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An experimental investigation of layer tints for relief maps in school atlases

By RICHARD J. PHILLIPS

Shell Centre for Mathematical Education, The University, Nottingham NG7 2RD, England

English teenage school children carried out some representative map-reading tasks to evaluate layer tints for use in school atlases. Two *spectral* colour schemes (loosely following the colours of the spectrum) were compared with two *tonal* schemes (varying tone, constant hue). Judgements of absolute height were carried out more accurately on the spectral maps, but judgements of relative height were better with the tonal maps. Other questions involving the map base and visualization of the relief showed no reliable differences between the maps. Spectral schemes have the disadvantage that colours are difficult to order correctly. The problem with tonal schemes is that colours are often hard to discriminate. Innovative design may overcome both these problems but given the alternatives considered here, the tonal maps seem preferable as relative height is more important than absolute height for children using atlases.

1. Introduction

The most common method of depicting relief on a map is with contour lines. A frequent refinement is the addition of *layer tints* between the contour lines in order to colour code each band of height. Layer tints are found in most world atlases as well as on some topographic and thematic maps. It is usual to print a key in the border of a layer tint map to show the height range indicated by each colour. On some layer-tint maps the original contour lines are omitted.

A number of studies have compared contour-line maps and layer-tint maps using tests of map-reading performance (Kempf and Poock 1969, Shaw 1972, Audley *et al.* 1974, Phillips *et al.* 1975, Phillips and Noyes 1978, Potash *et al.* 1978). With tests which involve visualization of the landform or the judgement of relative height, layer-tint maps are used more accurately and more quickly than contour maps. The effects are often quite large; on five out of 13 questions used by Phillips *et al.* (1975) the mean performance scores for layer tints were more than 50% greater than those for contours.

However, when heights have to be estimated, contour-line maps are sometimes superior to layer tint maps (see, for example, Phillips *et al.* 1975) but sometimes the reverse is found (see, for example, Kempf and Poock 1969). A possible reason for this inconsistency is discussed below.

There are many methods for portraying relief besides contours and layer tints (see Lawrence (1971) for a description of some of these, and Hopkin and Taylor (1979) for an ergonomic review). For small-scale topographic maps, however, no method has proved superior to layer tints for visualizing the relief. This paper is concerned with the best choice of colours for layer tints in school atlases. Cartographers and geographers have debated this question at length but there is little clear research on the question.

Most layer-tint schemes can be categorized as either *spectral* or *tonal*. Spectral layer tints approximately follow the order of colours in the spectrum; a typical sequence would be: green, yellow, orange, brown, violet. In contrast, tonal layer tints vary value and chroma but hold hue approximately constant. Graphic designers use the word '*tone*' to indicate the variation which occurs when a pigment is visually mixed with white paper by the use of screens. For example, blue, varying through successively lighter shades of blue, to white. More than 95% of the layer tints in British atlases are of the spectral kind. This investigation will compare the merits of spectral and tonal colour schemes.

A design principle favoured by some cartographers is to choose tints so that each step in the sequence appears perceptually equal (see, for example, Jenks and Knos 1961). There are a number of psychophysical approaches to achieving this, although probably most relevant is the early work of Lloyd Morgan (1900). However, it is questionable whether the steps in layer tints need to be matched in this way, particularly as the bands of height depicted are often unequal. There are also practical problems in printing tones on maps to the close tolerances this demands.

Another approach is to choose colours so that prominent landforms appear prominently on the map. The aim in choosing colours is to exploit apparent distance and figure-ground phenomena so that details stand out on the map in proportion to their real importance. The colour distance effects reported in the psychological literature are weak, inconsistent and difficult to apply to maps (Audley *et al.* 1981, working paper C). Despite this, map designers are often successful in exploiting the visual dominance of colours.

A different consideration in designing layer tints is their discriminability. This is most important when matching tints on the map with those in the key. It is easy to make a mistake because of the distance the eyes must move when a colour on the map is compared with one on the key. There are also distortions from induced colour. These problems are evident when subjects are asked to estimate heights on a layer-tint map, and explains why this, in contrast to other tasks, is sometimes performed better on a contour map than a layer map. Colours are probably easier to discriminate on a spectral map than a tonal map. In the present study this is investigated by comparing height estimation performance in spectral and tonal maps.

