

The Effects of Cognitive Abilities and Geographic Orientation Ability on Navigation in Verbal and Graphical Interfaces

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Abstract: Users performance when seeking for information in two information spaces of different design was correlated with their cognitive abilities, and their geographic orientation ability. One of the information spaces had a visuo-graphical interface, and the other a verbal interface. The results showed that correlations with spatial abilities and with geographical abilities were found only for the visuo-spatial system. This suggests that so-called information navigation perhaps is less similar to navigation in geographic space than has previously been thought, and as a consequence that designers perhaps should consider developing more verbally based help tools or interface designs to support users with less strong spatial abilities.

Keywords: Navigation, Cognitive abilities, Hypermedia

1 Introduction

The task of seeking for information in large information spaces is often called 'navigation', suggesting that this is a task similar to navigating in geographic space. And just as is the case for geographic navigation, also for information navigation correlations have been found between performance on these kinds of tasks and the users' spatial cognitive abilities (e.g. Benyon & Murray, 1993; Dahlbäck, Höök & Sjölander 1996).

But it should be noted that in most, if not all, cases studied, the information space has had some spatial qualities to it. The question addressed in the study presented in this paper is whether the previously obtained results for a correlation between spatial ability and ability to navigate in hypermedia holds for all kinds of information spaces.

We can distinguish between at least three levels in describing an information space like a hypertext or hypermedia system: The *inherent structure* of the content domain, the *structure imposed* by the system designers, and finally the users' *cognitive map* of the domain. When analyzing the hypermedia systems, it is important to distinguish between different mappings between the inherent structure and the

presented structure, where at least the following three cases can be distinguished.

1. Information about geographic information, e.g. tourist information about the hotels at a summer resort. Here there exists a real spatial structure that can be used by the users for structuring the information, and furthermore some of the information is inherently spatial in nature, e.g. the distance from the hotel to the beach.

2. Information about domains which are not real physical spaces, but which have some commonly agreed upon internal structure. Examples of this would be biological classification systems or educational systems (which often are described in terms of 'higher' and 'lower' education etc.).

3. Information about domains that do not have any commonly agreed upon internal structure. Examples of this are classification of different kinds of musical styles or classifications of art.

To address the question of whether spatial ability is related to the ability to navigate in hypermedia system, in this study we compared users performance in two information spaces, one with a clear spatial structure, and one which was a close approximation of the third case mentioned above, i.e. a domain where there does not exist any real spatial structure,

nor any culturally shared visuo-spatial metaphoric structure.

2 Method

3.1 Participants

46 students (25 male, 21 female) were paid two movie tickets for their participation. Age ranged from 20 to 43 years (median 24).

3.2 Materials and procedure

The study was conducted in two steps. In five group sessions the participants' cognitive and geographic navigational abilities were tested. This session took approximately one and a half hour. In a second session, that took place between one day and two weeks later, the participants were first given the cognitive tests that had to be administered individually. Finally the participants were presented with the navigational tasks for the verbal and the graphical domains. Half of them first used the text based help program, and the other half begun with the graphical CD-ROM. The second session took between one and one and a half hour

Cognitive abilities

A set of tests of cognitive abilities from the Dureman-Sälde test battery (Psykologiförlaget, 1971) were used. This is a widely used Swedish standardized test of cognitive abilities. The following 8 tests were used.

- *Verbal ability* was tested by a synonym test
- *Logical-inductive ability* was tested by a image classification test
- *Perceptual analysis ability* through imitating drawings of complex patterns
- *Spatial ability* was tested with three different tests
 - *Rotation of images* which is similar to the well known Shepard & Metzler mental rotation task
 - *Hand identification* were rotated drawings of hands should be identified as left or right hand
 - *Blocks test* which is a Swedish version of the Kuh's blocks test
- *Gottschaldt* which is a test of perceptual analysis

The classification of the tests are taken from the manual's description of them (but c.f. the analysis of this below).

