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Recker, M.M. (1994). *A methodology for analyzing students' interactions within educational hypertext.* (ERIC Document Reproduction Service No. ED 388 288)

Schwier, R., & Misanchuk, E.R. (1990, June). *Analytical tools and research issues for interactive media.* Paper presented at the Annual Meeting of the Association for Media and Technology in Education in Canada, St. John's, Newfoundland.

Schwier, R.A., & Misanchuk, E.R. (1993). *Interactive multimedia instruction.* Englewood Cliffs, NJ: Educational Technology Publications.

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Understanding Navigation and Disorientation in Hypermedia Learning Environments

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Difficulties with orientation are common in hyperdocuments. This paper describes an exploratory study into the role of a navigation map, as a helping tool, during browsing processes. We tried to establish the influence of this navigational tool, provided by a hypermedia prototype, in retrieval tasks. Twenty-two students tested this prototype and some data were collected: scores obtained in a task-test and a record of the path followed by the subjects. With these data we defined a set of ratios as an attempt to understand the subjects' browsing processes. Findings suggest that the map was not effective in the ameliorative role. Perhaps it is not wise to assume that a map that helps performance in a spatial context also forms an aid in a hypermedia environment under a nonhierarchical model.

Hypermedia environments are complex systems based in a nonlinear organization of the information (under multiple formats: text, image, sound). This conceptual assumption introduces new problems such as the hypertext design and the navigation performance in the system. Our present concern is the navigation process that results from the explosive ability of the system to develop complex networks of information. This situation has some direct implications in the user interaction with the systems, such as cognitive overhead and disorientation (Conklin, 1987).

We assume that hypertext systems are quite different from the textual ones, and the mental representation of the information system should be different from the sequential process embodied by printing techniques. Even when the expert reader of a printing text uses a nonsequential strategy of reading, there is a static reference of the book and the graphic layout of the textual interface, the page, the paragraph, and the word. These are permanent and fixed textual objects with which the reader interacts.

In a hypertext environment this reference is dynamic, and probably the user will need to deal with a virtual reference model. This model stresses the complexity of the user-centered hypertext nodal network of information. It also suggests that the mental representation of the information system developed by the user to accomplish his or her navigation process, should be dependent on the new environment hypermedia factors as information access cues and path complexity. The design of information access cues (specific information task tools) and path complexity (strategies of management and navigation) is essential to overcome the network complexity in the dynamic hypertext system. However the performance of multiple tasks leads to a high cognitive load upon the user. The lack of a set of narrative cues in hypertext systems, as they are presented in traditional paper-based media (organization in chapters and sections, typographical conventions, etc.), stresses the *cognitive overhead* problem because it constrains the user to make decisions about what to read next without the aid of established discoursive conventions (Kim & Hirtle, 1995). Thus, the interaction flexibility allowed by the multimodal information system drives the subjects to make metadecisions, evolving metacognitive processes of control and monitoring (Jones, Farquhar, & Surry, 1995).

Nonlinear environments lead to an active involvement of the learner over the system information, stressing the difference between computer-driven and user-driven learning. The prestructured system in a computer-driven environment is less cognitively demanding in strategy selection of searching and browsing activities than that in a user-driven environment. Nevertheless, the computer-driven design provides little understanding of the cognitive, individual differences related to the user's performance.

In a hypermedia environment individual, perceived control of the system increases subjects' engagement and promotes a user-driven process of interaction and navigation in the nodal network. The nonlinearity of hypertext defines a space with several path solutions, among the links of the network, that are selected and experienced by the user through a goal-oriented task process. Thus, navigation in the nodal network is a sort of experience of the field domain, and the pattern of the user's behaviour is a

representation of the user's understanding of the contents organization. However, increasing the level of complexity evidences a conflict between content integration and navigational decisions related to content survey, that leads to disorientation problems for the user.

Disorientation is another problem emerging from hypermedia environments that has been frequently reported (Conklin, 1987; Edwards & Hardman, 1989; Hammond & Allinson, 1989; Gygi, 1990) as a result of a user's behaviour in highly complex hypermedia environments. The design of these systems has been the object of particular developments and several approaches, to help users avoid disorientation problems while browsing hypermedia systems. The establishment of conventions as metaphors and the design of browsing tools as maps are some of them.