There are a number of other factors which affect the choice of layer tints. Clearly layer tint colours should not be so dark that they obscure other information on the map. A frequent problem with spectral colour schemes is that the ordering of tints appears arbitrary to the map reader. This is likely to affect judgements about which of two colours represents the higher ground. Patton and Crawford (1977) have criticized spectral colour schemes for a different reason. They argue that both children and adults can be misled easily into inferring false information about vegetation, temperature and rainfall from the spectral colours.

It is clear from the above discussion that there are many factors to consider in selecting layer tints. It is difficult for a map designer to assess these points fairly as they cannot easily be placed in any order of importance. One solution is to look directly at the effect of map design on map-reading performance. This experiment uses a number of simple representative map-reading tasks to test four versions of a layer-tint map. The questions used are ones which previous research has shown are sensitive to differences in map design. Phillips *et al.* (1975) has shown that at least four types of question are needed to assess adequately the legibility of relief maps: judgements of absolute height, judgements of relative height, visualization of the landform and the legibility of the map base. Questions of these four types were included.

2. Experiment 1

2.1. *Maps*

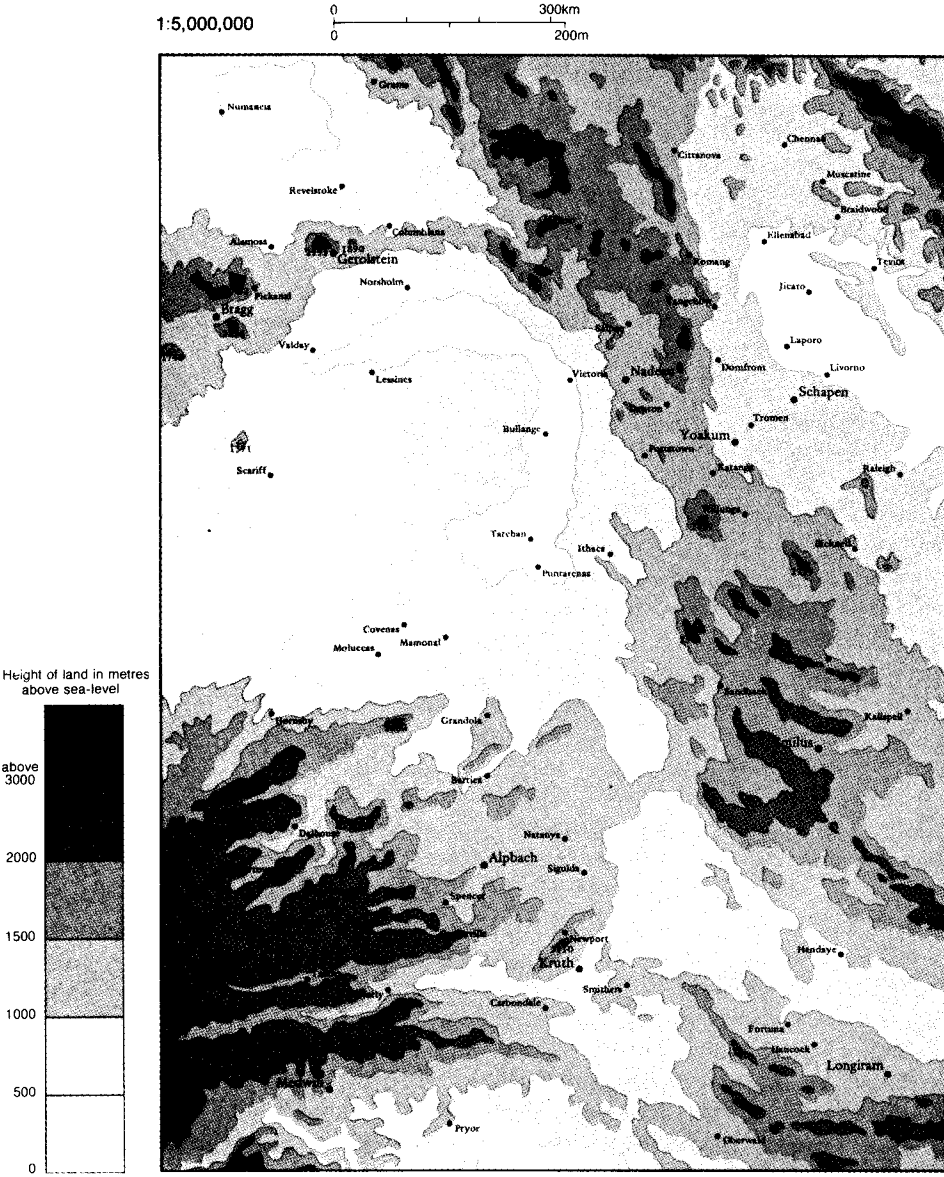
Four versions of a map prepared by a cartographic draughtsman were specially printed for this study using normal cartographic methods, materials and tolerances. The maps were identical apart from the layer colouring. The four are called *tonal dark hills*, *tonal light hills*, *spectral bright* and *spectral pale*. The tint colours used in each version are detailed in table 1 and one of the maps is illustrated in the figure. The tonal maps have tints ranging from dark brown, through lighter shades of brown to white. The difference between the two versions is simply whether the tones lighten or darken with increasing height. The two spectral maps have tints which are based on those frequently found in British school atlases. The two schemes differ in a number of ways but in one the colours are generally paler than in the other. As far as can be ascertained, no British school atlases use a tonal scheme.

