Working Paper E in: Audley, R. J., Phillips, R. J. & Noyes, L. (1981). Legibility criteria for maps. Final report to the United Kingdom Social Science Research Council for project HR 2917/1.

DISTORTIONS IN PERCEIVED DISTANCE RESULTING FROM THE PLACING OF NAMES ON MAPS

In the course of an experiment to evaluate relief maps (Phillips, De Lucia and Skelton, 1975) subjects were asked to write down the nearest town to Northwood (see Figure 1). Twenty-one out of 29 wrote down Stromsburg although in fact Jesup is nearer and the distance to Stromsburg is 16 per cent greater. It is debatable whether this would be a serious problem in real life map reading, where the reader could easily measure the map if accuracy was necessary. However some further investigation did seem worthwhile to discover the factors which cause this kind of error, and to see whether maps could be designed in a way to minimize it. A pilot experiment (see Audley, Bickmore and Phillips, 1974) suggested that two factors were at work: the positioning of the contour lines and the positioning of the names. Where judgments crossed contour lines there was a tendency for distances to be judged as greater than they were, and a similar effect occurred across tint boundaries on layer tine maps. This is perhaps a variation of the Oppel-Kundt illusion where a filled extent is also over-estimated (see Robinson, 1972). However, these are small effects and, on the map, the positioning of names appeared to have a greater effect.

If someone is asked to mark the midpoint between the two dots in Figure 2 there is a tendency to make the judgment too close to the name. Where the name is between the dots the bias is away from the name. This effect could be regarded as a distant relative of the Mueller-Lyer and similar illusions, although the error is smaller than with these, and Robinson (1972) suggests that an essential component of these illusions are convex or concave elements, which are not obviously present in Figure 2.

These experiments set out to measure the effect of name positioning on a line bisection task with the aim of discovering how the effect might operate in maps.

EXPERIMENT ONE

Apparatus

Subjects sat in fron of a Textronix storage display scope type 611 controlled by a PDP-12 computer. A distance of 100mm on the scope subtended approximately 12 degrees at the subjects' eyes. The display was light green against a dark background, and room illumination was kept low (about 0.2 foot lamberts). Subjects could adjust the horizontal position of a small spot of light on the scope by means of a rotary potentiometer, and they pressed a key to show they were satisfied with their judgment.

Subjects

These were seven men and one woman who were students or staff at University College.

Procedure

Subjects made 32 judgments where they adjusted a movable spot of light so that it appeared equidistant from two fixed spots. A key press recorded the position of the spot and initiated the next display. The name Fleming appeared in one of four positions:- on the outside of the left spot, the inside of the left spot, the inside of the right spot, or the outside of the right spot. Figure 2 illustrates this last case. For four subjects the separation betweeen the spots was held constant at

55mm and for the others it was 75mm. Each subject made eight judgments on each condition, with half of these the whole display was shifted slightly to the left of the scope, and with the other half to the right of the scope: this was to minimize any effects due to the edges of the scope. A different random order of presentations was used for each subject, and an additional eight trials were given for practice.

Subjects were told to make their judgments accurately bearing in mind that the name was there to distract them. They were asked to spend 10 to 15 seconds on each judgment, although in practice times differed considerably from subject to subject.

Results and Discussion

The computer recorded the position of the spot to an accuracy of about 0.1mm, measuring responses from the true bisection point and taking the predicted direction of errors as positive. Figure 3 gives the mean responses for each subject, combining data for left and right presentations of the word. When the word fell outside the spots, the systematic error was about 1 or 2mm in the direction of the word. When the word was between the dots there was a much wider range of scores, and although the general tendency was for systematic errors away from the word, one subject showed a strong effect in the opposite direction.

Subjects' comments suggest that when the word lies between the dots it is much more obtrusive and they make a greater effort to compensate for it and, presumably, this can result in over compensation. With the name placed outside the spots, there is less variation between subjects and the average strength of the effect is greater. For these reasons, the remaining experiments are limited to studying the case where the name lies outside the spots.

