows the most important factors which affect these two components. Only those below the dotted line can be influenced by the map designer.

Number of fixations	Mean fixation time
The search path followed by the eyes. The position of the target.	The similarity between the fixated name and the target, especially of the initial letter.
. . . .	. . . .
The number of names on the map (or in the area being searched).	Point size. Case.
Typographic coding by point size or colour.	Clutter from adjacent features, especially when close to the initial letter.

which affect mean fixation time produce smaller gains but these are still worthwhile. Appropriate changes in typography can sometimes reduce fixation times by about 10 *per cent.*

RECOMMENDATIONS

We end with some recommendations for the map designer.

(1) Legibility of type must be considered in relation to the legibility of the map as a whole. The designer should ask himself: Are the names among the most important features on the map, or are they of relatively minor importance?

(2) The size of type should be determined by the importance of individual names, and the importance of names in general for the map in question. Eight point type is easier to search for and is more accurately copied than six point type.

(3) Names set in lower case with an initial capital are easier to search for than names set entirely in capitals of the same point size. As lower case names also occupy less space on a map, they are strongly recommended.

(4) Bold type is no more legible than normal weight type and should be avoided as it has a cluttering effect on maps.

(5) The choice of typeface appears to have little effect on legibility. Names set in Times New Roman may be slightly easier to find than those set in Univers.

(6) Under the rare circumstances when it is especially important that names are copied correctly and at the same time names are likely to be very difficult to pronounce, capitals are preferable to lower case.

(7) Type should be placed in as clear a space as possible and it is particularly important that the space to the left of the initial letter is uncluttered either from other type or from symbols of a similar size and weight. Clutter in this position significantly increases the time taken to find a name, *e.g.* these arrangements should be avoided:

Stoke Burslem OHanley Longton

(8) Typographic coding by colour or by point size can considerably reduce the time taken to find a name if the map reader knows what size or colour to expect. Other kinds of typographic coding, for example, the use of roman and italic, are likely to be less effective in reducing search time. Irrelevant coding may actually increase search time.

(For further information on recommendations (1) to (6) see Phillips, Noyes and Audley (1977). For recommendation (7) see Noyes (1978). For recommendation (8) see Bartz (1970), Foster and Kirkland (1971) and this paper.)

Acknowledgements

The preparation of this paper forms part of the United Kingdom Social Science Research Council project HR2917/1 awarded to Professor R. J. Audley and Dr R. J. Phillips. We gratefully acknowledge the Council's financial support.

We would like to express our thanks to everyone who has contributed to this project with suggestions, criticisms and practical help.

References

Amachree, T. K. P., Bloemer, H. L. and Walter, B. J. Typographic legibility on maps: a comparative study. *Bulletin of the Society of University Cartographers*, **11** (1977), 27–39.

Audley, R. J., Bickmore, D. P. and Phillips, R. J. *Legibility criteria for the efficient use of maps.* Final report to the United Kingdom Social Science Research Council for project HR2167, 1974.

Audley, R. J. and Phillips, R. J. *Legibility criteria for maps.* Final report to the United Kingdom Social Science Research Council for project HR2917, 1979, in preparation.

Bartz, B. S. Search: an approach to cartographic type legibility. *Journal of Typographic Research*, **3** (1969), 387–98.

Bartz, B. S. Experimental use of the search task in an analysis of type legibility in cartography. *Cartographic Journal*, **7** (1970), 103–12.

Christner, C. A. and Ray, H. W. An evaluation of the effect of selected combinations of target and background coding on map-reading performance. *Human Factors*, **3** (1961), 131–46.

Foster, J. J. and Kirkland, W. Experimental studies of map typography. *Bulletin of the Society of University Cartographers*, **6** (1971), 40–45.

Noyes, E. J. The positioning of type on maps—how to reduce the masking of information. Paper to be read at the NATO Conference on the Visual Presentation of Information at Het Vennebos, Netherlands, September 1978.

Phillips, R. J. Eye fixations in searching for names on maps. Paper in preparation, 1979.

Phillips, R. J., De Lucia, A. and Skelton, N. Some objective tests of the legibility of relief maps. *Cartographic Journal*, **12** (1975), 39–46.

Phillips, R. J. and Noyes, L. Searching for names in two city street maps. *Applied Ergonomics*, **8** (1977), 73–77.

Phillips, R. J., Noyes, L. and Audley, R. J. The legibility of type on maps. *Ergonomics*, **20** (1977), 671–82.

Poulton, E. C. Quantitative subjective assessments are almost always biased, sometimes completely misleading. *British Journal of Psychology*, **68** (1977), 409–25.

Williams, L. G. The effects of target specification on objects fixated during visual search. *Acta Psychologia*, **27** (1967), 355–60.