An area in the Middle East was chosen for its unusual relief and, with some generalization, was presented as a 1 : 5 000 000 map measuring 149 × 212 mm on an A4 page (209 × 297 mm). Contour lines printed in a blue screen separated the six layer tints at 500, 1000, 1500, 2000 and 3000 m. Printed in black were 16 spot heights and 73 place names set in two point sizes. The names were chosen at random from the gazetteer of a world atlas but excluded any which were very difficult to pronounce. The map was printed with a height legend and a scale legend.

The experimental maps did not show any roads or rivers. These features often provide information about relief which could have been used instead of the layer tints.

Table 1. Each map had six tint colours—(1) represents the lowest ground and (6) the highest. The first line gives the approximate Munsell value of the colour. The second line shows the combination of printing inks and dot screens used. LB = light brown, BR = brown, B = blue, R = red, Y = yellow, 100 = solid ink, 60 = 60% screen, etc. The colour names on the third line are intended as a rough guide only.

	Tonal dark hills		Tonal light hills		Spectral bright		Spectral pale
(1)	N 9·5 — White	(1)	5YR 6/12 100LB, 100BR Brown	(1)	7·5GY 7/5 40B, 60Y Green	(1)	2·5G 8/3 30B, 30Y Sea green
(2)	7·5YR 9/2 30LB	(2)	5YR 7/10 100LB, 30BR	(2)	7·5GY 8/3 20B, 30Y Pale green	(2)	2·5GY 8·5/5 10B, 30Y Leaf green
(3)	7·5YR 8·5/3 70LB	(3)	7·5YR 8/6 100LB	(3)	7·5Y 9/5 30Y Yellow	(3)	7·5Y 9/5 30Y Yellow
(4)	7·5YR 8/6 100LB	(4)	7·5YR 8·5/3 70LB	(4)	5YR 8/4 20R, 30Y Flesh	(4)	10YR 8/7 10R, 30Y Orange
(5)	5YR 7/10 100LB, 30BR	(5)	7·5YR 9/2 30LB	(5)	5YR 7/8 40R, 60Y Tangerine	(5)	2·5P 8/3 10B, 10R Pale violet
(6)	5YR 6/12 100LB, 100BR Brown	(6)	N 9·5 — White	(6)	5P 5·5/6 40B, 40R Violet	(6)	N 9·5 — White



A monochrome reproduction of the *tonal dark hills* map. In the original the layer tints are brown and the contour lines are blue.

