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ABSTRACT

A study of first-year college students (n=121) in Taiwan investigated the effects of navigation maps and learner cognitive styles on performance in searches for information, estimation of course scope, and the development of cognitive maps within a hypertext learning course. Students were tested to determine level of perceptual field dependence and assigned to one of five groups: no map, global map, local map, local tracking map, and all maps. Students searched particular sections, and browsed through the course "Introduction to Computer Networks" delivered by the Cooperative Remotely Accessible Learning (CORAL) system, a courseware browser. Navigation map type has significant effects on students' search steps, search efficiency, and development of cognitive maps. Subjects in the global map and all-map groups took fewer steps and had higher search efficiency than subjects in the other groups. Map type also contributed to a significant difference in cognitive map development scores, with all-map and global map groups scoring higher than other map groups. Map type did not cause a significant effect on either search-task completeness or estimation accuracy. Cognitive style had a significant effect on subjects' cognitive map development, but did not have a significant effect on subjects' search performance. (Contains 24 references.) (Author/SWC)

Navigation Maps in a Computer-Networked Hypertext Learning System

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Abstract

This study investigated the effects of navigation maps and learner cognitive styles on performance in searches for information and on cognitive map development within a hypertext learning system. One hundred and twenty one college freshmen were blocked for field dependence and assigned to one of five treatments: no map, global map, local map, local tracking map, and all maps. Subjects searched particular nodes and browsed through the course "Introduction to Computer Networks" delivered by the CORAL system. Results indicate map type has significant effects on students' search steps, search efficiency, and the development of cognitive maps. Furthermore, cognitive style was significantly related to the development of cognitive map. No interaction between map type and cognitive style on any measure was observed. Implications for the design and development of navigation maps are provided.

Introduction

In the instructional technology field, computer-networked hypertext systems have recently received considerable attention. Hypertext consists of sets of information units connected by associative links. A hypertext system works like a database that stores learning materials and grants learners maximal freedom to navigate through hyperspace in which they access, select, search and browse through available information.

Hypertext is considered by many researchers (e.g., Jonassen & Grabinger, 1990; McAleese, 1991) to facilitate human learning. For example, in the most fundamental information-seeking stage of the human learning process, hypertext provides large integrated bodies of information in alternative representations for learners to browse through selectively. Using associative links and taking advantage of the structure of the information, learners are encouraged to explore and to find the information they need then progress to other learning activities.

After the initial information needs have been satisfied, the next stage is knowledge acquisition. In this stage, newly arriving knowledge is integrated with existing knowledge learners already possess through accretion, restructuring, and adaptation (Jonassen & Grabinger, 1990; Jonassen, 1990). Hypertext can facilitate this process by providing its interrelated ideas for learners to access and assimilate, permitting dynamic control capabilities for learners to integrate and reorganize information, and allow collaborative authoring to adapt learners' knowledge structures and learning styles.

Some researchers, such as Lee and Lehman (1993), as well as Spiro and Jehng (1990), have emphasized the active role learners must play in order to learn in hypertext-based learning environments. Learners have to actively interact with the learning environment and contents by browsing, selecting, searching, scanning and so on. Learning may occur when learners know not only what information is in a node, but also where and how to find that information within the web of nodes, and the contextual structure or organization of that information. However, these hypertext features and learning requirements sometimes confuse their learners. Learners who are navigating through hypertext systems often find themselves "lost" in hyperspace. Although researchers like Mayes, Kibby, and Anderson (1990) contend that some degree of disorientation and cognitive overhead are necessary in order to facilitate exploration and learning, Conklin (1987) in his keystone article stated that disorientation and cognitive overhead are the two most challenging problems in designing hypertext systems, and may ultimately limit the usefulness of hypertext.

The problem of disorientation or "getting lost in hyperspace" arises from the requirement to know one's location in hyperspace, where one came from, where one should go, and how one should go there (Stanton & Baber, 1992; Stanton, Taylor & Tweedie, 1992). Wickens (1990) suggested that "lostness" of navigation may due to the lack of correspondences among physical representations of the world and users' positions therein, what is seen in the forward field of view, and users' mental representations of the world. Edwards and Hardman (1989) stated that hypertext users should be allowed or aided to create cognitive representations of hypertext structures in the form of survey-type maps. The difficulties involved in developing cognitive maps may cause learner disorientation.

Review of Related Literature on Hypertext Navigation Tools

Many researchers have devoted their efforts to developing navigation tools to solve or at least to alleviate the disorientation and cognitive overhead problems. Lai and Waugh's (1995) study investigated the effects of two menu designs on users' attitudes, performances, and learning in search tasks in hierarchical or network hypertext document structures. The explicit menu was an enumerated list of all possible choices that explicitly mapped the organizational structure of its contents. By contrast, the embedded menu in their study offered the menu choices fixed within the surrounding texts, more like "anchors" as they are known in basic hypertext system concepts, or the "hotkeys" used in most popular World-Wide Web (WWW) browsers like Netscape. The results indicated that the combination of embedded menus and network structuring was unfamiliar to most information searchers and required greater efforts on their part to learn how to use and greater mental efforts to master. Results also revealed that explicit menus signaling hierarchical organization of the learning content were better received by learners and produced better search performances in most cases.

