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Making Maps Easy to Read: A Summary of Research

Richard J. Phillips

Poorly designed maps can seriously reduce the efficiency of the map reader and lead to mistakes which are inconvenient, costly, or even dangerous. Experimental studies of map legibility are beginning to provide the map designer with objective information on topics such as colour coding, relief portrayal, and lettering. Two research groups are active in the United Kingdom and a number elsewhere, particularly in the United States. As testing methods improve, there is a good possibility that designers may be persuaded to use tests themselves to compare alternative map designs.

In this paper I shall describe some experimental studies on making maps easy to read, including some which I have conducted with R. J. Audley and Liza Noyes at University College London. I should emphasize that this is not a review of the literature, nor even a representative sample, but just a personal choice. For further information, Board's (1976) bibliography and Brandes's (1976) review are both useful.

There are two schools of thought on the question of making maps easy to read: one holds that the deficiency is in the user. This view assumes that maps, on the whole, are sufficiently legible and that people should be trained to be better map readers. The other view blames the maps. Since poorly designed maps hinder good and bad map readers alike, and because misreading a map can be wasteful, inconvenient, or even dangerous, maps should be designed to be as legible as possible. The view that the fault is in the user is frequently held by those who teach geography (Balchin, 1972). But it is also a view expressed by cartographers who are responsible for map design (Wood, 1972).

Most people have little training in map reading, certainly very little in comparison to training in reading words, but then the time spent reading for most people, map reading is an important but relatively infrequent activity. If training is to be worthwhile, it must be sustained by practice, but is this possible when map reading occupies so little of the user's time?

There is a surprising degree of uniformity in the design of atlases and topographic maps. This may of course mean we are all close to producing the best possible map, but there could be other, less satisfactory reasons. As Robinson (1952) points out, the map buying public is a conservative customer; map design is perhaps excessively influenced by the taste of school principals in purchasing atlases.

Cartographers and designers have written at length about the problems of map design, often with great intelligence and imagination (Bertin, 1967). But it is only recently that experimental research has entered the field. Compared to the amount of research on the legibility of print, research on map legibility is small, and includes a high proportion of studies of doubtful experimental validity. Often a paper which purports to study the perception of maps does no more than ask subjects to arrange alternative designs in order of preference (Jenks & Knos, 1961; Crawford, 1976).

Search

When reading a map, a large amount of time is spent in searching. It is not unusual for people to spend over a minute locating a name on a city street map (Phillips & Noyes, 1977), and finding a feature on a map frequently takes longer than interpreting it. A number of studies have shown that colour-coded map symbols take less time to find than those coded by letter, number, or shape (Hitt, 1961; Christner & Ray, 1961). The reason for this has been neatly demonstrated in a series of experiments by L. G. Williams (1967, 1973).

Williams 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.

Peripheral vision plays an important part in the search process. While a person is fixating on one stimulus he must decide, on the basis of information available in peripheral vision, where to place his eyes next. Clearly, colour codes are easy to distinguish in peripheral vision, size codes are more difficult, and shape codes still more difficult.

Williams observed that the time taken to fixate a stimulus and make a saccade remained fairly constant at about 300msec. Therefore the total search time is simply dependent on the number of fixations made during the search. From this, Williams developed a mathematical model which was successful in predicting median search times from the type of target and display.

For the map designer, it is clearly important to ensure that the more important categories of map symbols can be discriminated in peripheral

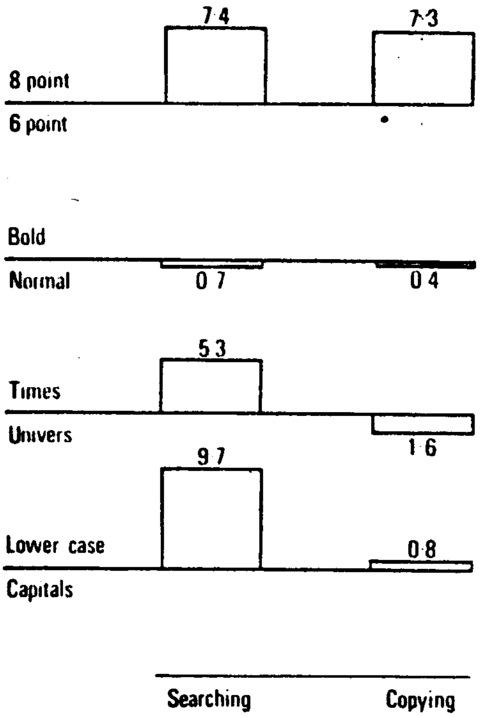

Figure 1. In an experiment to investigate the legibility of type on maps, subjects searched for and copied place names. The figure shows the effect of type style on performance as percentage differences. For example, searching was 7.4 per cent faster with 8 point type than with 6 point type.

vision. Colour coding is one way to achieve this, although too many colours can lead to confusion (Halsey & Chapanis, 1951). An example where search presents few problems to the map reader is Alice Coleman's series of British 1:25,000 Land Use maps which use colours to distinguish major types of land use (Arable, Transport, Industry) subdivided by texture patterns (Arable split into Cereals, Roots, Fodder).

