Navigation and Learning

A Cognitive Analysis of User Tasks in Electronic Information Spaces

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ABSTRACT
Information navigation and use in an electronic information space was studied in an experiment that considered the relationships between individual differences in cognitive abilities and learning styles. It was shown that users with different basic cognitive and learning styles have different types of problems when searching for and using information in a large electronic information space. One subgroup of users have difficulties with the ‘pure’ navigation task, but perform well on acquiring and making use of the information once it has been found, while another sub-group perform well on the navigation as such, but has difficulties in the finding and structuring of detailed pieces of information. The results suggest that the distinction between navigation and information tasks is important, and that different design solutions for supporting the low performing users are probably required.

Keywords
Navigation, information space, cognitive abilities, learning style, user studies

1 INTRODUCTION
The navigation metaphor has received widespread support from the HCI community. But while the term is commonly used its meaning and the consequences of viewing human-computer interaction from this perspective are not uniform. The CHI’97 workshop on Navigation in Electronic Worlds was described as follows by Jul and Furnas (1997) in their summary “no definitive solutions were reached, [but] much of the problem space was laid out.” The views on the usefulness of the navigation approach have in fact a very wide range. Benyon (1998, p 35) argues that “Navigation in Information Space’ is not (just) a metaphor, it is a paradigm shift. (...) [it] is a new paradigm for thinking about HCI, just as Direct Manipulation was a new paradigm in the 1980s.” On the other hand, Dillon and Vaughan (1997) claim that “navigation is a limited metaphor for hypermedia and website use that potentially constrains our understanding of human-computer interaction” (p 91). The many different possible positions are well illustrated by the position papers from the above-mentioned workshop.

Even if one accepts the basic assumption behind the navigation metaphor, e.g. as formulated by Kim and Hirtle (1995): “One approach to the problem, which we have found beneficial, is to compare navigation in the physical world with navigation in electronic worlds”, the user is not only navigating, but navigating the information space in order to complete some other task. Kim and Hirtle (ibid.) make an important distinction between
The primary task which the navigation supports. Is it possible to simultaneously work on the navigation and cognitive overhead (Conklin, 1987) is too large to make it possible to simultaneously work on the navigation and the primary task which the navigation supports.

In our view, it is important to distinguish between these two cases, since the remedies for the problems identified in all likelihood will be different; in one case the user will need navigation support in the form of maps or more easily navigated designs, in the other we probably instead should develop software that will support for instance the collection and integration of the different pieces of information found. All user problems are not navigation problems.

But can we distinguish between tasks that are different because of navigation problems, and tasks that are difficult for other reasons? We believe that the answer is ‘yes’, and that one possible way of doing this is to clarify which underlying cognitive abilities that are most critical in the fulfillment of the tasks.

It has previously been shown (e.g. Dahlbäck, Höök, Sjölinder, 1996) that the spatial ability that is required to navigate information spaces with a graphical or map like interface is subject to large variation. In the same study it was also shown that these differences in mental rotation ability (but not other spatial or other cognitive tasks) show a large correlation with the performance in navigation tasks. Gustavsson (1998) took this work one step further, by having users seek for information in two systems; one with an hierarchical text based interface (similar to a table of contents in a ordinary book), and one with a graphical user interface. It was shown here that task performance correlated only with spatial ability in the graphical interface, but not in the text based. A closer item based analysis indicated that a high spatial ability was particularly important when the user’s task was to search for and compare pieces of information found at different places in the system.

We stated above that all the user does is not navigation in the strict sense of the word. Once the information is found it is used for something. Two of the more or less generic tasks possible to identify here are; to learn something, and to solve a problem of some kind. A possible corollary of this is that for these tasks other cognitive abilities are more important than spatial abilities like e.g. mental rotation.

The aim of the present study is to investigate whether we can identify the different tasks that the users are involved in, or rather that are the most difficult aspect of a particular task, by studying which basic cognitive abilities that lie behind successful performance. In addition to different spatial abilities, we are interested in reasoning ability, and in styles of learning.

There are many different classifications of reasoning tasks and abilities (Carrol, 1993). We have here focused on the factor called Sequential Reasoning (RG) by Carrol; which is concerned with “the ability to reason and draw conclusions from given conditions or premises, often in a series of two or more sequential steps. The stimulus or test material can be of almost any type – literal, verbal (semantic), numerical, pictorial, or figural” (ibid, p 234).