Also, using embedded hotkeys in hypertextual contents, Hammond and Allinson (1989) studied exploratory and directed searches by 80 university students under five navigation facility conditions: hypertext links alone, with graphical maps added, with keyword-index added, with guided tours added, and with all of these facilities added. Their results indicated the facility used had no significant effect on posttests of factual knowledge in exploration and search tasks. However, the subjects that used hypertext alone were considerably less efficient when exposured to new information than other subjects. In other words, the use of facilities in addition to hypertext resulted in wider coverage of the material and in more efficient access to new information. When all facilities were available, usage patterns were highly task-dependent: subjects used tours heavily, more for exploratory tasks, and used the index for directed tasks.

Stanton, Taylor and Tweedie (1992) studied the use of maps as navigational aids in a 42-screen hypertext environment. A small sample size of 12 students was used for each map and no-map condition. Their results suggest that when compared to the no-map condition, the provision of a map results in poorer performance, less use of the system, lower perceived control, and poorer development of "cognitive maps." Therefore, the researchers concluded the assumption of map as a useful navigation aid was "wrong", and needed to be studied further.

Leader and Klein's study (1996) investigated the effects of four search tools and learner cognitive styles on field dependence in searches for information within a hypermedia database. The search tool had four types: (1) a browser to navigate between contiguous screens, (2) index/find listing of descriptive names of every screen in the database that allowed typed text strings for searching, (3) maps displaying a hierarchical arrangement of the content, and (4) an all-tools choice that combined the above-mentioned types. Their results indicated that subjects using the four tool types accessed information from the database differently. Subjects who used the browser accessed significantly more screens than did subjects using the index/find type, and those in the all-tools treatment. Their results also indicated that search achievements in the index/find treatment were significantly better for the field-independent learners than for the field-dependent learners. Furthermore, learner cognitive styles were significantly related to achievement, tool use, and attitude. When the all-tools option was used, learners spent about 70% of their time using the browser, compared with 28% for the index/find tool, and 2% for the map to access screens.

From this study, it seems apparent that using a map was the least desirable type to the users offered the all-tools type, and produced no significant help in search task achievement. However, when the map design in this study was carefully examined, it was found the maps displayed a hierarchical arrangement of the content scope in terms of section, subsection, and individual screens. Such a combination of content scopes within one map may confound the effects of map usage. Moreover, unlike the other tools, the maps in this study were not available on every content screen, and therefore needed to be accessed from separate map screens. This inconvenience may have impeded users' willingness to use them. Similar problems were also observed in Stanton, Taylor and Tweedie's (1992) study in which a map was situated on separate screens. Students had to click a "Map" button in order to use the maps, and then to click a "Return" button to go back to the preceding instructional screen.

The Leader and Klein study serves to remind us to pay attention to individual differences in hypertext learning courses. It also underlies the idea of aptitude treatment interaction (ATI), in which students with different aptitudes, such as cognitive styles, should be given different treatment, such as navigation tools. Among all the individual difference in cognitive styles, field-dependence has been most studied by researchers under the leadership of the Witkin Group (e.g., Witkin, Oltman, Raskin, & Karp, 1971; Witkin, Moore, Goodenough, & Cox, 1977), and used in computer-assisted instruction (e.g., Hozaki, 1987; Stanton & Baber, 1994; Wey, 1995).

Field-dependence was proven to account for differences in differentiating the parts from the field (Witkin et al., 1971). Field-independent learners and field-dependent learners are theoretically different in: (1) breaking down a complex stimulus into its component elements, (2) providing structure for an ambiguous stimulus complex, and (3) providing a different structure from that inherent in the stimulus complex (Davis & Cochran, 1982). In other words, field-independent individuals tended to experience the parts as distinct from the field as an organized whole, while field- dependent individuals tended to experience the parts as fused in the whole. Field independence was proven to be related to learning ability, in particular, structuring and analytical abilities. Roberston (1982) considered field independence appropriate for study especially in a non-linear learning environments. In the context of hypertext, field-dependence may result in different abilities and performances in accessing particular pages from, and in navigating through a hypertextual web of instructional pages. Field-dependent learners are expected to benefit more when instructional material is encountered in a structured manner, and when guidance tools are provided in a global approach (Witkin et al., 1971).

As mentioned above, in Leader and Klein's study (1996), maps were designed to provide global overviews of the learning content, therefore, they should benefit, or at least not be disadvantageous to field-dependent subjects. However, in order to use maps, learners must be forced out of the context of the current content screen. Thus, this map design only benefited field-independent learners who have greater abilities to transfer concepts to new contexts. It suggests a need to re-examine map design and the effects of maps on learners with different field-dependence.

