User testing of colour for subordinate variables

Salla Multimäki

The aim of this study was to find the number of subordinate variables that can effectively show in one symbol. In this research we studied visualization of multi-variable information in the situation where some subordinate information was attached with the main variable in one symbol.

The test case

The focus was in the use of colour. In this case, the main variable was the data class of the symbol (i.e. "operation" or "actor unit" in crisis management) that was represented by the hue of the symbol colour.

In visualizing uncertainty or temporal dimensions of objects, some methods have been commonly considered in recent studies. On the basis of these studies (i.e. MacEachren & al. 2005, Olson & Brewer 1997), the following methods were chosen for testing (see Figure 1):

1. Colour saturation decreasing to visualize information uncertainty, which in this case means the confirmation of the information
2. Fuzziness of the symbol border line to visualize location uncertainty
3. Transparency of the symbol to visualize history
4. Dashed border line and striped colour of the symbol to visualize estimation in the future.

After the first user testing the visual variables were modified in order to enhance the visualization, and the test was repeated with a limited group of subjects. The modified design is explained later in this paper.

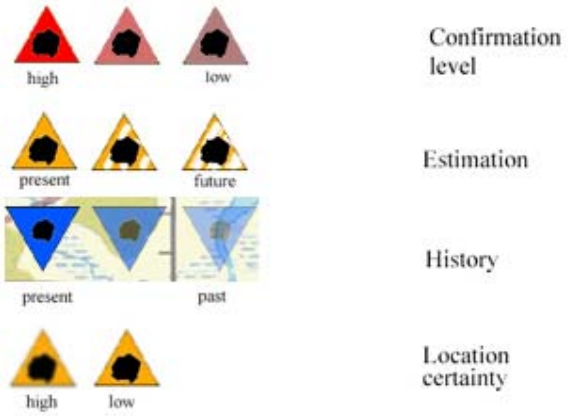

Figure 1. The visualization methods used in the first test.

The case in this study was the situation picture of international crisis management. In the situation picture, different types of objects occur in different locations, shown on a background map. These objects can be points, lines or polygons as spatial objects.

Users with colour impairment were taken into account: the goal was to find visualizations that are equally effective and easy to interpret to both, colour blind and those with normal colour vision.

In international crisis management the background maps of situation pictures may vary from case to case. This means that the colours of the symbols cannot be designed for any specific map only. In this test, the background map in the first user test was the NATO's V-map (scale 1:250.000) from western Africa area. In the second test the map was changed to 1:50.000 and 1:250.000 topographic maps from southern Finland. In both tests, a 40% transparent white film was overlaid on the map to lighten the colours of the original map.

Test setting

Altogether 19 test pictures were created, each with one, two, or three subordinate variables shown in the map (see table 1). All variables had three possible values, except location certainty (with only two values: certain and uncertain) and the area-type history variable. Because all area-type presentations must have some transparency since otherwise the background map would have disappear totally, only two values for area-type history (present and past) were used.

The first set of test pictures included maps with only one subordinate variable in each. In the maps of the second set there were symbols with two or three subordinate variable in different combinations (see Table 1).

Table 1. Variables used in the first user test. The number shows in which picture each variable existed (see also figure 3).

1st set

	point	line	polygon
confirmation level	W11	W15	W18
location uncertainty	W12		W19
history	W13	W16	
Future estimation	W14	W17	

2nd set

	point	line	polygon
confirmation level	W21,W24,W27,W29	W22,W25	W23,W26,W28,W210
location uncertainty	W21,W27,W29	W22	W23,W28,W210
history	W24,W27	W25	W26,W28
future estimation	W29		W210

The meaning of the symbol variables was explained verbally at the beginning of the test. Also, the legend (see figure 2) was visible all the time during the test.
The test method was simple: first the test user saw the simple question, such as "What feature is the oldest?". After reading a question, the test user clicked the button "Show map" and the test picture came visible. Once the test user clicked a feature on the map, he/she moved automatically to the next question. The first set of test pictures

with more simple maps were shown first, but within each of the two sets of test pictures, the pictures were shuffled into an occasional order.
On the last page of the test, background information about the test user was collected.