Therefore their inclusion could have considerably reduced the chance of detecting statistically reliable differences between the four versions of the map. A similar consideration led to the choice of an area with unusual relief. A more predictable landscape would have made it difficult to detect any differences. In any ergonomic experiment it is necessary to strike a compromise between ecological validity and the demands of an experimental design. Totally realistic map-reading experiments are worthless if they cannot show any reliable differences.

2.2. *Subjects*

The subjects were 103 boys and 98 girls from a single year of a London comprehensive school and were tested in two groups. They were aged between 13 and 15 years and spanned the full range of academic abilities. All the world atlases used in this school had spectral layer tints.

2.3. *General procedure*

Roughly equal numbers of children were assigned at random to the four types of map and each child used the same map throughout the tests. All questions, apart from question 1, were presented in a booklet with a different copy of the map used for each question. Accurate time limits were maintained by inserting blank pages in the booklet between the maps, so that the maps were only visible when a question was actually being answered. Every question was carefully explained before it was attempted. When necessary examples were inserted in the test booklet. Before starting, the children were briefed on the purpose of the tests and it was strongly emphasized that everyone should do as well as they could, regardless of their opinion of the maps.

With the exception of question 1, all the questions are based on tasks which occur frequently in the classroom in the context of larger map-interpretation exercises. This type of exercise could not be used directly to evaluate the maps as individual variation in performance is too great to be able to detect any statistically significant differences.

2.4. *Question 1: ordering tints*

The questions are numbered in the order they were attempted. The first question, based on a procedure devised by Hopkin (1973), was given before the children saw any maps. Each child received an envelope containing six pieces of paper measuring 15 mm square coloured with the six tints from the map they were to use. They were asked to place these colour samples in the best order for showing heights on a map. They had several minutes to decide and were then asked to number the samples from 1 to 6, where 1 represented the lowest ground and 6 the highest. They returned the samples to the envelopes and sealed them up.

2.5. *Familiarization*

The children were asked to open the booklet and look at the map they were to use for all the remaining questions. They were asked to examine the legend carefully and note the correct order of the tints. They were then given 1 min to try to imagine the landscape shown on the map. After this, they were asked to mark the highest and lowest points on the map with two crosses. A further minute was allowed for this.

2.6. *Question 2: short lines*

Each map used for this question was overprinted with 16 straight lines 20 mm long. The children were instructed to mark the higher end of each line with a circle. The score was the number of correct responses minus the number incorrect. The time limit was 45 s.

2.7. *Question 3: profiles*

The children were asked to match nine profiles printed underneath the map with nine lines printed on the map. One was already done as an example. The lines on the map were 80 mm long, the profiles were 55 mm wide, and all were labelled *a* at one end and *b* at the other.

2.8. *Question 4: names*

This question was included to discover whether differences in the layer tints affected the legibility of the base map. The children were given a list of 24 names which appeared in the list. They were instructed to circle each name on the map as they found it and join it to the previous name with a line. The time limit was 2 min and the score was the number found.

2.9 *Question 5: rivers*

The children were told that each of the ten towns shown in the larger type size had a river flowing through its centre. They were asked to guess the direction each river would follow as it left the town, and mark this with a small arrow. Three judges determined the acceptable range of answers for each river. The average range spanned about 120°. The time limit was 1 min and the score was the number of correct responses.

2.10. *Question 6: heights*

The map was overprinted with 12 crosses labelled with the letters *A* to *L*. The children were told to work in alphabetical order, estimate the height of each cross to the nearest 100 m, and write the answer underneath the map.

Three judges agreed on a loose and strict method of scoring. With loose scoring, an answer was counted as correct if it fell within the correct contour interval, or in the case of two crosses which fell on the contour, the answer had to be within 100 m of it. The score was the number of correct responses minus the number incorrect.

With the strict scoring, answers had to fall within a 200 m range (e.g. 1200–1400 m inclusive) except for two crosses in higher regions where a wider range was allowed. The strict score was the number correct without deductions for errors. The time limit was 2 min.