In the present study, the map design was further investigated, and its effects on learners with different field-dependence tendencies was examined. The study utilized a factorial aptitude treatment interaction design, with cognitive style as the aptitude variable and map type as the treatment. The cognitive style variable had two levels: field independent and field dependent. Map type had five levels: global, local, local tracking, none and all maps. The first three map types developed in this study can be differentiated in terms of the course presentation scope and the proximity to user's locations within the course, as described in the next section. All maps were persistently situated at the left side of the screen occupying about one-third of the screen area. The major research question addressed in this study was: Will students using navigation map(s) and having different cognitive styles exhibit significant differences in search-task performance, course-scope estimation, and cognitive map development?

Method

Subjects

Participating in the present study were 121 students at two mid-sized universities in northern Taiwan enrolled in the required freshmen course "Introduction to Information Technology." Among them, 81% (98 students) were male, while 19% (23 students) were female. The imbalance gender ratio of our sample matched the overall male vs. female ratio of these two science- and technology-oriented universities. Given this condition, researchers specifically encouraged female students to participate when recruiting.

All subjects' prior knowledge and usage of computer networks was collected and analyzed. Although results indicated that most of the subjects had some knowledge of and experience using computers networks, there were no significant correlations with our dependent measurements.

Materials

Materials used in the present study included a hypertext learning course, a survey, a pre-test, the Group Embedded Figures Test, and an instruction and test booklet. All materials were pilot-tested on 26 volunteer subjects one month before the start of the experiment, and minor revisions were made according to the pilot-test results.

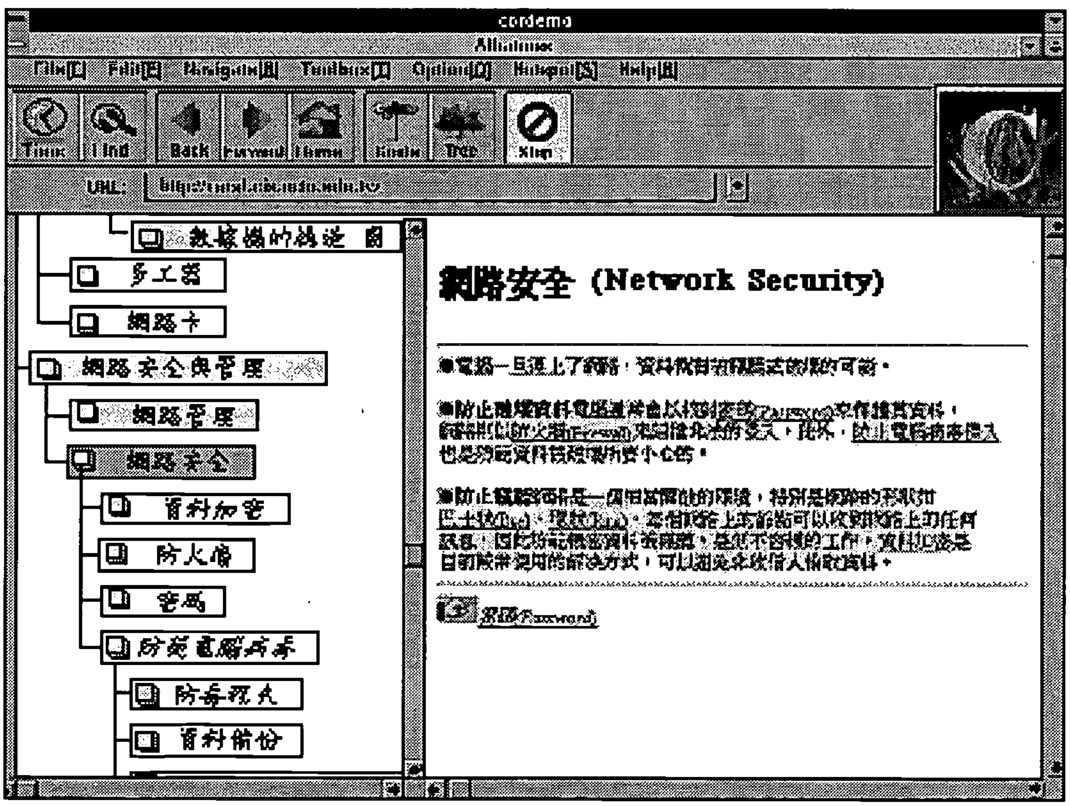
Hypertext Learning Course

The course content used in this study was Computer networks. Basic computer-network topics were delivered, including hardware, software, data-transfer techniques, protocols, applications, security, management, maintenance, and so forth. The learning domain for this course was identified as information, in particular, concept learning. The materials for each topic were fragmented and placed into learning nodes, which resulted in a total of 94 nodes in this course. Basically, the name of the node represented the concept taught in that node. Every node contained multimedia (text, graphics, animation, audio and/or video) presentations, and was written in Hypertext Markup Language (HTML) format.

The course was delivered over the Cooperative Remotely Accessible Learning (CORAL) system, developed by National Chiao Tung University in Taiwan. The CORAL system design comprises two major parts: a courseware browser and a group of communication channels. For more detailed explanations of the CORAL system, please refer to Chou and Sun (1996).