Identified as "being lost in hyperspace" (Edwards & Hardman, 1989), disorientation is the main concern of the present study: how and what tools should be used to aid navigation through the system; how users deal with reference tools, as maps. Feeling lost, not knowing where we are, and having difficulties to select the next node of information to visit are some features of this problem.

Edwards and Hardman (1989) identified three distinct situations when the users feel lost: (a) not knowing where to go next, (b) knowing where to go but not knowing how to get there, and (c) not knowing the current position relative to the overall hypermedia structure. Foss (1989) describes two undesirable consequences of browsing observed in users of hypermedia systems: (a) *The embedded digression problem* occurs when users pursue multiple paths and digressions that could lead them to lose their place, to forget the return from digressions, or to neglect important paths related to the main task because of their constant distraction; (b) *the art museum phenomenon* is similar to what happens after spending a day visiting an art museum without giving any special attention to a particular painting or style. At the end of the day we probably would not be able to describe to someone what we have seen.

The assumption of the hypertext as a virtual space performed by a universe of texts, images, and sounds guides the general tendency to assume hypertext design is based in human spatial processing and navigation theoretical perspectives. This is a reference frame for the development of the metaphors of the real world to the interface design and to the specific browsing tools, as maps or guided tours. The analogy between navigation in physical environments and information ones was proposed by Canter, Rivers, and Storrs (1985) who emphasize the analogy of the psychological processes involved in both domains. They recognized that it is fruitful to

establish a direct parallel "between navigating concrete environments, such as cities or buildings, and navigating data. After all, such parallels are implicit in the navigation metaphor, so it is worth establishing whether or not there is a fruitful analogy between the psychological processes involved" (p. 93). Thus, users should develop a spatial cognitive representation of the information environment.

Edwards and Hardman (1989) defined as good navigation skills the (a) ability to generate specific routes as task demands require, (b) ability to traverse or generate new routes as skillfully as familiar ones, and (c) orientation ability (i.e., developing a concept of "here" in relation to other places). This last item reveals the need of users to create a comprehensive cognitive spatial map of the system structure to orient themselves. These authors suggested that the representation provided by navigational tools (such as maps, indexes, and guides) should be similar to the cognitive representation formed by the users. Cognitive mapping seems to be a process developed by the user to overcome the uncomfortable feeling of being lost.

Cognitive maps are mental representations of external spatial relations used to navigate in physical spaces. In the spatial approach, hypertext systems have a virtual topology, and the human spatial knowledge processing (place, route and survey knowledge) is a reference to understanding and modelling individual performance in the network. Navigation within a physical environment leads us to the definition of spatial relations between places that includes the knowledge of route and the survey knowledge: directions and distances between prominent places (Kim & Hirtle, 1995). However, Stanton, Taylor, and Tweedie (1992) suggest that a cognitive map "does indicate that there is some long-term semantic memory representation of the environment, but that is more like a network map than a survey map" (p. 432), and stress the relationship between the formation of a cognitive map, under the spatial map reference, and an efficient navigation through hypermedia environments.

Conceived as spatial metaphors of the information network, spatial maps could be cognitive aids to improve the cognitive mapping of the hypertext structure and reduce users' disorientation. This research examines specially the role performed by navigational aids as an approach to reduce disorientation and analyzes a particular tool: a navigation map. Nielsen (1990) argued that the use of the tourist metaphor (embodied by a map) tries to provide some of the same orientation assistance to hypermedia users as the one given to tourists.

Several researchers have investigated the effects of map interfaces on learners' disorientation in hypermedia environments. Billingsley (1982) reported the use of a map in a hierarchical system to seek information. Billingsley's work demonstrated that previewing a map can facilitate this task more effectively than an index or no assistance at all.

Hitch, Sutcliffe, Bowers, and Eccles (1986) investigated the use of a menu and map interfaces to retrieve information from a hierarchically organized geographical database. Findings suggested that maps are supportive for naive users and permit the use of more efficient, rapid modes of operation for experts.

Stanton, Taylor, and Tweedie (1992) conducted a study to determine if maps were an effective navigation aid for browsing in a nonhierarchical hypermedia domain. They used two groups of subjects: one with access to the map and another without access to the map. The results showed that task performance was poorer in the presence of the map than in a "no-map" condition.