2.11. *Question 7: intervisibility*

The children were asked to imagine that they were standing at one position marked on the map and to decide whether or not they would be able to see people standing at 12 other positions marked with crosses and labelled from *A* to *L*. They were told to ignore the distances involved and consider only whether hills or mountains would block the line of sight. Answers, 'yes' or 'no', were written underneath the map. One minute was allowed and the score was the number of correct responses minus the number incorrect.

2.12. *Results*

The means for questions 2–7 are shown in table 2. One-way analyses of variance showed statistically significant effects on question 2 (short lines) ($F(3, 197) = 7{\cdot}6$, $p < 0{\cdot}001$) and on question 6 (heights) (loose scoring, $F(3, 193) = 4{\cdot}3$, $p < 0{\cdot}01$; strict scoring, $F(3, 193) = 3{\cdot}7$, $p < 0{\cdot}05$).

On question 2 performance on the two tonal maps was better than on the two spectral maps. A Duncan's multiple range test, adopting the $p < 0{\cdot}05$ level, showed that scores on the *tonal dark hills* maps differed significantly from the other three conditions.

In contrast question 6 (heights) was performed better on the spectral maps than the tonal maps. A similar Duncan's test showed that scores on the *spectral pale* maps were significantly greater than those on either tonal map. The loose method of scoring also showed a significant difference between the *spectral bright* and the *tonal light hills* conditions.

Table 2. Mean scores for experiment 1.

Question number	Tonal dark hills	Tonal light hills	Spectral bright	Spectral pale
2	12·5	8·4	7·0	7·7***
3	3·6	2·9	3·4	3·5
4	11·6	10·5	10·5	10·3
5	6·4	5·3	5·9	6·1
6 (loose)	3·5	2·9	5·4	6·0**
6 (strict)	4·3	4·3	5·1	5·9*
7	3·5	2·4	3·0	2·6

*** $p<0{\cdot}001$; ** $p<0{\cdot}01$; * $p<0{\cdot}05$.

2.13. *Analysis of question 1*

The children who had colours from the tonal maps showed a fair level of agreement. Seventy three out of 102 ordered the colours in the way used on the *tonal dark hills* map, 24 gave the reverse order used on the *tonal light hills* map, and five gave three other orders.

The 49 children who had colours from the *spectral bright* map produced 26 different orderings. Only two children gave the order used on the map and none gave the reverse order. The commonest, given by 10 children, was yellow, pale green, flesh, green, tangerine and violet, in ascending order. This is also the most popular order found by counting the colour most frequently placed in each position. Another kind of analysis counts pairs of colours placed together without considering their absolute position in the sequence. The pairs which were chosen by 19 children or more were: yellow–flesh, pale green–green, green–tangerine and tangerine–lilac (the second colour is always the one placed higher). The order used on the map includes the pairs, green–pale green and pale green–yellow, but only six children include these pairs in their orders while 19 and 17, respectively, placed these pairs in the reverse order.

Fifty children had colours from the *spectral pale* map. They gave 25 different orderings, but only one gave the order used on the map and no one gave the reverse order. The most popular order, chosen by 11 children, was white, yellow, orange, leaf green, sea green and pale lilac, and again this is the most popular order found by counting the colour most frequently placed in each position. This order is also popular if one considers pairs of colours placed together. Those chosen by 19 children or more were: white–yellow, yellow–orange, orange–leaf green, leaf green–sea green and sea green–pale lilac. The order used on the map includes the pairs sea green–leaf green and leaf green–yellow but only seven and five children, respectively, gave these while 27 and 13 gave them in the reverse order.

2.14. *Discussion*

Question 2 required judgements of relative height and these were performed better on the tonal maps than on the spectral maps. The *tonal dark hills* map is significantly better than the other three. Almost the opposite result was found with question 6 which required judgements of absolute height. Here the spectral maps were superior to the tonal maps.

Before seeing the maps, the children were asked to choose the best order of tints for showing height on a map. Some caution is needed in interpreting tasks of this kind done without the context of the map. With tonal tints most children chose an order where tints darkened with increasing height. There was much less consistency in ordering the spectral tints and very few gave the orders used on the spectral maps. This suggests that children do not perceive the spectral tints as forming a natural progression.