The second experiment investigates how the error is affected by variables such as the size of the word and the size of the spots: these are factors which cartographers could alter if they substantially affect the amount of distortion.

EXPERIMENT TWO

Design

Each subject made 192 judgments making up a 3 x 4 x 2 x 2 x 4 factorial design. The variables were:- (1) The type of background display, which was either blank, or a regular grid, or consisted of curved lines resembling contour lines. (2) The type of word. The word Fleming was used throughout but this varied in length (14mm or 19mm) and height (4mm or 5mm), making four versions in all. (3) The diameter of the fixed spots which were either 1.00mm or 2.0mm. The size of the movable spot was constant. (4) Position of the word. The word always appeared on the outside of the spots, either on the left side or the right side. (5) Position of the display on the scope. The whole display was shifted horizontally into one of four positions in order to eliminate any effects due to the edges of the scope. However, the grid and the contour lines were not shifted and remained in a fixed position throughout the experiment. An example of the display is shown in Figure 4.

Subjects

There were four men and two women, all students at University College.

Apparatus and Procedure

These were the same as for experiment one. The distance between the spots was held constant at 55mm.

Results

An analysis of each individual's data showed considerable agreement between subjects, although there were noticeable individual biases towards greater errors with the name on either the left or the right side of the scope. Subjects who reported using the grid background for measurement were slightly more accurate in this condition than those who did not. An analysis of variance revealed five statistically significant effects, but three of these were high order interactions for which no interpretation is offered. The other two were main effects: the type of background ($p < .01$) and the size of the spot ($p < .025$). With no background the mean error was 1.22mm, with contours it was 0.58mm and with the grid it was 0.44mm. With large spots the mean was 0.69mm and with small spots it was 0.80mm.

Discussion

The size of the name appears to have no effect and the size of the spots has such a small effect as to be negligible. The type of background has a more definite effect: with a grid or contour line background the systematic error is reduced to less than half of the error with no background. The simplest explanation is that any increase in visual noise in the display reduces the effect. If this is correct there should be less systematic error in the context of a map, where visual noise is invariably high, than with the relatively simple display used in this experiment. Of course, this reduction in systematic error may be accompanied by an increase in errors of other types, but that is another question.

For several reasons, it seems unlikely that the effect investigated in this experiment has practical consequences for map design. Firstly, the effect is already a very small one. Secondly, it is likely that in a real map the effect would be reduced still further by the introduction of visual noise. And thirdly, there seems to be no obvious way of designing a map to reduce the effect.

However, it is possible that the two experiments described so far have obscured interesting effects, and a third experiment was carried out to look at the effects of two further variables. The distance between the spots has not been adequately investigated as a variable: when the spots are close together they can be taken in in a single eye fixation but as they are moved apart it becomes increasingly necessary to use two fixations to see their relative positions. It is possible that, as eye movements become increasingly necessary, the effect will change qualitatively or quantitatively. The third experiment varied the distance between the spots from 20mm to 90mm.

One possible explanation for the interfering effect of the word is that it is difficult to visually separate the spot from the word. If this is correct the small distance between the spot and the word should be of importance, so that the smaller the distance, the greater the confusion and the greater the error. In the first two experiments this distance was held constant, but in experiment three it is varied from the spot just touching the word to a gap of 1.0mm.

EXPERIMENT THREE

Design

Each subject made 96 judgments forming a 3 x 8 x 2 x 2 factorial design. The variables were: (1) The distance between the word and the adjacent spot which was 0.0mm, 0.5mm or 1.0mm. (2) The separation between the spots which was 20, 30, 40, 50, 60, 70, 80, or 90mm. (3) The position of the word, on the right or the left, and (4) The position of the display on the scope, being one of two positions shifted horizontally from each other. The spot size was held constant at 1.0mm diameter.

Subjects

These were three men and three women, all students at University College.

Apparatus and Procedure

The same as for the previous experiments.