In this study, only the CORAL courseware browser was utilized. The browser is compatible with Netscape, however, it was specially designed for instructional purposes, or for collaborative learning and working purposes by enhancing the functions of the original Netscape browser. Moreover, since the CORAL browser was developed in-house, we tailored its functions, buttons, and appearance just for the purpose of this study, as shown in Figure 1.

Figure 1: A sample screen from the CORAL system browser, including a multimedia window for course content, with a global map at the left side. A "Find" button and a "Time" button in the left part of the menu bar were specially designed for this study.



Survey and Pretest

The purpose of the survey was to detect whether subjects demographic characteristics and prior computer experience influenced our dependent measurements. The survey asked subjects about the average number of hours they spent using computers and networks, in particular, using Telnet, FTP, BBSs, and the WWW, and about the total number of formal or informal hours they had spent in computer-network-related courses. The survey also asked whether subjects owned personal computers.

The pretest assessed subjects' familiarity with computers and computer networks. The pretest comprised 30 multiple-choice questions developed by the researchers. The test questions were validated by an experienced computer science professor who has been teaching computer networks for years. The split-half reliability for the pre-test was 0.77. The survey and pretest results were analyzed through SPSSX as not correlating with our dependent measurements, therefore, a co-variance analysis was not needed in our study.

The Group Embedded Figures Test

The Group Embedded Figures Test (GEFT) (Witkin, et al., 1971) was used to determine the cognitive style--field dependence--of each learner in this study. The GEFT assesses a global versus analytical dimension of cognitive style. It measures the ability to locate a simple figure within a larger complex figure which has been designed to obscure or embed the simple one. A subject's score is the number of correct tracings of simple figures, ranging from 0 to 18. A low score on this timed test indicates perceptual field dependence, whereas a high score indicates perceptual field independence. The mean GEFT score for the college students used as a norming sample was 11.4 (SD = 4.2) (Witkin, et at,. 1971). For subjects in the current study, the mean was 14.2 (SD = 4.1).

Instruction and Test Booklet

An instruction and test booklet was used during and after the treatment session. The booklet comprised four parts totaling 19 pages. The first part was an introduction to the CORAL system in general, and the CORAL browser's functions. Subjects were instructed to navigate through the course in three basic ways: (1) hotkeys, which allowed them to jump to selected nodes, (2) the "next" buttons at the end of each node indicating the designer's recommendation for the next node to visit, and (3) the map type(s) for different groups, except for the no-map groups. Uses of hotkeys and next buttons were both counted together as hotkey usages. Before being visited, hotkeys and map choices remained light blue; afterwards, they changed to dark blue. This design helped subjects know which nodes they had visited and which they had not.

The second part of the booklet explained the procedures for conducting search tasks. Subjects had to follow directions to find 10 particular instructional nodes (pages), such as the Fiber Optics node. The procedures instructed them to click the "Find" button on the menu bar in order to start the task. When subjects had called up the page on the screen and clicked the "Find" button again, the task was considered completed. Any moves involving use of hotkeys and/or map choices between two "Find" clickings were recorded by the computers. It is worth noting that whenever subjects clicked the "Find" button, the system would automatically go to the first page of the course, no matter what page was shown on the screen at that time. This design allowed subjects to proceed with each search task from the same starting point, that is, the first page of the course.

The third part of the booklet instructed subjects to browse freely in the course for 30 minutes. Whenever they were ready to start, they had to click the "Time" button on the browser's menu bar, and the system began timing 30 minutes for them. When their time was up, the system automatically showed a "Stop" sign in the middle of the screen, and the subjects could then start the post-test in the booklet.

The fourth part of the booklet was the post test. It first asked subjects to estimate the total number of instructional nodes (pages) contained in the course, and then assessed the cognitive map developed by the subjects. It asked subjects to answer 5 multiple-choice questions, 10 matching questions, and one charting question in which they had to construct a tree-like hierarchical chart of 14 concepts. All question types assessed their construction of the relationship among concepts (nodes) presented in the course. The total score for these 15 questions was 100.

Design and Data Analysis

A 5 x 2 (Map Type x Cognitive Style) factorial, posttest-only control group experimental design was used, with random assignment to treatment groups after blocking according to cognitive style.

Independent Variables

There were two independent variables in this study. The first was a 5-levels map type: global, local, local tracking, none and all maps. The global map (GM) showed the entire hierarchical knowledge structure, listing the names of the 94 hypertext nodes contained in the course. Since the name of a node represented the concept taught within that node, a tree-like overview map provided the conceptual structure. By using scroll bar, subjects could use the global map to find where they were (indicated in red), where they had visited (indicated in dark blue) and where hadn't (indicated in blue), as shown in Figure 1.