Beasley and Waugh (1995) developed a study whose purpose was to assess the relative effects of hotwords and two distinct cognitive mapping architectures (spider maps and hierarchical maps) on learner disorientation in a hierarchically organized hypermedia environment. The results of this research suggested that the presence of a properly constructed cognitive map can diminish disorientation in the learner. Our hypothesis is that the presence of a navigation map (as an overview of the content organization) in a nonhierarchical hyperdocument should be appropriate to improve navigation during the learning process in a hypermedia environment.

METHOD AND PROCEDURE

A total of 22 students participated in this study. They were high schools students enrolled in the geology class; the 15 females and 7 males were between the ages of 17 and 21. In order for the present study to be undertaken, a hypermedia prototype concerning the theory of tectonic plates (a global theory of geology) was developed. The hypermedia structure to organize the information in the prototype was the web model proposed by Brockmann, Horton, and Brock (1989): "anything can be linked to anything else; associations are not bound to strict rules" (p. 184), as for example, in the hierarchical structure. Nevertheless, the designer must preset some paths to lead the user through the "jungle of information." This particular model of organization can be potentially confusing and unpredictable as it is suggested by the same authors, but that was assumed as a condition in this exploratory study. Therefore we think that a hypermedia system

must be conceived more like a network of nodes and links than simply a hierarchical information system in spite of all the risks that it involves.

Information (text and images) is presented in nodes pages, and the users can have access to several tools from any screen page by clicking on icons, as a notecard for individual comments, animation and, in a high level of the interaction, the navigation tools. Users can go from one area to another by using on-screen movements commands (e.g., forward, backward, back) or use a "map" icon that informs the user that a map is available for orientation. In this study the focus was on a specific tool: the navigation map. We describe the map as a content index with the representation of the path followed by the student and the stages remaining. With the map we provide a global overview of the network, but we exempted the representation of the multiple links among screen pages because it tends to be space-intensive and consuming. From the tool map the student could have access to any screen page.

The research design also included a task-test to gather data from the instructional session with the hypermedia prototype organized in 12 task-questions that students should answer during the work session. Its goal was to lead students to search for requested information and then to write it down. Each task presented would imply that students were able to find the right pathway into the hypermedia network to get the information requested. The task given had the role of a stimulus to make active the users' information-seeking process. To accomplish the task students should develop an oriented browsing style based on the map tool or another strategy such as the main menu.

We intended to explore the relationships between students' performance in searching information in a nonlinear database and the use of the navigation map presented by the prototype. This research included two different moments: a drill and practice session with a special prototype made for it, and a major session with the application described above. During the first session (that we designate as the short session) participants became familiar with the hypermedia environment and received a brief explanation of the researchers' purposes. During the second session students had a maximum of 45 minutes (time of a regular class) for participating in the study. They worked through the hypermedia prototype at an individual computer. Necessary instructions were given in the beginning of the session concerning the main aspects of the prototype interface and the aims of the task-test.

The prototype included a general function of identification of the user that generates a permanent file of each student's use of it. This program

recorded the path followed by each student during the session time with the hypermedia application. The data recorded included

- code, sex, age, and frequency of computer use of each student;
- name of the visited screen page;
- the objects clicked in each screen page that were important to solve the task-test;
- time spent in each screen page (seconds); and
- frequency of visit to each screen page.

DATA ANALYSIS

This is an exploratory study that examines the relationship among variables through the use of specific research tools to evaluate users' performance. The data analysis was based in the score obtained in the task-test, time spent in each screen page visited, frequency of visits to each information node, frequency of visit to the map, and time spent in the navigation map. Students could obtain a score in the task-test ranging from 0 (any question was correct) to 100 (all questions were correct).

The remaining data were gathered in a traversal path record that took the form of a list of nodes selected by the student. Each student traversal path list could be compared to an ideal path, predefined by the authors, that referred only to important information nodes to the task-test. To deal with this data we used ratios as a measurement of the student's performance through the information network. These were oriented by specific parameters: *search* , *orientation, access,* and *time*.