Results

An examination of individual data revealed a large degree of consistency between subjects. An analysis of variance gave a significant effect of the separation between spots, and this had a significant linear component ($p < .01$) while other orthogonal components were not significant. The only other item to reach significance was an interaction between the position of the word and the distance between the word and the spot ($p < .05$) but as no interpretation could be put on this it was regarded as anomalous. The separation between the word and the spot seems to have no effect on the task.

Figure 5 shows the mean error as a function of the separation between spots. The regression line passes close to the origin and suggests the error is a constant 2.4 per cent of the separation between the spots.

GENERAL DISCUSSION

Experiment three demonstrated that the separation between the word and the adjacent spot does not affect the amount of error, and the previous experiments showed that other variables under the map designer's control, for example, the spot size, are likely to have a negligible effect on accuracy. The amount of distortion in perceived distance was much smaller in these experiments than that found in the 'Northwood' example.

The weakness of the effect may also explain why there have been no previous studies of this type of illusion, while the Mueller-Lyer and similarly strong illusions have attracted numerous investigations. One advantage of studying weak illusions is that it is unlikely that more than one source of bias is present. Richards and Miller (1971) have argued that the relatively strong corridor illusion is the sum of several factors acting together, and it is possible that this is also true of the Mueller-Lyer illusion.

While these experiments have not proved of practical value to the map designer, they raise some questions of theoretical interest. What is the cause of the linear relationship found in experiment three? Does the size of the interfering stimulus begin to have an effect when a larger range of sizes are studied? Why did Baldwin (1895) find errors in the opposite direction when subjects bisected a line with a square at one end of it? Baldwin always placed the square on the left of the line (or on the top in a vertical condition) and so interference from other parts of the display was not controlled for, although this does not necessarily explain his opposite finding.

REFERENCES

AUDLEY, R. J., BICKMORE, D. P. and PHILLIPS, B. J. (1974). Legibility criteria for the efficient use of maps. Final report to the Social Science Research Council for project HR 2167.

BALDWIN, J. H. (1895). The effect of size-contrast upon judgments of position in the retinal field. Psychological Review, 2, 244-259.

PHILLIPS, R. J., DE LUCIA, A. and SKELTON, N. (1975). Some objective tests of the legibility of relief maps. Cartographic Journal, 12, 39-46.

RICHARDS, W. and MILLER, J. F., Jr. (1971). The corridor illusion. Perception and Psychophysics, 9, 421-423.

ROBINSON, J. O. (1972). The psychology of visual illusions. London: Hutchinson.