When it comes to learning styles, Pask (1976) makes a distinction between a local and global approach to learning a complex material. The holist learners try first to build a global view of the domain, trying to consider many aspects simultaneously. In the early phases the holist focuses on information high in the hierarchical structure, and uses a top-down approach. Pask (ibid.) claims that the holist’s problem is lack of focus and ‘globetrotting’.

In contrast to the holist, the serialist focuses initially on details before trying to arrive to a global picture. The learning is a bottom-up process, where learning takes place in small steps. The difficulties that Pask has identified for the serialist are a tendency to ignore important connections, and a lack of foresight.

Pask (1984) also describes a flexible learning style. This is a person that can use both holist and serialist approaches depending on which is the more appropriate at a particular moment.

In choosing a material for the hypermedia navigation task we had the following requirements. We wanted a domain where our participants did not have much knowledge, but which they hopefully would find interesting to learn more about. Another requirement was that it should not be a domain with a large and complicated technical vocabulary, since this presumably would create a large initial threshold for the users. After a number of pilot trials, we set on the history of western philosophy as the chosen domain.

2 METHOD

2.1 Participants

21 participants volunteered for the study. 13 of the participants were first-year students at the Linköping Uni-
versity in Sweden and eight were recruited individually by the authors. Median age 26 years (range 19 to 44 years). 11 participants were female and 10 were male. All participants were at an undergraduate level of education. The participants were paid two cinema tickets at the conclusion of the study.

2.2 Materials and procedure

The study was concluded in two steps. Initially the participant’s cognitive and spatial abilities were tested. This session was administered in groups and took approximately 40 minutes. In a second session, which had to be administered individually, the participants were presented with the hypermedia navigation tasks. The second session took between 22 and 39 minutes.

2.3 Cognitive and spatial abilities

We used a battery consisting of two spatial ability tests, one test for 'logic reasoning' and one for spatial-logic reasoning. The tests used were the following:

- Plåtmodeller (paper folding) (Psykologiförlaget 1976) measures spatial visualization. The participant is to identify which ready-folded model a drawing of an unfolded model can turn into. This test is similar but not identical to paper folding tests.

- Mentala rotationer (mental rotation) (Psykologiförlaget, 1978) measures the ability of mental rotation. The test is a paper-and-pencil test where the participant is to identify two three-dimensional objects that have been rotated in comparison to an original model. (The test is a version of the Shepard and Metzler (1971) mental rotation task.)

- GRE, Graduate Record Examination Test. The parts used are divided into two different areas. They both measure logic reasoning but one part, called GRE (i), measure a more spatially loaded logic reasoning i.e. the questions are of a nature where a spatial organization of the known data considerably support the participants possibilities for success. The other part, called GRE (j) is more within the realm of classic logic reasoning. The test was given in a shortened form to keep the total time spent at a reasonable level.

- Planlösning (plan solving) (Psykologiförlaget, 1975) measures a spatial-logic reasoning ability. The participant is given the task of dividing a matrix of squares into a certain pattern given rules on how the squares may and may not be connected.

2.4 Learning Style Questionnaire

We used the ‘Study Preference Questionnaire’, developed by Ford (1985) to assess preferences for one or other sequence of learning approaches. Global description building (holist) before local procedure building (serialist), or vice versa. A number of items are included relating to students’ reading and information-seeking activities which might be sensitive to any wider manifestation of holist or serialist preferences also in navigation in hypermedia.

2.5 Navigation task

The hypermedia navigation task was conducted using the interactive CD-ROM ‘Sophie’s World’ (Norstedts Multimedia), which contains information about western philosophy. The contents of the hypermedia should in detail be new to the participants. We here assumed that the participants would be familiar with general philosophical history and concepts, but not knowledgeable on details thus being ‘forced’ to use the hypermedia to give the correct answers to the questions.

‘Sophie’s World’ is hierarchically structured in three levels. The nodes consist of text, pictures, animations and video sequences. The participant initially sees a timeline where the different philosophers are grouped in their respective school and time. The timeline is scrollable back and forth. Each philosopher’s name is a hyperlink through which the participant can reach the next node containing overview information about the philosopher. From that level there is another hyperlink through which the participant is led to a more detailed, deeper level of information. This level in turn contains links to other philosophers, schools etceteras. From here the user can go up to the time-line at the top-level again. In summary, there are three different levels, and the top level is an overview map.