Ratios used in the present study were developed by the authors for the web model followed in the hyperdocument and adapted from previous research in the domain (Canter, Rivers, & Storrs, 1985; Marchionini & Shneiderman, 1988; Stanton, Taylor, & Tweedie, 1992; Gillingham, 1993). In order to identify users' performances in the experimental hypermedia application, we define the following ratios:

- *Search ratio* (RSe) = the number of information nodes of the predefined path visited / the total number of nodes of the predefined path. This ratio measures the amount of relevant information accessed by the users. It is equal to 1 if all relevant nodes are visited and equal to 0 if none of them have been visited.
- *Orientation ratio* (ROr) = the number of information nodes of the predefined path visited / the total number of nodes visited. This ratio measures the degree of disorientation because it determines the precision of

information retrieval. It is equal to 1 if the user is oriented and only visited relevant information nodes and equal to 0 if none of them have been visited and the subject is utterly bewildered.

- *Access ratio* (RAc) = the number of selected information nodes of the predefined path / the sum of those nodes plus the number of nodes visited unnecessarily. This ratio is a measure of efficient information access. It is equal to 1 if the user is efficient and equal to 0 if he/she is completely inefficient.
- *Time ratio* (RTi) = the time spent in nodes from the predefined path / the total time spent in screen pages of the Web. This ratio measures the efficiency of information accessed and distinguishes the users who have spent time in important screen pages from those who have spent time in important and unimportant screen pages. This ratio is 1 if time is spent only on important screen pages and 0 if time is spent only on unimportant screen pages.

The use of ratios in this study pretended to define the pattern of the user's performance within a learning task. We were specially concerned in understanding the constraints to the navigation process in a hypermedia learning environment.

Statistical comparisons were made to analyze data from the users' browsing processes in the hyperdocument. A nonparametrics statistical procedure was used because of the small sample size (N=22). The Kruskal-Wallis one-way analysis of variance by ranks was used at an alpha level of 0.05, to analyze the significance of the frequency of the visit and time spent in the map with estimated ratios and results from the task-test for the three groups of performance identified. The StatView $^{SE+}$ computer program was used to conduct the data analyses.

RESULTS

Data obtained from the task-test showed a medium result of resolution for the subjects, based in the modal score that was 50, with a mean score of 57.7 (SD = 18.1). Analysing individual performance in the task-test, we identified that 5 out of 22 subjects (23%) had a score less than 50, and 17 out of 22 subjects (77%) had a score greater than or equal to 50.

Search ratio (RSe), orientation ratio (ROr), access ratio (RAc), and time ratio (RTi) data were computed for each subject. Search ratio (RSe) ranged from a low of 0.55 to a high of 0.95 (mean=0.79; SD=0.12). Orientation ratio (ROr) ranged from a low of 0.05 to a high of 0.36 (mean=0.13;

SD=0.07). Access ratio (RAc) values ranged between 0.05 and 0.47 (mean=0.16; SD=0.09); and time ratio (RTi) ranged between 0.46 and 0.77 (mean=0.59; SD=0.77).

The orientation ratio showed that students behaved like disoriented users and gathered information in an inefficient way. Through this interaction behaviour they show a pattern of information-seeking not based in the navigation map, through which they searched for relevant information. However, the searching tendency was constricted by an inefficient management strategy to access relevant information, since the score of the access ratio showed that subjects did not follow a goal-oriented strategy to navigate through relevant information. Instead they evidenced a performance of multiple movements within the information web that allowed them to find information and to spend some time in important node pages.

To understand the use of the navigation map we employed two parameters: frequency of visit to the map and time spent in the map. For the first one we obtained a mean value of 7.8 visits (SD=8.2), ranging from a low of 0 to a high of 29. For time spent in the map, the mean score was 160 seconds (SD=165.8), ranging between 0 and 566. It is important to report that a total of 7 students (32% of the sample) never visited the navigation map.

A correlation analysis between data variables was done. Using the Pearson correlation coefficient between data variables (frequency of visits to the map, time spent in the map, ratios of search, orientation, access, and time, and task-test), we had the following results (Table 1).