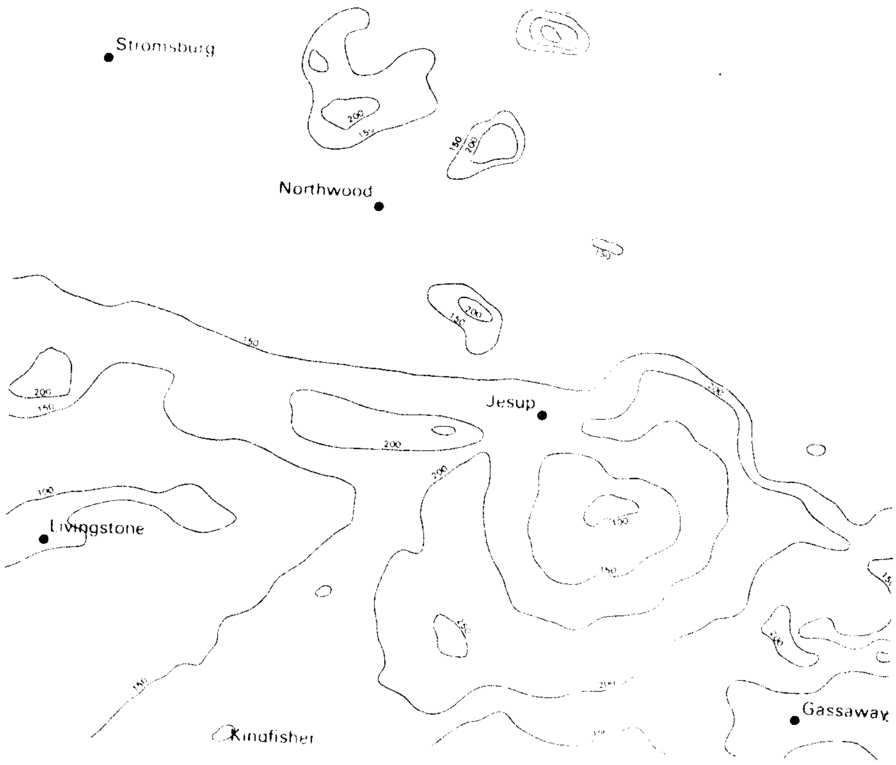

Figure 1.

Part of a contour map tested by Phillips, De Lucia and Skelton (1975). The contour lines were printed in brown and the names in black.

Figure 2.

An example of a display used in experiment one. In this case, the distance between the spots was 55mm.