The participants were given different tasks, which demanded that they navigate the hypermedia to find the appropriate information to be able to answer the questions. We devised a set of tasks which we tried to make as varied as possible. In some cases we wanted the focus to be on navigation i.e. quickly and easily answered questions where the answer could be found just looking at one specific point in the hypermedia. (e.g. “Which school of philosophy did Plotinos (205-270 AD) belong to?”). For other tasks the emphasis was on information and coordination, where the user had to visit several nodes in the hypermedia and coordinate and compare the information given to be able to give the correct answer (“Was Socrates Plato’s pupil or teacher?”).
3 RESULTS

To make certain that the cognitive tests used in the study were measuring independent abilities, we first checked for correlations between them. The only significant correlations were found between the two tests initially classified as spatial, something which confirmed that the tests measured independent abilities.

In a second phase we correlated each task with the different cognitive tests. The results are presented in table 1. It can there be seen that only a few tasks show correlation with more than one cognitive test. For the learning style test we excluded the middle, flexible, group, and only included the most extreme serialists and holists. The reason for this was that the flexible participants can shift between the two learning styles, and would hence probably dilute patterns of dependence with ‘pure’ serialist or holist ability.

In the final step, we analyzed what was common between the different tasks that correlated with the same single cognitive test. Space does not permit a detailed analysis here (see Lönnqvist, forth., for more details on this). We will here only present prototypical examples of the different categories. For the GRE (i) and (j) tests no unique tasks were identified.

3.1 Navigation tasks

Task #9 is characteristic of the ones that show a correlation with mental rotation ability; When Charles Darwin boarded the ship Beagle, he brought a book by the British biologist Sir Charles Lyell. What was the title of that book?

What seems to characterize these tasks is that the user is required to search for one piece of information, and that this information is easily found once the place where it is has been reached. These are in a sense the most pure navigation tasks.

Similar to the previous tasks are the ones that show a correlation with Pålmodeller (paper folding), but here the user is required to compare two facts. An example is #12 One of the earlier found philosophers speaks of ‘impressions and ideas’, who? But in both cases these tasks are primarily about navigating and finding easily identified facts in the information space.

3.2 Using relations between nodes

A typical case here is #15. He who died from cancer also occurs in ‘The Philosophy of the Mind’ where there is a ‘Related Philosopher’ that used a particular method. What was that method? What seems to characterize these tasks is that not only information in a particular node is required to solve them, but also the user needs to identify and make use of the type of relations that exist between the nodes, to arrive to the correct answer. These tasks differ from the previous ones in that they do not seem to require a high spatial ability for successful performance. Instead some kind of reasoning ability is helpful in solving the task.

3.3 Detailed reading/learning

This is a set of tasks, all of which require very little navigation to find the answer and solve the task. An example is #2 Was Socrates Plato’s pupil or teacher? The difficulty here lies in the fact that the particular information sought for is embedded in longer stretches of text; it can therefore not be found at a glance once the correct node is found. It is interesting to note that these tasks show a correlation with Pask’s serialist learning style, which is characterized by a high ability to work with low level details, but which has difficulties with finding important connections between different pieces of information. Analysis of Variance (ANOVA) show that for question 2 (F(2,18) 10.501, p<.001) serialists perform significantly better than holists. This is also shown in question 8 (F(2,18) 4.788, p<.05). For the other questions there are obvious differences between the different groups, but as they show a results not statistically significant they are excluded from this paper (See further Lönnqvist, forth.).
3.4 Complex tasks

There are also among our tasks some that clearly are complex, and which require both a high ability to navigate, and a high ability to sort through large sets of information, for successful performance. This is true both for #11. In ‘Language Philosophy’ we can see three anti-metaphysicists, which three?, and #16. In the same circle on the philosophy map as this [earlier found] user of a particular method there are two other philosophers. One of them was offered a professorship at the University in Heidelberg, but declined. Who was that?

4 EMERGING PATTERNS

When we shift from a low-level description of the results to a birds-eye view of our results, an interesting pattern of learning styles and cognitive abilities seems to emerge. A pattern that might be taken as support for the hypotheses on learning styles described in the introduction.

4.1 The serialist pattern

On the cognitive tests, the serialist is good at ‘Planlösning’ (plan solving), a test that requires careful detailed control of the information, and comparison and integration of data, but performs significantly worse than the other groups on 3D mental rotation tests. The serialist is good at searching for information on the deeper levels, and to take in and compare these to other data. The serialist’s navigation is not fast, but s/he is good at making use of the information sought, once it is found. S/he performs best on tasks that requires a careful reading of the information on different places in the deepest layers where the most information rich texts are found. The serialist has considerably more problems when required to quickly acquire an overview of the information space. In summary; the serialist is good at processing the information but has problems with the navigation.