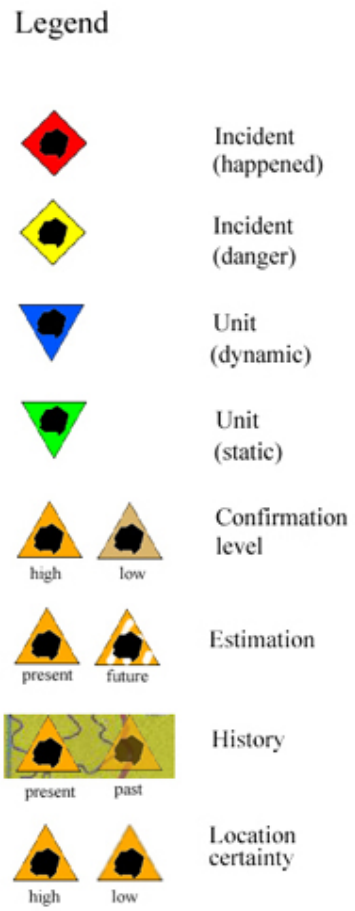

Figure 2. The legend of the first test.

Analysis

The data collected for every picture, each user's answer as the coordinates of the clicked point and the reaction time (the time the subject used after clicking "show map" button to answer the question) in milliseconds. In the analysis, the answers were sorted simply to "right" and "wrong" answers. In some cases, there were several possible right answers in the picture. These were all considered as right answers.
The percentage of right answers was calculated, first to each picture and then to each test subject. Also, an average of the reaction times was calculated correspondingly. Reaction times over 100 seconds were eliminated. It is likely that these subjects did not use all that time to answer the question.

The results of the first user test

The main hypothesis was that adding subordinate variables would decrease the number of right answers and also make the interpretation slower. It was also expected that colour impairment test users would have fewer right answers and longer reaction times.

We got the total of 61 subjects making the test during a two-week testing period. The age of the subjects varied between 25 and 62 years, and 12 % of them were female. About 1/3 of test users were military actors and the rest considered themselves as civilians. There were 9 different nationalities among the test users, the biggest groups being Finnish and American.

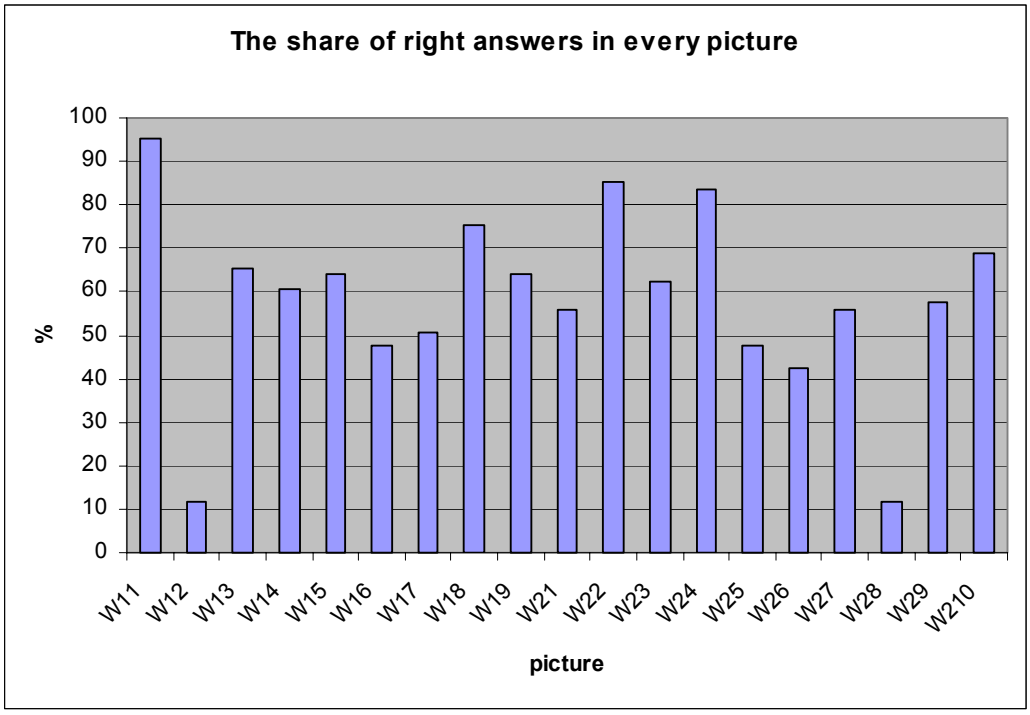

Figure 3. The proportion of right answers for each picture in the first user test. The first set of test pictures is marked with W1 and the second set by W2.

The proportion of right answers varied between 95 % and 11 % (see figure 3). The best results we got with the one-variable pictures, as expected. Reaction times got shorter when the number of subordinate variables increased. This contradicted with the expectation but a possible explanation is that answering one-variable picture questions first trained the subjects to interpret the more complex situation pictures.