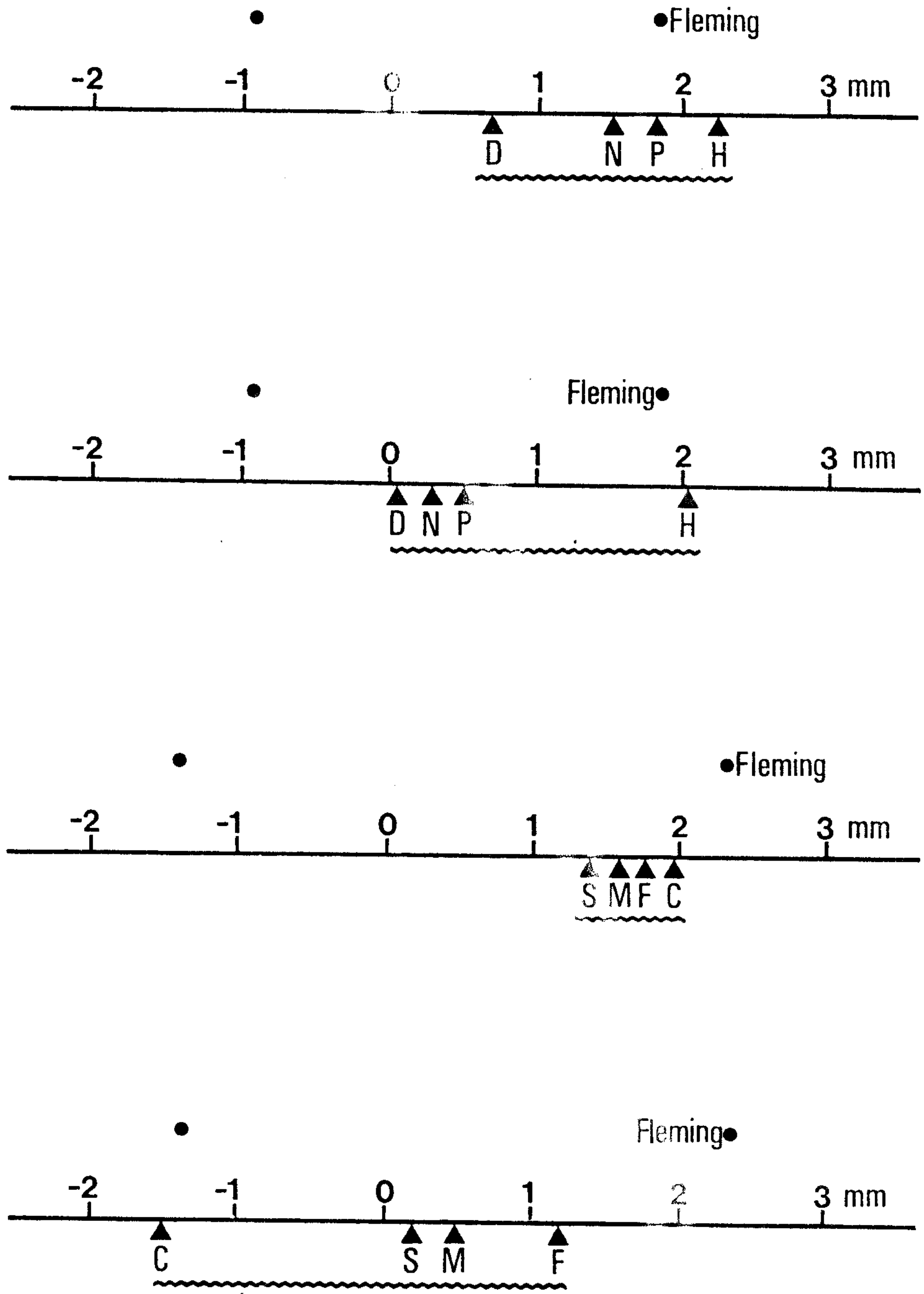

Figure 3.

The mean errors for each subject in experiment one. Zero is the true midpoint, and the predicted direction of errors is shown as positive. The two upper scales show means for the 55mm separation and the two lower scales are for the 75mm separation.