Geographic orientation ability

To measure geographic navigational ability, we used a revised version of a geographic orientation previously used by Gärling, Lindberg, & Mäntylä,

(1983). The participants were presented with the location of two well-known familiar places on the campus or in the city, and were then asked to indicate the location of a third place relative to these two. The dependent measure used was the distance from the given to the true position, since this combines both distance and angle information. Each participant received 5 such tasks.

Hypermedia systems used

Most studies on information navigation have used systems developed for the particular study, or at least with interfaces or navigation tools developed for the particular study. The advantage of this approach is that differences between users' performance can be attributed to the variables of interest in the study, and not to other confounding factors. But this approach has some important drawbacks too. First, there is a risk that the hypotheses of the researchers influence the design in a biased way. Second, the particular information contents may be more appropriate for one interface design than another. To avoid these drawbacks, in this study two publicly available information spaces were used.

The following requirements were set on the information spaces to be used. They should differ markedly on the spatial-verbal dimension. The information space should be conceptually familiar to the users, but the particular contents should be new to them. This because we did not want the users to know the answers beforehand, but on the other hand we wanted them to be familiar with the general concepts used for describing the domain. For the verbal domain we selected the help system for the FrameMaker word processor. All our users were familiar with word processors, and hence knew the basic concepts such as 'paragraph', 'font', etc, as well as which tasks that could be performed, but they did not know how to do this in this particular system. For the visuo-spatial hypermedia we used the graphical CD-ROM *Voyage to Egypt*, which contains information on ancient Egyptian history. We here assumed that the participants were familiar with general historical concepts like 'dynasty', and 'temple', but had little or no detailed knowledge of Egyptian history.

Voyage in Egypt (VE) is hierarchically structured in four levels. The nodes consist of text, photographs, music, auditive comments, animations, and video sequences. Two of the four views that can be reached from the first page, and which were used in this study, called 'Voyage' and 'History' have a similar design. In 'Voyage' the geography of the Nile area is described on two levels. In the top left

corner there is a small map of the area, and a section of this map is displayed in the main part of the window. A slider can be moved along the small map to change the selection of the area depicted in the main window. The 'History' view is similar in structure, with a time axis in a small map with a slider to select the part of the time axis to be displayed in the main window.

The FrameMaker (FM) help system has also a hierarchical hypertext structure, where the user can move between the levels by clicking on the words displayed. Some navigational support is given. When e.g. going down from the first to second level, the first remains in the window too.

Hypermedia tasks

For *Voyage in Egypt* the following tasks were used (translated from Swedish).

1. On which side of the Nile, east or west, is Beni Hassan?
2. Which bird is associated with the God Horus?
3. Which of the three dynasties, XVII dynasty, XX dynasty, or XXX dynasty had the longest period of reign?
4. How many 2 ½ ton blocks of stone were moved from Aswan to Giza to build the Cheop's pyramid?
5. There were two types of temples in ancient Egypt. Which were these?

For the *FrameMaker* help program the tasks were the following.

1. Which short cuts are used to show the next page in the document?
2. How do you create a two-column document?
3. How do you check the spelling of a word?
4. You have mis-spelled a word. It occurs many times in the document, and is not included in the program's dictionary. What is the simplest way to ensure that the word will be correctly spelled through the document?
5. How do you change the font in all headings from Times New Roman to Arial?

Dependent variable was the time taken to find the answer to the question. Time to report the answer was not included in this. For each task there was a maximum time; based on pilot studies this was 6 minutes (in one case 8 minutes).

3 Results and discussion

As has been the case in previous studies, there were large individual differences in task completion time. For FrameMaker the range was from 6.46 to 32 minutes, and for *Voyage in Egypt* it was 4.46 to

19.72 minutes. There was also a marked difference in the difficulty of the tasks in the two domains. In *Voyage to Egypt*, 35 of the 46 participants solved all the tasks, whereas only 5 did so for the FrameMaker help system. The difficult question was the fifth, which therefore was excluded from the analysis. The verbal ability test had a marked floor effect, which precluded its use in the analysis. The other cognitive abilities tests showed tendencies for ceiling effects, something which probably lowered the magnitude of the effects found on the relationship between the visuo-spatial tests and navigational performance, but not the general pattern.