3. Experiment 2

3.1. *Introduction*

Experiment 2 was an attempt to strengthen the result found in the first experiment for question 2. It is possible that the decision made in question 1 could have biased the result of question 2. It is also possible that a different result would have been obtained if question 2 had occurred later in the test. These objections seem unlikely in view of the careful familiarization procedure. However, to be sure, in this second experiment these possible sources of bias were eliminated by giving question 2 twice and by removing question 1. Questions 4, 5 and 6 were also omitted.

3.2. *Method*

Thirty five boys and 26 girls aged 13 or 14 years were tested in three groups at a different comprehensive school from that used in experiment 1. All the atlases used in this school employed spectral layer tints. Children were randomly assigned to the four layer-tint conditions and each child used the same layer-tint scheme throughout the tests.

The procedure and material were similar to experiment 1 except that questions 1, 4, 5 and 6 were omitted and question 2 was repeated at the end of the test on a second set of maps. These second maps were identical in design to the first set but depicted a different area in the Middle East.

3.3. *Results*

The mean scores are shown in table 3. Analyses of variance showed statistically significant differences only on the two versions of question 2 (short lines) (first attempt, $F(3, 54) = 6{\cdot}0$, $p < 0{\cdot}01$; second attempt, $F(3, 56) = 3{\cdot}7$, $p < 0{\cdot}05$). In both, performance on the tonal maps was superior to that on the spectral maps.

Duncan's multiple range tests, adopting the $p < 0{\cdot}05$ level, in both cases showed a significant difference between the *tonal dark hills* map and the two spectral maps. With the first attempt at question 2 there is also a significant difference between *tonal light hills* and *spectral bright*.

Table 3. Mean scores for experiment 2.

Question number	Tonal dark hills	Tonal light hills	Spectral bright	Spectral pale
2 (first)	12·7	8·9	4·4	7·5**
3	2·7	2·7	1·7	2·7
7	4·1	3·1	2·6	3·0
2 (second)	14·7	12·5	10·3	9·8*

* $p < 0{\cdot}05$; ** $p < 0{\cdot}01$.

3.4. *Discussion*

The results of experiment 2 are in good agreement with experiment 1. The relative height judgements made in question 2 were performed better on the tonal maps than on the spectral maps. The best performance was on the *tonal dark hills* map.

4. General discussion

In these experiments spectral maps are better for absolute height judgements; tonal maps are better for relative height judgements. The optimum design depends on the use to which the map is put.

The maps in school atlases are used for many purposes but it is reasonable to suppose that some uses are more important than others. The judgement of whether one location is higher than another, or whether the land slopes uphill or downhill seems more important than finding the numerical value of a height. If this is correct tonal maps seem preferable to spectral maps for school atlases. Questions 1 and 2 of experiment 1 suggest that tonal maps should darken with increasing height.

The likely reason for poor relative height judgements on spectral maps is that the sequence of colours are not perceived as a natural progression and so the order is hard to guess or to remember. Without the context of the map only three out of 99 children could place the spectral colours in the correct order, although all had previous experience with similar spectral colour schemes from using school atlases. The orders chosen most often in question 1 seem to be influenced by the Munsell value of the tints. For the *spectral bright* maps the Spearman rank correlation between the value of the tints and the most frequently chosen order is 0·97. For the spectral pale maps it is 0·83. As with the *tonal* maps, the preference was for decreasing value (i.e. darkening) with increasing height. The ordering of colour codes according to the spectrum is appropriate for some applications (see, for example, Poulton 1975) but seems to offer no advantages for layer-tint maps.

The poor absolute height judgements on tonal maps are likely to be due to difficulties in discriminating the colours when they are matched to the height legend. Shaw (1972) compared contour maps and tonal-layer maps using a height estimation task. On maps with five height intervals the layer maps were superior to the contour maps, but when there were six height intervals the contour maps were superior. It is likely in this case that the crossover is due to the fact that it is easier to discriminate between five tint colours than between six.