The local maps (LM) could be described as parts of the global map showing a particular knowledge areas in the course. It focused on only the neighborhoods of activated nodes, that is, one level above (usually the super-concept) and two levels down (the sub-concepts, if any) in this study. Users were always in the *current* local map, but did not know exactly where they were in the overall courseware. Local maps were not update until users had moved to nodes outside the current local maps.

The local tracking map (TM) was similar to the local map, but always showed the activated node in the center of the map in "You-Are-Here" fashion. In other words, the current nodes in red were always situated at the same places--the second item from the top--on the maps. The local tracking maps were updated whenever users moved to other nodes.

Figure 2 shows the same local map and local tracking map for users studying the Network Security node. Figure 3 shows the local map when a LO user moved from the Network Security node to the Anti-virus node. The local map was the same as preceding local map, as shown in Figure 2. If a LT user moved from the Network Security node to the Anti-virus node, the local tracking map was updated. The Anti-virus node was listed as the second item from the top of the updated local tracking map, as shown in Figure 4.

Figure 2: The same local map and local tracking map for users studying the Network Security node

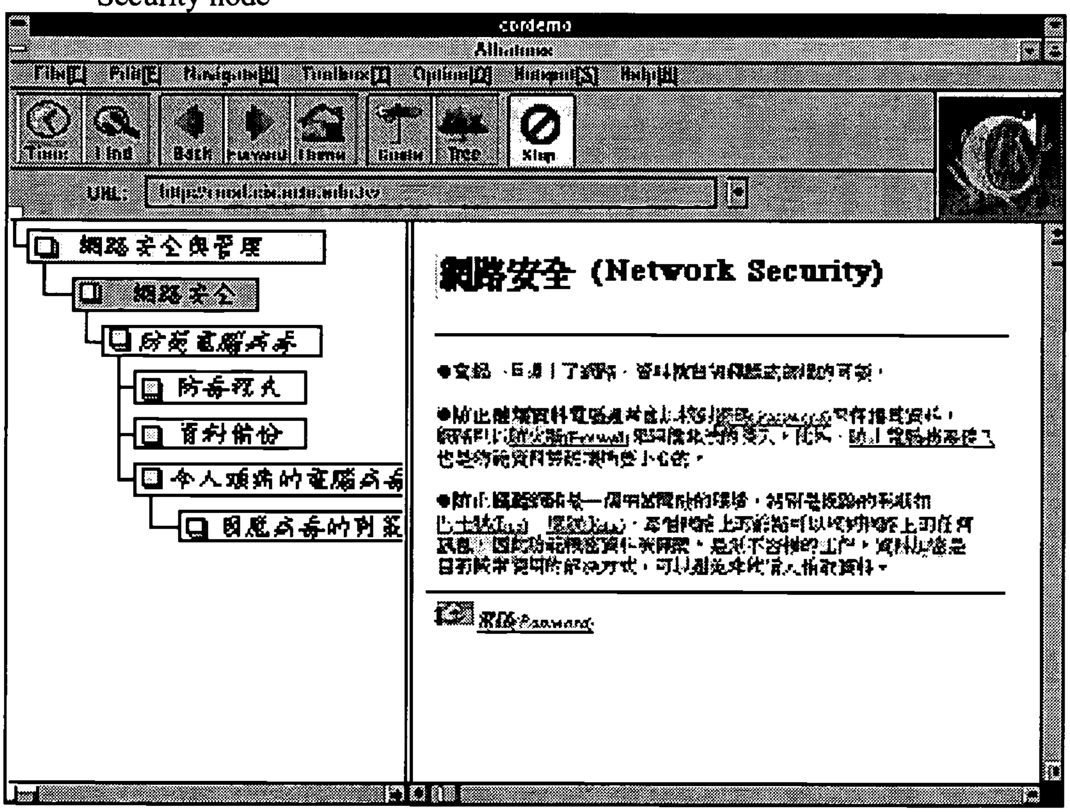
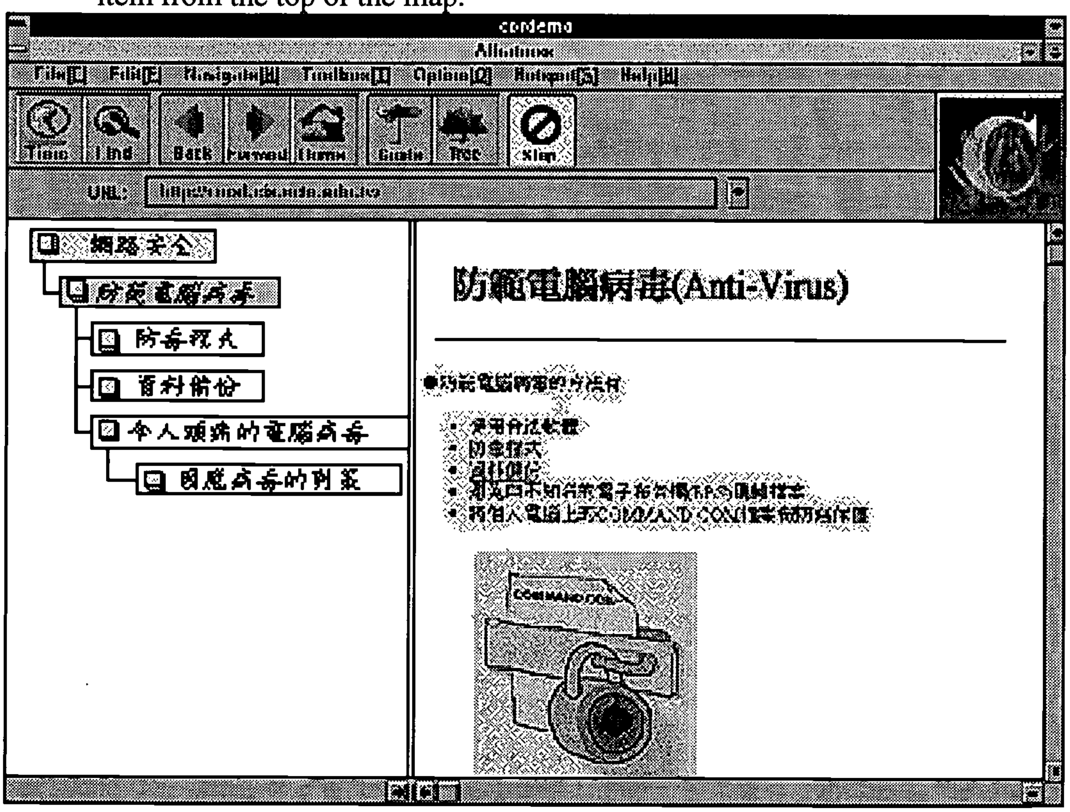