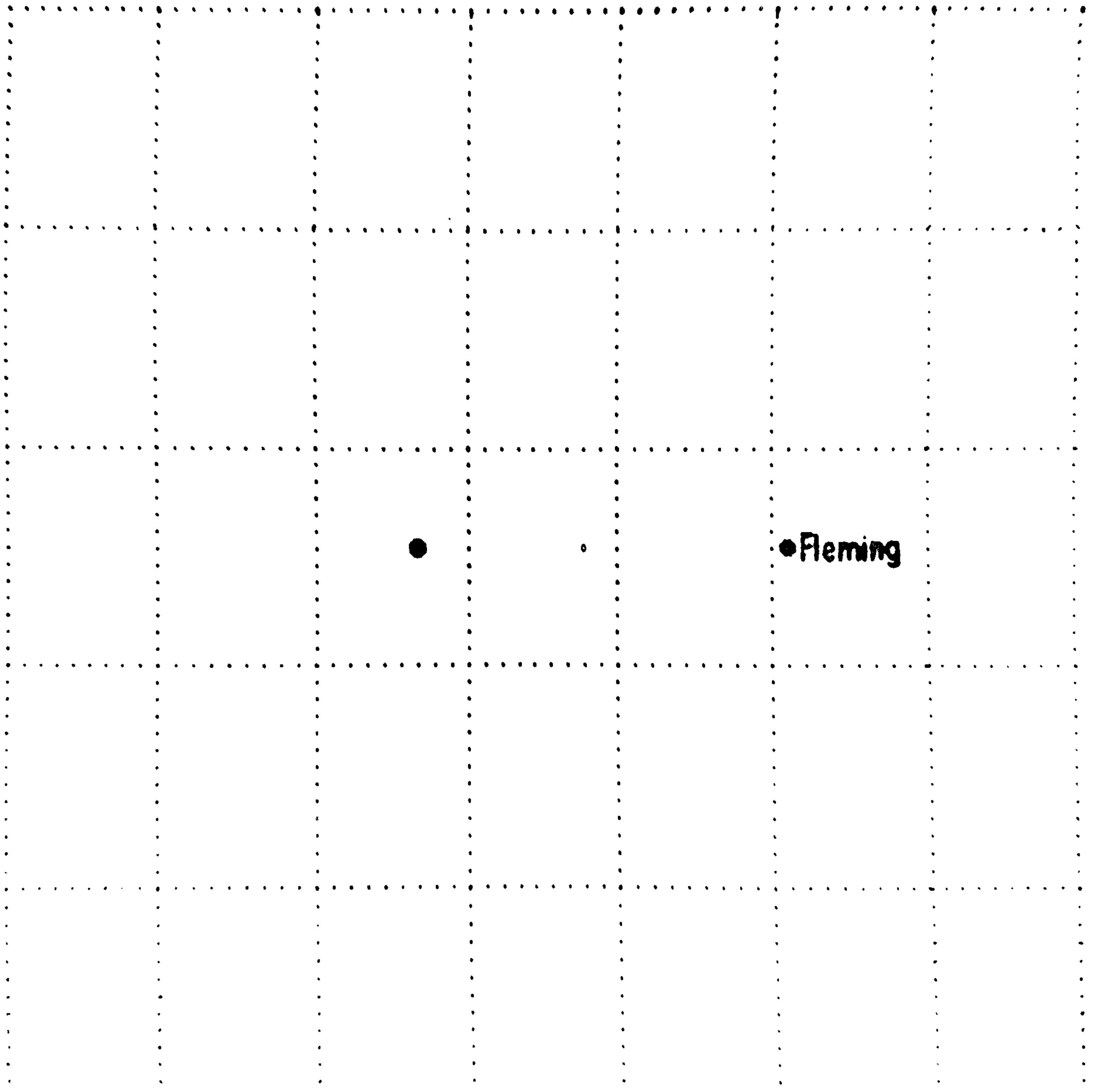

Figure 4.

One of the displays used in experiment two. The distance between the spots was 55mm.

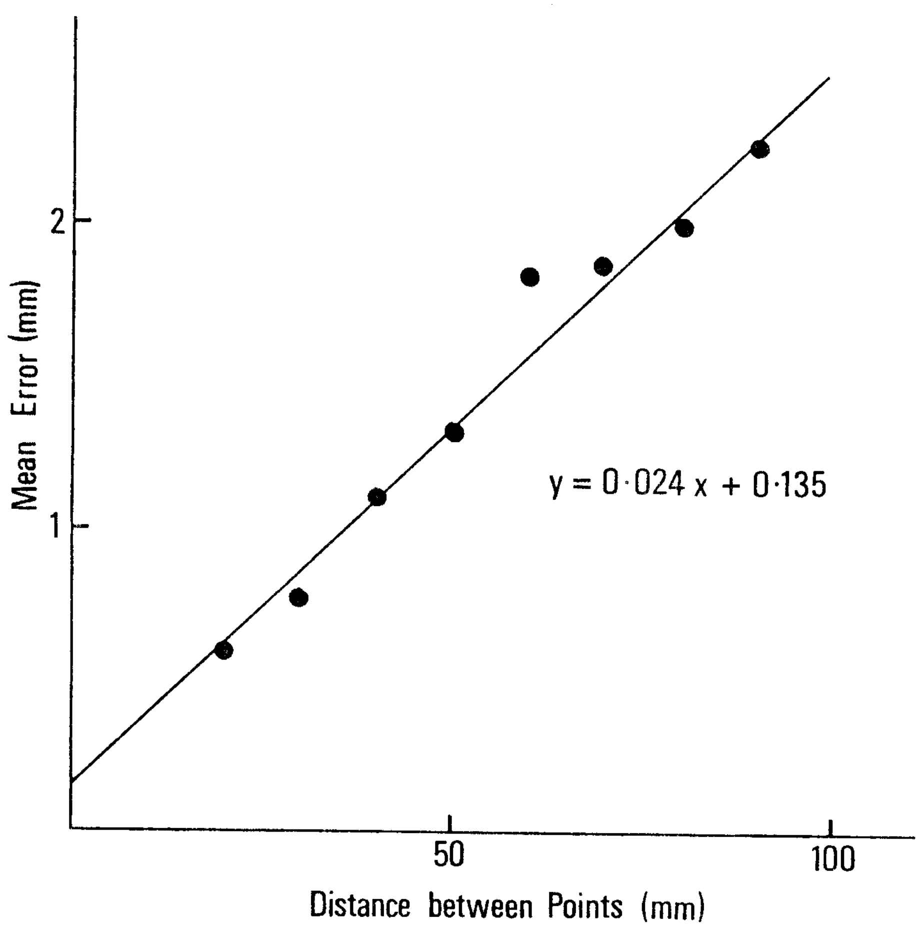

Figure 5.

The mean error as a function of the separation of the spots (experiment three).