The most complex test picture combined low confirmation, location uncertainty and history information in polygon-type objects (picture W28). Only seven test users could separate the right area (see figure 4). In general, line-type objects (pictures W15, W16 and W17) and pictures with history as one of several variables (pictures W25, W26 and W27) were interpreted poorly. Another picture with low percent of right answers (picture W12) had only one variable (location certainty), but the

visualization was implemented poorly: the fuzziness of the border line was drawn so that the difference between certain and uncertain information could not be distinguished.

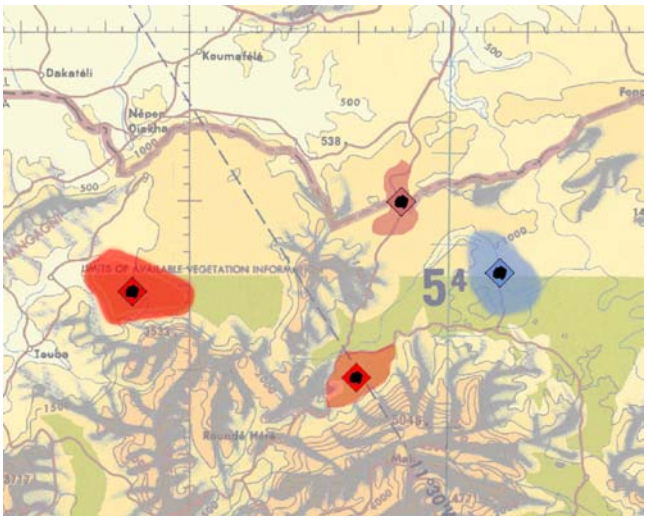

Figure 4. The most complex test picture from the first user test.

There were minor differences between those with normal colour vision and colour impairment, but the differences were not statistically significant in 5 % significance level. This shows that the chosen visualization methods are useful and effective regardless of the level of colour vision. Also, significant differences between the other user groups (i.e. military – civilian, American – European, male – female or the level of experience in using situation pictures) did not occur.

Further developed visualization and the second user test

Based on the results (showing the malfunction of transparency as a visualization for history), a new visualization for history was designed before the second user test. In the modified visualization, the border line of the point symbol changes from black to grey, and also the black pictogram inside the symbol turns to grey. When the situation evolves and the symbol goes further off, the grey contour line gets thicker. At the same time, the grey colour gets lighter to avoid the impression of heavier symbols.

The test pictures were designed so that some of them showed real situations in crisis management (created in an exercise with SHIFT) and others showed imaginary, illogical situations. The aim was to find out whether the subjects use their logics and previous experience in the interpretation of the symbols, or do they ground the interpretation only on the legend (see figure 5).

Figure 5. A logical situation picture (left) and an illogical situation (right). There are equal numbers of symbols and different variables in both pictures.

In the first test the symbols had draft frame shapes and colours, and a dummy pictogram was used. In this second test, the frames and pictograms designed and tested by Jari Korpi (see the document User testing of pictorial symbols) were used. The frames and colours used as the main variable in the test are shown in Figure 6.

At the beginning of the test, the subjects were asked which visualization method they would choose to present the confirmation of the information: lower saturation of the symbol colour or the grey border line and pictogram. The alternatives were also displayed. After this first question, instructions, verbal explanation of the used methods and the legend were shown.

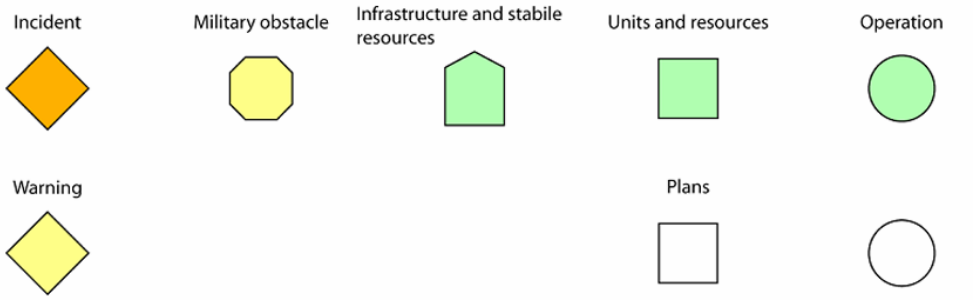

Figure 6. Symbol frames and colours used in the second test.

In total, 9 test pictures were designed. One test picture was shown twice, with different questions. The questions were of the same type as in previous test. All test pictures contained only point-type symbols, and different combinations of one, two, or three subordinate variables were displayed, again in the occasional order. Future estimation symbols did not occur in this test, and the fuzziness of the border line was drawn more carefully.