Table 1
Correlation Matrix Among Variables

	Intercorrelations (r)					
	Time spent in the map	RSe	ROr	RAc	RTi	Task-test
Frequency of visit to the map	0.93*	-0.33	0.58*	0.62*	0.34	0.13
Time spent in the map		-0.32	0.70*	0.73*	0.35	0.14
Search ratio (RSe)			-0.16	-0.37	0.36	0.36
Orientation ratio (ROr)				0.97*	0.08	0.00
Access ratio (RAc)					-0.01	-0.08
Time ratio (RTi)						0.58*
Task-test						

(*p<0.01)

From the analyses of the frequency of visits to the map tool in the hyperdocument we identified, among the subjects, three modes of use. The first group had 10 out of 22 subjects (45%) who visited the map very rarely (less than or equal to 5 times) during the session; the second group, with 5 out of 22 subjects (23%), visited the map rarely (between 6 and 10 times) during the session; and the third group, with 7 out of 22 subjects (32%), visited the map tool more often (greater than or equal to 11 times [see Table 2]).

Table 2
Frequency of Visit to the Map Tool

% of subjects	nº of visits
45	≤ 5
23	6 to 10
32	≥ 11

Time spent by the subjects in the map tool also led us to identify three groups of performance during the session. The first group had 9 out of 22 subjects (41%) who spent a short time (less than or equal to 100 seconds); the second group had 7 out of 22 subjects (32%) who spent a moderate time (between 101 and 250 seconds); and the third group, with 6 out of 22 subjects (27%), spent a long time (greater than or equal to 251 seconds [see Table 3]).

Table 3
Time of Visit to the Map Tool

% of subjects	time in seconds
41	≤ 100
32	101 to 250
27	≥ 251

The analysis of statistical significance concerning frequency of visits to the map, the ratios, and task-test scores showed significant differences among the groups, to the orientation ratio (ROr)—0.007—and to the access ratio (RAc)—0.003, with $p < 0.05$. We found also a value of 0.062 for the variable task-test, with $p < 0.05$. Although not significant, the present value shows the existence of differences among the three groups concerned with frequency of visits to the map, relative to the score obtained in the task-test. The medium group (6-10 visits) had the highest score and is probably responsible for the slight statistical differences among these groups (Table 4).

Table 4
Frequency of Visit to the Map Tool: Kruskall-Wallis Test Results

Groups / Ratios	≤ 5 Mean Rank	6 to 10 Mean Rank	≥ 11 Mean Rank	p
RSe	12.5	14.3	8.1	0.203
ROr	6.9	13.6	16.6	0.007
RAc	6.6	13.6	17.1	0.003
RTi	9.9	13.2	12.6	0.565
Task-test	9.1	17.3	10.9	0.062

There was a significant difference concerning the time spent in the map for the three groups in the variables of orientation ratio (ROr)—0.033, and access ratio (RAc)—0.007, with $p < 0.05$. We obtained also a score of 0.063 for the search ratio (RSe). Although not significant, it can be interpreted as showing some differences among the groups concerned with time of visit to the map: The group who spent the longest time in the map had the lowest mean ranking (Table 5).

Table 5
Time of Visit to the Map Tool: Kruskall-Wallis Test Results

Groups / Ratios	≤ 100 Mean Rank	101 to 250 Mean Rank	≥ 251 Mean Rank	p
RSe	13.4	13.5	6.3	0.063
ROr	7.4	12.7	16.2	0.033
RAc	6.6	13.0	17.1	0.007
RTi	10.0	12.6	12.5	0.666
Task-test	9.6	15.0	10.3	0.216

CONCLUSIONS

Results do not show a significant difference in the performance of the groups related to frequency of visits to the map with the search ratio. This ratio indicates clearly the necessary effort to follow the nodes of information that subjects will need to answer in the task-test.

Correlation analysis between data variables (frequency of visit / time spent in the map tool, and search ratio) showed an inverse effort: more visits to the map, less relevant search; more time spent on it, less search

effort. We stress that search ratio measures the amount of information gathered by the user that is relevant to the task. Thus, the search ratio may indicate the formation of a mental representation of the relevant information gathered by the user.