4.2 The holist pattern

The holist is good at three-dimensional mental rotation tests. S/he is good at quickly acquiring an overview of the information space, and is good at navigating and moving between the different nodes in the space. The serialist performs best on tasks where the information is quickly found, but has problems in tasks of the type that requires a careful reading of the information. The holist has not only problems with reading and processing the deeper and richer text structure, but also to integrate information from different places in the information space. In summary, the holist is good at navigating, but has problems with the information work.

4.3 The flexible pattern

Since the flexible can shift strategies, s/he belongs to both the groups on the navigation loaded tasks and the information work loaded tasks. In the study the flexible group ends up in between the other two considering performance in the navigation tasks. Sometimes they outperform both the serialist and holist groups and sometimes they end up with the lowest score. This might be a result of difficulties in putting the shift of strategy into work at appropriate times. Most of the time they end up close to the most successful group, either serialist or holist, both in the cognitive tasks and in the navigation tasks, which signifies that there in fact is a flexible strategy. Pask (1985) concludes that the flexible are not a homogenous group but rather one consisting of people with knowledge about the two strategies and biases towards either one of them.

4.4 Concluding remarks

People that have difficulties with mental rotation tasks have problems with navigation in electronic information spaces. But once they have found nodes, they are good at acquiring the information presented there, and making use of it. On the other hand people that are good at mental rotation and similar cognitive tasks are good at finding their way around in information spaces, but have difficulties in finding and integrating detailed information. While both groups have difficulties at times when searching for and making use of information in electronic spaces, it seems clear that their difficulties are not in all cases difficulties in navigation in the strict sense of the word.

5 DISCUSSION

Since the study here only concerns one specific information space, and since it also is concerned with only a small set of tasks, it is of course wise to be careful in generalizing the obtained results. But with this caveat in mind, we still consider the approach taken and the results presented as promising. Through the approach taken we have been able to empirically support our initial hypothesis that navigation is a limited metaphor for explaining users’ difficulties in large information spaces. It is by no means wrong, far from it. But there are also other problems for users. The importance of this is that we now can begin to understand which other tasks that need to be catered for in the design of large hypermedia systems, if they are to be useful for all, regardless of their different cognitive abilities, and regardless of the different needs or tasks that they bring to the space. By being able to find connections between the different task types and different basic cognitive abilities, we can also have some first suggestions for which basic kinds of
support that are needed. It is for instance difficult to see how a better map could help users that have difficulties in finding detailed information in large texts or tables. Here instead a different design or a possibility to search for or ask in a natural language dialogue for this information would suggest itself as a better alternative. But whether this will help users that have difficulties in seeing relations between different nodes is not clear.

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REFERENCES


APPENDIX

Navigation Task Questions
1. Which school of philosophy did Plotinos (205-270 AD) belong to?
2. Was Socrates Plato’s pupil or teacher?
3. Where was Aristotle born?
4. What is the ‘line of thought’ Immanuel Kant belongs to called?
5. Which of whom, Socrates or Plato, lived the longest life?
6. What year was Sigmund Freud’s *Traumdeutung* first published?
7. Who founded the cynic school of philosophy?
8. Which philosopher comes first in the circle ‘The French Enlightenment’?
9. When Charles Darwin boarded the ship Beagle, he brought a book by the British biologist Sir Charles Lyell. What was the title of that book?
10. In ‘The Philosophy of the Mind’ there are two links to ‘Related Philosophers’. These, in turn, have links to one particular philosopher, who?
11. In ‘Language Philosophy’ we can see three anti-metaphysicists, which three?
12. One of these philosophers speaks of ‘impressions and ideas’, who?
13. One of these philosophers died of cancer, who?
14. The one of these philosophers who lived the longest, where was he born?
15. He who died of cancer also occurs in ‘The Philosophy of the Mind’ where there is a ‘Related Philosopher’ that used a particular method. What was that method?
16. In the same circle on the philosophy map as this user of a particular method there are two other philosophers. One of them was offered a professorship at the University in Heidelberg, but declined. Who was that?
17. The latest living of the three earlier mentioned anti-metaphysicists, was he a rationalist or an empirist?