It may not always be practical to code map symbols by colour, and in these cases data are needed on the discriminability of other codes in peripheral vision. Following Williams' methods, we are conducting some experiments on how to make the best of our rather poor discrimination of shape in peripheral vision.

Place Names

Search is an important consideration not only in the design of map symbols but also for place names. Bartz (1970) and Foster and Kirkland (1971) have shown that names are found more quickly when the type size or the colour in which they appear is known. No doubt, as in Williams' experiments, most fixations are placed on names of the correct size or colour.

In an experiment using 256 geography undergraduates as subjects, a factorial design was employed to investigate the effect of type style on the speed of finding names on a map, and the speed and accuracy of copying them (Phillips, Noyes, & Audley, 1977). Typeface, size, weight, and case, as well as the complexity of the map and the pronounceability of the names was varied. Names set in lower case with an initial capital, although occupying less space on the map, were found 10 per cent more quickly than names in capitals. There was also some evidence for faster search with names set in Times rather than Univers, but this result was not statistically significant.

We have also investigated the eye movements used in searching for names on maps. A Polymetric V-1164-3 Eye Movement Recorder linked to a PDP-12 computer was used to record eye fixations using a corneal reflection monitored by a television camera. Subjects searched for names in map-like displays consisting of 20 typewritten names.

Our results were surprisingly different from the eye movements of people searching for symbols. In a series of experiments no evidence was found that subjects make a greater number of fixations on names resembling the target. We examined the first, second, and last letter of the name, the word shape, and the number of letters, but none of these showed an effect. When subjects move their eyes, they simply fixate one of the nearest names not fixated before, often following a search path characteristic of the individual. When we examined search times we found that these were not constant, but were consistently longer on names which resembled the target, for example, fixations on names with the same initial letter as the target were on average 97 msec longer than on names with a different initial.

Searching for names and searching for coloured symbols produce quite different eye movement data. In some ways, the data for names resemble the eye movements used in normal reading discussed by Levy-Schoen and O'Regan and others (this volume): the use of peripheral vision is very limited and fixation time reflects difficulty.

On maps, names are often placed close together. We have studied how this affects fixation times in a search task. Subjects were asked to search for horizontally placed names and ignore those vertically placed. When they fixated a horizontal name with a vertical name close to its initial letter, fixation times increased significantly, but there was no increase when the vertical name occurred at the end of a horizontal name. This suggests that when names are closely packed on a map the cartographer should try to keep the area surrounding the initial letter of a name free from other lettering.

Relief Maps

On a completely different topic, I will describe some work undertaken with Alan De Lucia and Nicholas Skelton (Phillips, De Lucia, & Skelton, 1975; described more fully in a report by Audley, Bickmore, & Phillips, 1974). We wanted to compare different ways in which a three-dimensional surface could be portrayed on a map. In a relief map this surface is the height of the land