3.3 Navigation and spatial cognition

After a factor analysis of the cognitive tests, three factors were identified, with high factor loadings for two tests each, showing a pattern similar to the one found for similar tests in the study by Dahlbäck, Höök and Sjölander (1996), with one set of tests for mental transformations, one for other spatial cognition and finally one which is more difficult to give a label to. The results of the six tests were therefore grouped in three sets, where a summary value was computed by adding the stanine scores from the tests' normalization data.

When we look at the correlations between the cognitive tests and the performance on the navigational tasks, the pattern is rather clear-cut. The only correlations are found with the mental transformation tests.

There are no significant correlations between performance in the verbal hypermedia (FM) and the mental rotation tests ($r = .0004$, n.s.).

In the visuo-spatial domain (VE) on the other hand, there are significant correlations with the tests of mental transformation ($r = .453$, $p < .005$), but not with the other spatial tests.

The result for the visuo-spatial domain is similar to the one found in Dahlbäck, Höök, Sjölander (1996), though somewhat smaller in magnitude, something which probably can be explained by the ceiling effects in the cognitive tests, and the set maximum time per task. Since the same pattern is obtained for these kinds of tests in two systems with a clear visuo-spatial interface, and with very different user groups (professional programmers versus students from mainly the faculty of arts and sciences), this gives both reason to believe that the data reflect some recurring pattern for these kinds of systems, and also suggest that the lack of such a pattern of correlation between the users' spatial ability and their navigation performance in the

verbally based system in this study points to some real differences in the cognitive requirements that the two kinds of systems put on the users.

3.4 Navigation in geographic and electronic space

In the visuo-spatial domain there was one task which differed from the other (#3 *Which of the three dynasties, XVII dynasty, XX dynasty, or XXX dynasty had the longest period of reign?*). The answer to this question could not be found in one place. Instead the user had to navigate the time axis to find the three dynasties and compare the values found. The users' tasks were here made more difficult by not only requiring of them to find the sought for values by navigating the information space using the navigation tool, but also at the same time memorizing the values found in the different locations in order to be able to compare them. It is therefore of some interest to perform a separate analysis of the correlations with the users' performance on this particular task.

The results on the orientation ability test showed large individual variations (56 to 268 millimeters, $M = 129$). The performance on this task did not show any correlation with the navigation in FM. There was, however, significant correlations with navigation in VE, both for all tasks ($r=.316$, $p<.05$) and with task #3 ($r=.401$, $p<.01$).

Since there are possible intercorrelations between the orientation ability task and the spatial ability tests used, these were entered into a stepwise (forward) multiple regression analysis with VE-navigation time as dependent variable. The only variable entering the equation for VE was image rotation ($R=.418$, $p<.001$). For subtask #3 both the image rotation and the Gottshaldt test of perceptual analysis enter the equation ($R=.636$, $p<.001$).

Taken together, these data suggest that so called information navigation, at least as measured here, from a cognitive point of view to a large extent is not quite as much a spatially loaded task (similar to geographic navigation) as has been previously thought.

If the information space is basically verbal and list-based, the two tasks seem completely independent of each other. And also in the case of visuo-spatial information spaces the correlations are not strong and, furthermore, seem to be dependent on a common underlying visuo-spatial factor.

3.5 Any conclusions from this?

One should of course be careful in drawing long reaching conclusions from just one single study, but to us the results presented here at least suggest the hypothesis that the task of searching for information in large information spaces perhaps not always should be seen as an activity similar to navigation in geographic space. And this in turn suggests that other means than map like tools for supporting users in these tasks could be considered. In their review of work on individual differences in cognitive styles (as distinct from the cognitive abilities considered in this study), Riding and Ranyer (1998) claim that they find two major dimensions, where the one concerning preferences for presenting or representing information is the visual-verbal one. And this at least to us suggests that a fruitful complement to today's map-like tools primarily supporting users with strong visuo-spatial abilities should be complemented with verbally based tools, or verbally based interface designs, for users who prefer such information presentation styles.

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