Table 2. Variables displayed in the test pictures in the second user test.

picture	Confirmation level	Location uncertainty	history
1	X		
2			X
3	X		X
4	X		X
5	X	X	
6	X	X	X
7	X		X
8		X	X
9	X	X	X

The results of the second user test

In total 19 subjects made the test. They were all Finnish males, age varying from 25 to 60 years. About half of them were military actors and half civilians, i.e. fire and rescue actors.

The subjects' opinion, in general, was that the combination of grey contour line and grey pictogram is a better way to visualize uncertainty: 12 subjects users chose that, when only 6 users preferred the saturation of the colour. (One subject did not answer to this question.) This result is interesting because it is at variance with some previous studies, in which lower colour saturation was suggested to visualize uncertainty.

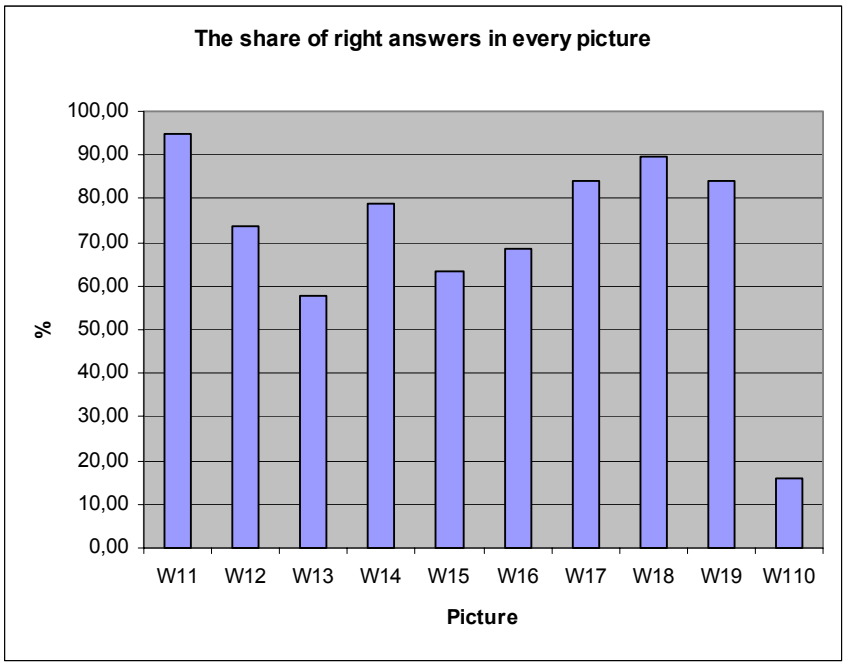

Figure 7. The proportion of right answers for each picture in the second user test.

In general, the results of this test were better than in the first test (see figure 7). Especially the pictures with history variable were understood better. The most remarkable discovery was that the picture with all three subordinate variables and an illogical situation (W110) was understood by only 16 % of the test users, while the same variables in the real situation (W16) was interpreted correctly by 68 % (see figure 3). This indicates that the test users use their former knowledge and experience when they answer the questions. This argument is also supported by the fact that none of the three users, who had the right answer on illogical situation, were military actors.

Based on this two-phase user testing, we can recommend the use of grey border line as a subordinate variable of the symbols in the SHIFT crisis management tool, whereas transparency of the symbol does not seem to work well.

Conclusions

This study, with a two-phase design and user testing to find out the most effective visualization methods for several subordinate variables showed some unexpected results. The fact that the test users' shorter reaction times correlated with right answers suggests that the interpretation of the symbols in a situation picture map is done quickly. The results also showed that adding several subordinate variables into one symbol decreases the percentage of right answers and weakens the interpretation. The influence is clear but yet smaller than we expected.

The other interesting result was the indication that the test users lean not only to the information that is clearly seen on the map but also to their former experience and knowledge about the possible situations. Already the design stage showed that the background map has a remarkable influence in the map interpretation. The colours and texture of the background had the strongest influence when the symbol colours were close to the map colours, or when one of the subordinate variables was visualized with the transparency of the colour.

This research clearly pointed out that users' needs, the use case, and the circumstances have such a big influence on map interpretation that they must always be taken into account in design of colours and other visual variables.

References

MacEachren, A.M. et al., 2005. Visualizing Geospatial Information Uncertainty: What We Know and What We Need to Know. *Cartography and Geographic Information Science*, 32(3):139-160.

Olson, J.M., Brewer, C.A., 1997. An Evaluation of Color Selections to Accommodate Map Users with Color Vision Impairments. *Annals of the Association of American Geographers*, 87(1): 103-134.