Figure 3: The local map when a LO user moved from the Network Security node to the Anti-virus node.

Figure 4: The update local tracking map when a LT user moved from the Network Security node to the Anti-virus node. The Anti-virus node was now listed as the second item from the top of the map.



The no map (NM) groups had no maps to use. NM subjects could only use hotkeys to navigate through the course. The all-maps (AM) groups, on the other hand, could choose among above-mentioned three maps by clicking the map type listed in the pull-down menu under the name of "ToolBox[T]", as shown in Figure 5.

Figure 5: The map choices among three map are listed in the pull-down menu under the name of "ToolBox[T]" for the all-map groups.

The second independent variable was cognitive style, that is, field-dependence, as assessed by the GEFT. A total of 157 subjects participated in the GEFT. Among them, those scoring 16 to 18 (72 students) were grouped as field-independent, while those scoring 2 to 13 (49 students) were grouped as field-dependent. Any data on those scoring 14 and 15 (36 students) were abandoned. A total of 121 students were accepted as valid subjects. The grouping was based on the bimodal shape of the GEFT score distribution, which indicated dichotomies learners. The split-half reliability of the GEFT used in our study was 0.89.

Dependent Variables

Five dependent variables were used in this study: search steps, search efficiency, search- task completion, estimation accuracy, and the cognitive map development.

(1) Search steps: the average number of steps subjects moved in order to complete 10 search tasks. The fewer steps, the better search performance was.

(2) Search efficiency: the degree of efficiency with which subjects finished 10 search tasks. The lower the number, the higher the efficiency was. The difference between search efficiency and search steps was search efficiency took the map type into account; therefore, we considered it to be "fairer" for treatment groups. The measure for search efficiency was:

$$\text{Search efficiency} = \frac{\text{number of steps subjects moved - number of theoretically fewest steps to find}}{\text{number of theoretically fewest steps to find}}$$

"Number of theoretically fewest steps to find" means the steps researchers counted from the first page to the page being searched for. The number was different for each treatment group. For example, in the searching task for the Fiber Optics node, subjects in the GM group could see the name of the Fiber Optics node on their global maps and directly click on the name to go that node, therefore the number of theoretically fewest steps to find was 1. If Subject A in this group moved 3 steps to find the Fiber Optics node, then her search efficiency score for this task was (3-1)/1=2.

On the other hand, if subjects in the NM group had a shortest path involving use of 3 hotkeys to go to the Fiber Optics node, then the number of theoretically fewest steps was 3. If Subject B in NM group moved 10 steps in order to find that particular node, then his search efficiency score for this task was (10-3)/3=2.33.

(3) Search tasks completion: the number of search tasks completed. The possible scores subjects could achieve ranged from 0 to 10. The higher the number, the better the completion performance was.

(4) Estimation accuracy: the difference between the number of nodes subjects thought this course had and the actual number of nodes this course had, that is, 94. The lower the number, the greater the accuracy. The measure for estimation accuracy was:

Estimation accuracy = | the number of nodes subjects estimate - 94 |

For example, Subject A estimated there were 90 nodes contained in the course, then her estimation accuracy was | 90 - 94 | = 4. If Subject B estimated 120, then his estimation accuracy was | 120 - 94 | = 26.

(5) Development of cognitive map: how well subjects were able to reconstruct the relationships among course nodes (concepts). it was assessed by a total of 15 questions on the post-test and graded by the researchers. The score range was 0 to 100. The higher the score, the better the performance was.