The four types of layer tint used in this experiment are typical of the colour schemes used on maps throughout the world. But there are other ways of constructing sequences of layer tints. It may be possible to devise a scheme which avoids both the discriminability problems found with tonal maps and the ordering problems with spectral maps. Such a scheme would have to vary hue to make the tints sufficiently discriminable, but would not necessarily have to follow the normal order of colours in spectral maps. The results of question 1 suggest that the value of tints may be the most important factor in achieving an easily perceived progression of heights.

Some idea of the function of layer tints can be achieved by comparing contour maps with layer-tint maps. Layer tints are certainly important in removing much of the ambiguity about the direction of slope across contour lines, but they must have another function as well. Phillips (1979) has argued that if this were their sole purpose, then we would expect other graphical techniques which provide information about direction of slope to produce levels of map-reading performance which are comparable with layer-tint maps. However, Phillips has shown that two simple elaborations of contour-line maps which make it easier to discover the direction of slope do not appear to help map readers, although the addition of layer tints improves performance substantially on question involving judgements of relative height and visualization.

There are probably two important reasons why layer-tint maps are more successful at depicting relief than contour maps. The first is that with certain types of terrain, for example, chalk downs, it is not immediately obvious which side of a contour line represents the higher ground, but on a layer-tint map the direction can be seen more easily. The second reason may relate to the demands made on memory when reading a map. When good map readers are asked to study a small area of contour map they will have no difficulty in visualizing the depicted landscape. However, if the map is removed and they are asked to sketch the contours, the result is a very crude reproduction of the original, often including gross inaccuracies. A large area of relief is probably difficult to hold in memory, even for the short periods necessary to integrate relief information across different parts of the map. If we are looking at a particular location on a contour map, it is only in the immediately surrounding area that contour lines can be seen distinctly: other information must be held in memory. But on a layer-tint map it is possible to see a much larger area without moving one's eyes. In peripheral vision, areas of colour are much easier to discriminate than thin lines. It seems likely that this makes the integration of the shape of the landform much easier on a layer-tint map than on a contour map.

The manipulation of tint colours in experiments 1 and 2 appears to affect the first of these factors (direction of slope) more than the second (integration of relief) as differences were detected in relative height performance but not on any of the visualization questions.

5. Conclusions

These experiments compared spectral and tonal layer-tint maps for use in world atlases for secondary schools. The results suggest that spectral maps are better for the judgement of absolute height but tonal maps are better for the judgement of relative height. As relative height judgements are of greater importance in using school atlases, tonal colour schemes are recommended. The tones should be ordered so that they darken with increasing height.

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On a demandé à des écoliers anglais d'effectuer une tâche conventionnelle de lecture d'une carte géographique, afin d'évaluer les teintes à utiliser dans les atlas scolaires. Deux modèles de *couleurs spectrales* (reproduisant approximativement les couleurs du spectre) ont été comparés à deux modèles de *tonalités* (tonalité variable, teinte constante). Le jugement de l'altitude absolue a

été effectué avec plus de précision sur les cartes spectrales, mais les jugements de l'altitude relative étaient meilleurs sur les cartes tonales. D'autres questions relatives au fond de la carte et à la visualisation du relief n'ont pas mis en évidence des différences entre les cartes. L'inconvénient avec les modèles spectraux est qu'il est difficile de classer correctement les couleurs. Avec les modèles tonaux, par contre, la difficulté réside dans la discrimination des couleurs. Des innovations dans la conception pourraient cependant circonvenir ces problèmes, mais étant donné les choix pris en considération ici, il semble que la préférence pourrait aller aux cartes tonales, puisque les altitudes relatives sont plus importantes que les altitudes absolues pour les enfants qui utilisent les atlas.