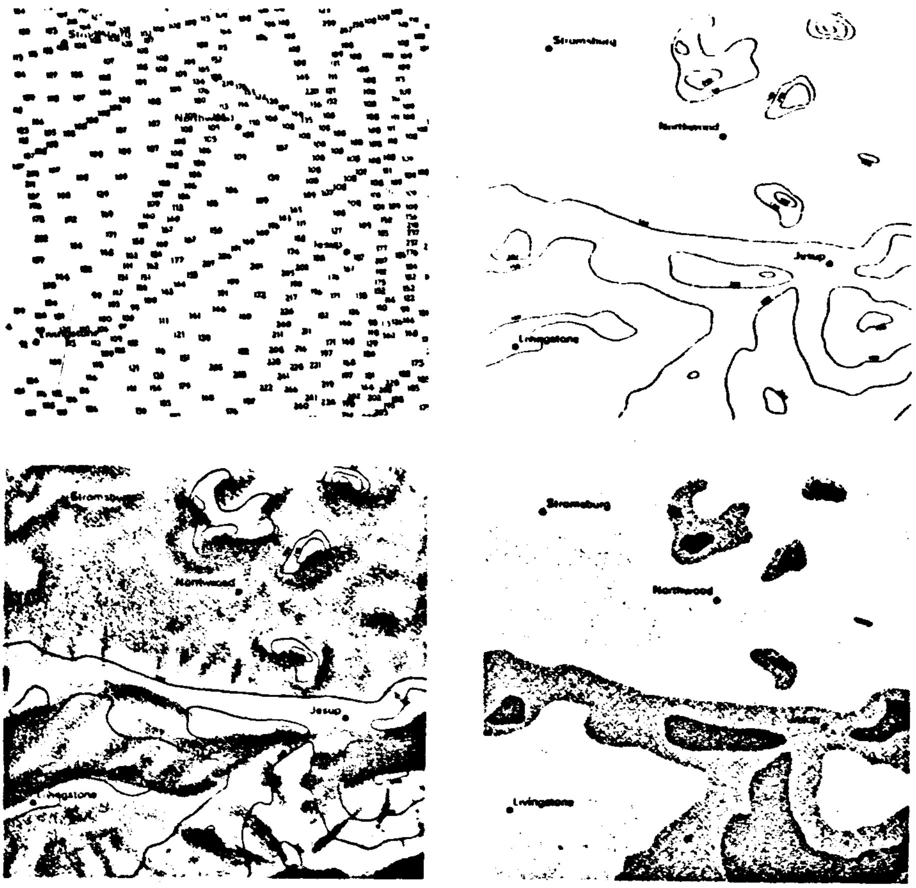

Figure 2. The four types of map used in the relief experiment: Digits (top left), Contours (top right), Shading (bottom left), and Tints (bottom right). The original maps were printed in black and brown.

across hills and valleys, but there are similar problems in depicting theoretical surfaces such as distribution of a mineral, annual rainfall, or degree of magnetic anomaly. Two areas from an oceanographic map were presented as a landscape to make it easy to ask questions about them. They were drawn in four different ways: contour lines, contour lines with hill shading, layer (or hypsometric) tints, and digits (a large number of spot heights resembling a nautical chart); see Figure 2.

A group of 179 police cadets were randomly assigned to one of the four types of map and were given a series of timed map reading questions. In one question short black lines were overprinted on the map and labelled alphabetically. The subjects were asked to work quickly and put a ring around the end of each line which was on higher ground. The time limit was half a minute and the score was the number of correct items completed.

In another question three profiles were printed at the bottom of the map and subjects had to match these with three straight lines printed on the map. Here there was less time pressure -- subjects had a minute and a half.

A third question involved the use of a plastic relief model. A number of small areas of a map were cut out and mounted on separate pages of a booklet and the subjects were asked to locate these areas on the model.

Although limited to what could be done with subjects sitting at desks, we chose as wide a variety of questions as possible. When the results were analyzed it was found that the 13 questions could be divided into four groups on the basis of their scores, and this division was supported by a cluster analysis.

The first group included a number of questions about relative height -- decide which end of a straight line was on higher ground and draw a river which consistently flowed downhill. Figure 3 shows that for this type of question the tint maps were best. In the second group there was a single question on absolute height -- subjects simply had to estimate heights -- and for this the digital maps were best. The third group consisted of questions requiring subjects to visualize the landscape and included matching the map to the plastic relief model, and a question on intervisibility (whether someone

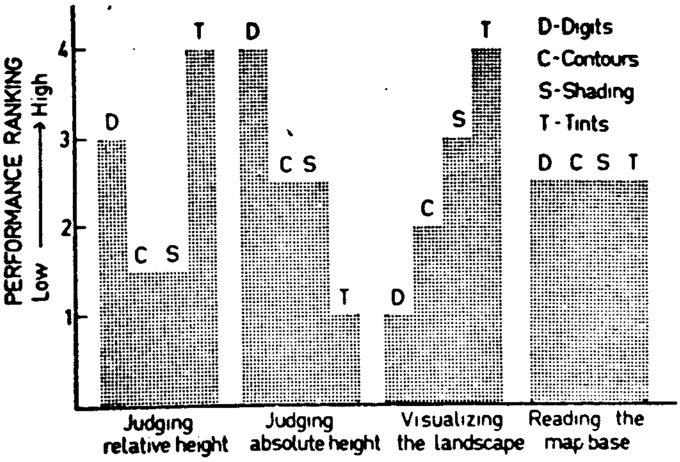

Figure 3. A summary of the results of an experiment to compare the legibility of relief maps using a number of map reading questions.

standing at one location could see a person standing somewhere else). For this group the tint maps were best. The fourth group of questions was about the map base, for example, searching for place names, but these failed to show any significant differences.