The first three dependent measures (search steps, search efficiency, and search-task completion) were unobtrusively recorded and calculated by the system, using Common Gateway Interface (CGI) programming developed by the researchers on the server. The estimation accuracy and the development of cognitive map were assessed by the post-test in the instructional and test booklet.

Data Analysis

All data obtained from the experiment were analyzed using Analysis of Variance (ANOVA). Because of the unequal cell sizes in the study design, homogeneity of variance for the post-test scores was a concern. Levene's test was used to check assumptions concerning the homogeneity of variance among cell groups. If test results indicated the assumption of homogeneity of variance was violated on any test score, such as the search steps in this study, then the critical value from the F distribution table was used instead to check whether the obtained F was significant. A post-hoc test -- the Scheffe method was utilized to investigate sources of significant differences for each test included in the ANOVA.

Procedures

This study was conducted in two sessions. In the first session, researchers were granted instructors' permissions to go into their classes to administer the survey, the pretest, and the GEFT. This session took about 25 minutes to finish.

One week after the first session, test subjects came to the National Chiao Tung University computer center for the second session of the current study. They were blocked according to their GEFT scores and then randomly assigned to treatment groups: none, global, local, local tracking, and all maps. Due to the blocking for field dependence, cell sizes were unequal, with the five treatment cells for the field-dependent students containing 10, 9, 9, 10, and 11 subjects, respectively, and the five treatment cells for the field-independent students containing 13, 13, 14, 15, and 17 subjects, respectively.

For the second session, subjects were assigned to their respective computers and received their versions of the instructional and test booklet. The researchers first gave a brief introduction of the study and the booklet, and guided the subjects in reading the first three pages of the booklet explaining the buttons and functions of the CORAL browser. Subjects were not allowed to turn the booklet pages unless otherwise instructed by booklet. The researchers gave all subjects 10 minutes to practice the operation of the computer and the browser. This design was based on the suggestions of Leader and Klein (1994) that subjects should be allowed to practice with the navigation tools before assessment of their search efficiency; otherwise, differences among tool usages would not show at all.

After the 10-minute practice, subjects were instructed to start their search tasks with no time limitation imposed. They had to follow the instructions in the booklet and proceed with the tasks in order. Upon completion of the 10 search tasks, subjects clicked the "Time" button to start browsing the course freely for 30 minutes. After they saw a "Stop" sign shown in the

Most of the subjects finished the on-line search and browsing work and the off-line post-test in about 120 minutes.

Results

The primary question of this study was would students using navigation map(s) and having different cognitive styles exhibit significant differences in search performance (search steps, search efficiency, search-task completion), course scope estimation accuracy, and cognitive map development?

Search Step

Table 1 displays the analysis of variance for search steps by treatment groups. ANOVA revealed a significant main effect of map type, $F = 14.812$, $p < .01$. A post-hoc analysis using the Scheffe test indicated that the AM groups search steps, (1.76) were significantly lower than those of the LM (6.33), TM (7.37) and NM (7.57) groups, and search steps for the GM groups (1.65) were significantly lower than those of the LM, TM and NM groups.

ANOVA indicated cognitive style had no main effect on search steps, and that there was no significant interaction between map type and cognitive style.

Table 1: Analysis of Variance for Search Steps by Treatment Groups

Source of Variance	Sum of Squares	DF	Mean Square	F
Main Effects				
Cognitive Style	9.014	1	9.014	0.634
Map Type	842.034	4	210.509	14.812*
Interaction	23.691	4	5.928	0.417
Residual	1506.434	106	14.212	
Total	2374.226	115	20.645	

p < .01

Search Efficiency

Table 2 shows the analysis of variance for search efficiency by treatment groups. ANOVA revealed that map type had a significant main effect on search efficiency, $F = 8.31$, $p = 0.000$. A post-hoc analysis using the Scheffe test indicated that the search efficiency of the AM (0.79) groups and GM (0.65) groups were significantly higher than those of the TM (1.79), and NM (2.10) groups

ANOVA indicated cognitive style had no main effect on search efficiency, and that there was no significant interaction between map type and cognitive style.

Table 2: Analysis of Variance for Search Efficiency by Treatment Groups

Source of Variance	Sum of Squares	DF	Mean Square	F	p
Main Effects					
Cognitive Style	0.032	1	0.032	0.028	0.867
Map Type	37.533	4	9.383	8.310	0.000*
Interaction	9.120	4	2.280	2.019	0.097
Residual	119.687	106	1.129		
Total	166.354	115	1.447		

Search-Task Completion

The mean number of search tasks that all treatment groups completed ranged from 9.6 to 10 out of the full number of 10. ANOVA indicated cognitive style and map type had no main effect on search-task completeness, and that there was no significant interaction between cognitive style and map type.