Englische Schüler führten einige Kartenleseaufgaben durch, um Höhenfärbungen für den Gebrauch in Schulatlanten zu bewerten. Zwei spektrale Farbschemata (angenähert den Farben des Spektrums folgend) wurden mit zwei tonalen Schemata (variieren des Farbtons, konstante Farbe) verglichen. Die Beurteilungen der absoluten Höhe waren auf den spektralen Karten genauer, aber die Beurteilungen der relativen Höhe waren auf den tonalen Karten besser. Andere Fragen betreffend die Kartengrundfläche und die optische Darstellung des Reliefs zeigten keine typischen Unterschiede zwischen den Karten. Spektrale Schemata haben den Nachteil, daß es schwierig ist, die Farben richtig zu ordnen. Die Schwierigkeit bei tonalen Schemata besteht darin, daß Farben oft schwer zu unterscheiden sind. Eine neue Gestaltung kann diese beiden Schwierigkeiten überwinden, aber under den hier erörterten Alternativen sind die tonalen Karten vorzuziehen, da die relative Höhe für Kinder, die Atlanten benutzen, wichtiger ist als die absolute Höhe.

学校用地図帳に使用する地勢表現法を評価するため英国の10代の学校生徒にいくつかの典型的な読図作業を行なわせた。2つのスペクトル方式(虹の7色にほぼ準じた色を使用)と2つの明暗方式（色を一定にして明暗を変化させる）とを比較した。絶対的な高さの判断についてはスペクトル方式の方が正確で，相対的な高さの判断については明暗方式の方がすぐれていた。地図のベースと起伏の視覚化に関する問題については2つの方式の間にははっきりとした差はなかった。スペクトル方式には色を正確に定めるのが難しいという欠点がある。明暗方式の問題点は色の識別が困難になりがちな点である。もっと革新的な方式によって両方の問題を克服できようが，ここで扱った2方式のどちらを選ぶかと言えば，地図帳を用いる生徒にとって絶対的な高さの判断よりも相対的な高さの判断の方が重要であるので，明暗方式の方が好ましいと思われる。

References

AUDLEY, R. J., BICKMORE, D. P., and PHILLIPS, R. J., 1974, Legibility criteria for the efficient use of maps. Final Report to Social Science Research Council, HR2167.

AUDLEY, R. J., PHILLIPS, R. J., and NOYES, L., 1981, Legibility criteria for maps. Final Report to Social Science Research Council, HR2917/1.

HOPKIN, V. D., 1973, An experimental study of height layer tints in the Joint Operations Graphic map. RAF Institute of Aviation Medicine Report No. S108.

HOPKIN, V. D., and TAYLOR, R. M., 1979, Human factors in the design and evaluation of aviation maps. Neuilly-sur-Seine: NATO AGARDograph No. AG 225.

JENKS, G. F., and KNOS, D. S., 1961, The use of shading patterns in a graded series. *Annals of the Association of American Geographers*, **51**, 316–334.

KEMPF, R. P., and POOCK, G. K., 1969, Some effects of layer tinting on maps. *Perceptual and Motor Skills*, **29**, 279–281.

LAWRENCE, G. R. P., 1971, *Cartographic Methods* (London: METHUEN).

LLOYD MORGAN, C., 1900, On the relation of stimulus to sensation in visual impressions. *Psychological Review*, **7**, 217–233.

PATTON, J. C., and CRAWFORD, P. V., 1977, The perception of hypsometric colours. *Cartographic Journal*, **14**, 115–127.

PHILLIPS, R. J., 1979, An experiment with contour lines. *Cartographic Journal*, **16**, 72–76.

PHILLIPS, R. J., DELUCIA, A., and SKELTON, N., 1975, Some objective tests of the legibility of relief maps. *Cartographic Journal*, **12**, 39–46.

PHILLIPS, R. J., and NOYES, L., 1978, An objective comparison of relief maps produced with the SYMAP and SYMVU programs. *Bulletin of the Society of University Cartographers*, **12**, 12–35.

POTASH, L. M., FARRELL, J. P., and JEFFREY, T. A., 1978, A technique for assessing relief map legibility. *Cartographic Journal*, **15**, 28–35.

POULTON, E. C., 1975, Colours for sizes: a recommended ergonomic code. *Applied Ergonomics*, **6**, 231–235.

SHAW, M. A., 1972, Objective evaluation of graphic displays of information. Final Report to Social Science Research Council, HR 976.

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