Figure 3 illustrates the fact that one cannot talk of "map legibility" without reference to the way a map will be used. Previous experiments on relief maps (Kempf & Poock, 1969; Shaw & MacLagan, 1972) have often compared one map with another on the basis of just one or two questions -- estimating heights was always one of them. Height estimation tasks are a misleading way of evaluating relief maps. As Figure 3 shows, the rank order of maps is nearly reversed when absolute height questions are compared with visualization questions.

We have replicated this experiment with geography undergraduates and have completed a second experiment on computer generated methods of depicting relief using the SYMAP and SYMVU programs. One further experiment is planned on relief representation. The two long term aims of this research are to provide the map designer with objective data to help him relate map design to map usage, and to encourage designers to test maps themselves. We hope to make some recommendations on a series of relief map tests which are easy to carry out, sensitive enough to show statistically significant differences with small numbers of subjects, and representative of most types of real life map reading.

Symbols for Woodland

R. M. Taylor and V. D. Hopkin of the RAF Institute of Aviation Medicine at Farnborough have carried out a number of interesting studies of map legibility. Although all their work is on aeronautical charts for military use, their results are often relevant to map design in general. Aeronautical charts and other topographic maps at a scale of about 1:250,000 frequently show woodland as a solid green area. This obscures other information on the map making it impossible to show layer tints which portray the height of the land. This problem is particularly serious on aeronautical charts where height information is needed for safety and where the shape of woods and forests is a useful navigational aid. Taylor (1975) has conducted some experiments to compare the solid green woodland symbol with some alternatives such as the use of a "vignette" where dark green on the edge of a wood fades into a light green interior, or where the interior is marked with repeated tree symbols.

Forty subjects were shown small areas of woodland printed in green against a white background and asked to decide whether the woods were present on specially printed test maps. Although this seems simple, it led to surprisingly large differences between the alternative maps. When subjects used an experimental control map which showed nothing but woodland (also in solid green on white), search times were about six seconds. With a realistic map using a similar solid green symbol, search time was doubled. But with other types of woodland symbols such as vignettes the search took roughly three times as long.

Taylor discussed the problem of identifying woodland shapes in terms of segregating the visual field into areas of figure and ground. If woodlands were shaped like squares or triangles, there would be little difficulty in recognizing them. But they are usually irregular areas which lack "figural goodness." Even with a solid green woodland symbol, it is sometimes difficult to see the outline of a wood as a whole against the background clutter of the map. With other symbols such as vignettes, the separation of figure from ground becomes even more difficult.

Taylor's experiment is a good example of what the psychologist can offer the map designer. There is no simple solution, but alternatives which the designer should decide among on the basis of the psychologist's data. If aeronautical charts are to have woodland symbols, these must be areas of solid green, but this inevitably reduces the legibility of the rest of the map. A possible compromise is to depict only small areas of woodland which are useful as landmarks, and leave out large forests which obscure more than they inform. Vignettes are not a good compromise because they are difficult to use and obscure the map base as much as a solid green symbol does.

Repertory Grid Techniques

Most experiments on map legibility use performance tests: they measure the map reader's speed and accuracy. Although this is undoubtedly the right approach, other methods are also interesting. For example, Stringer (1973) was interested in comparing the efficacy of four types of map in communicating a number of different plans for the development of an area in south London. The plans affected an existing shopping centre and women living in the area were interviewed using a repertory grid technique. They looked at pairs of maps and suggested the implications for people living in the area. These "constructs" were then ranked for the alternative plans as well as for the present use of the land. Analysis of the data revealed the number of functionally distinct constructs elicited for each type of map. Using this and several other scores, Stringer assessed the merits of each type of map for this purpose.

This is an original approach to testing maps. It seems useful when maps are used in a divergent way, that is to say, where the user has no definite goal in using the map but is exploring possibilities, looking for ideas, and grasping implications. This can be contrasted with the convergent use of maps where specific information such as the shortest route home or the best place to bore for oil is sought. There is no doubt that maps are used in both convergent and divergent ways, although it can be argued that for the professional user -- the geologist or pilot -- convergent map reading is more frequent.

Conclusions

These examples illustrate current research on making maps easy to read. It has not been possible to describe other studies which are equally interesting, for example, Hill's (1974) work on orthophoto maps, or a large number of experiments on the perceived size of cartographic symbols (Williams, 1956; Clarke, 1959; Wright, 1967), or research on tactile maps for the blind (Leonard & Newman, 1970).

Map legibility resarch is too recent a phenomenon to assess its effect on map design. Cartographers' reactions to experimental data range from enthusiasm to scepticism. The sceptics may eventually be convinced by the size of effects found in map legibility experiments: differences of 50 or 100 per cent in speed or accuracy between one map and another are not uncommon, and it may be difficult to ignore the implications for real life map reading.

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