Moreover, there was a significant difference between groups of frequency of visit / time spent in the map tool and ratios of orientation (ROr) and access (RAc). It can be interpreted that the map tool was used as an anchor by the subjects. Although a great number of students behaved like disoriented users and accessed information in an inefficient way, the highest scores of ROr and RAc were earned by the subjects who visited the map more often and spent a long time there. This situation indicates a long cycle of navigation within the web, determined by the map but not by the relevance of the information for the individual performance. (That is why RSe > 0.55.) We may conclude that the frequency of visiting the map and the time spent in it do not guarantee orientation to the process of organizing and acquiring relevant information. Correlation between frequency of visit and time spent in the map (the score 0.93 from the data) reveals that they are good parameters to measure the use of the navigation map. The lack of a clear relationship between task resolution and frequency of visit to the map can indicate a certain degree of cognitive overhead experienced by the groups of the highest frequency. Subjects in this condition attribute the control of their performance to the system, as we may conclude by the results of the task-test, which did not show significant differences among the three groups of frequency of visit / time spent in the map.

These findings are consistent with the previous suggestions of Stanton, Taylor, and Tweedie (1992), who argue that the provision of a map results in poorer performance, less use of the system, lower perceived control, and poorer development of mental representations when compared to a condition with no map present. Nevertheless, we used a different research design that did not include the representation of cognitive maps. Perhaps it is not wise to assume that a map that helps performance in a spatial context also forms an aid in a hypermedia environment under a nonhierarchical model.

References

Beasley, R., & Waugh, M. (1995). Cognitive mapping architectures and hypermedia disorientation: An empirical study. *Journal of Educational Multimedia and Hypermedia, 4*(2/3), 239-255.

Billingsley, P. (1982). Navigation through hierarchical menu structures: Does it help to have a map? *Proceedings of the Human Factors Society, 26th Annual Meeting*, pp. 103-107.

Brockmann, R., Horton, W., & Brock, K. (1989). From database to hypertext via electronic publishing: An information odyssey. In E. Barrett, (Ed.), *The society of text: Hypertext, hypermedia, and the social construction of information* (pp.162-205). Cambridge, MA: MIT Press.

Canter, D., Rivers, R., & Storrs, G. (1985). Charaterizing user navigation through complex data structures. *Behaviour & Information Technology, 4*(2), 93-102.

Conklin, J. (1987). Hypertext: An introduction and survey. *IEEE Computer, 20*(9), 17-47.

Edwards, D., & Hardman, L. (1989). Lost in hyperspace: Cognitive mapping navigation in a hypertext environment. In R. McAleese (Ed.), *Hypertext: Theory into practice*. Norwood, NJ: Ablex Publishing.

Foss, C. (1989). Tools for reading and browsing hypertext. *Information Processing & Management, 25*(4), 407-418.

Gillingham, M. (1993). Effects of question complexity and reader strategies on adults' hypertext comprehension. *Journal of Research on Computing Education, 26*(1), 1-15.

Gygi, K. (1990). Recognizing the symptoms of hypertext...and what to do about it. In B. Laurel (Ed.), *The art of human-computer interface design* (pp. 279-287). Reading, MA: Addison-Wesley Publishing.

Hammond, N., & Allinson, L. (1989). Extending hypertext for learning: An investigation of access and guidance tools. In D. Diaper & R. Winder (Eds.), *People and Computers V: Proceedings of the Fifth Conference of the British Computer Society Human-Computer Interaction Specialist Group* (pp. 75-90). Cambridge, MA: Cambridge University Press.

Hitch, G., Sutcliffe, A., Bowers, J., & Eccles, L. (1986). Empirical evaluation of map interfaces: A preliminary study. In M. Harrison & A. Monk (Eds.), *People and computers: Designing for usability* (pp. 565-585). Cambridge: Cambridge University Press.

Jones, M., Farquhar, J., & Surry, D. (1995). Using metacognitive theories to design user interfaces for computer-based learning. *Educational Technology, 35*(4),12-22.

Kim, H., & Hirtle, S. (1995). Spatial metaphors and disorientation in hypertext browsing. *Behaviour & Information Technology, 14*(4), 239-250.

Marchionini, G., & Shneiderman, B. (1988). Finding facts vs. browsing knowledge in hypertext systems. *IEEE Computer, 21*(1), 70-80.

Nielsen, J. (1990). *Hypertext and hypermedia*. London: Academic Press.

Stanton, N., Taylor, R., & Tweedie, L. (1992). Maps as navigational aids in hypertext environments: An empirical evaluation. *Journal of Educational Multimedia and Hypermedia, 1*(4), 431-444.