Estimation Accuracy

The mean number of differences between the number of nodes treatment groups estimated and actual 94 nodes ranged from 30 to 51. ANOVA indicated cognitive style and map type had no main effect on search-task completeness, and that there was no significant interaction between cognitive style and map type. However, the F value for the main effect of cognitive style on estimation accuracy was 3.822, with p = .052, close to the alpha of .05 we decided to judge significant in this study.

Development of Cognitive Maps

Table 3 displays the analysis of variance for cognitive map scores by treatment groups. ANOVA revealed a significant main effect of cognitive style on cognitive map scores, F = 14.480, p = 0.000. The mean cognitive map score for field-independent subjects were significantly higher than those of their field-dependent counterparts (75.43 vs. 65.00). ANOVA also indicated a significant main effect of map type on cognitive map scores, F = 3.304, p = 0.013. Although the more conservative Scheffe post-hoc test indicated no significant difference among all map-type groups, the Tukey HSD test indicated that the cognitive map scores for the AM (74.61) and the GM (73.71) groups were significant higher than those of the TM (59.57) groups. ANOVA indicated, however, no interaction between cognitive style and map type.

Table 3: Analysis of Variance for Cognitive Map Scores by Treatment Groups

Source of Variance	Sum of Squares	DF	Mean Square	F	p
Main Effects					
Cognitive Style	3740.330	1	3740.330	14.480	0.000*
Map Type	3713.311	4	853.328	3.304	0.013*
Interaction	807.367	4	201.842	0.781	0.540
Residual	28671.505	111	258.302		
Total	36852.876	120	307.107		

Discussion

The purpose of this study was to investigate the effects of map type and cognitive style on students' search performance, estimation of course scope, and the development of cognitive maps in a hypertext learning course. Subjects assigned to one of five map type treatments searched for and browsed information in the course "Introduction to Computer Networks" delivered by the CORAL system. Cognitive style was defined in terms of field-dependence, as measured by the GEFT. This section discusses the results of the statistical analysis and includes some interpretations.

Effects of Map Type

From this study, it was found that the map type caused significant effects on the subjects search steps, search efficiency, and the development of cognitive maps, and an almost significant main effect on estimation accuracy. Subjects in the global map and all-map groups took fewer steps (jumping from one node to another using either the global map or hotkeys) than subjects in the local map, local tracking map, and no-map groups. Since all maps groups used global maps more often than other maps (84% of total map usages), the results of the mean search steps for the all-maps groups were similar to the results for the global map groups. It was concluded that a global map helped learners search for particular information in fewer steps.

Compared with the global map, local maps provided partial coverage of the course. If a subject had to search for the name of a node outside the current local map the subject was in, she or he had to try to move to another local map to find where the desired node was listed. Therefore, more search steps were needed for them to move from one local map to another, and from one node to another. The local tracking groups were in a situation similar to that of the local map groups. It is interesting to note that the search steps for local and local tracking map groups were not significantly different from those for the no-map groups. One possible explanation is that the coverages of the local and local tracking maps designed for this study were too small, with only one level above and two levels down. The small and limited coverage did not make the local and local tracking maps much more useful to the subjects than having no map at all, as in the no-map group, in which subjects had to use the context and embedded hotkeys in each node to search for particular information.

The search efficiency test assessed how quickly, or in how many steps subjects were able to finish their search tasks. This measure took map type into account, therefore, treatment groups having different map types had different starting points; thus, the comparison among them was considered "fairer." The results indicated that all-maps groups and global map groups were more efficient in their search tasks than their local, local tracking, and no-map counterparts. The interpretations of these findings were similar to those for the search steps findings. Local and local tracking groups took more steps to find a particular node from one local map to another, and from one node to another. No-map groups had to use only the hotkeys to finish their tasks. Therefore, even though the local, local tracking and no-map groups had different starting points, they were still less efficient in their search tasks.

In this study, map type did not cause a significant main effect on search-task completeness. Subjects in different treatment groups finished most of the search tasks given no time limitation. This result was consistent with that in Hammond and Allinson's study (1989) in which subjects in 5 different navigation-facilities categories were not significantly different in their exploration-task accuracy. This suggests that different guidance tools, as in the Hammond and Allinson study, and navigation maps, as in the present study, could be used efficiently for subjects to finish searching for some particular information in hypertext learning courses, given enough time.

In this study, map type did not cause a significant main effect on estimation accuracy. However, it was observed that subjects in the global map groups more accurately estimated the number of nodes (mean = -0.26). The local map groups overestimated the number, whereas, the local tracking, all-map, and no-map groups underestimated the number. The difference among all map type groups was not significant though.

Cognitive map development scores subjects achieved on the post-test, showed map type contributed to a significant difference among treatment groups. The Tukey HSD test indicated that the all-map and global map groups scored higher than the local tracking map groups. Since the global map and all-maps subjects could use scroll bars to view the entire course structure in the global map provided by the CORAL browser, they could easily retain the whole picture of the relationships among course nodes. However, the local map subjects could only view the partial course structure presented in local maps, they developed their cognitive map, in terms of the relationship among course nodes, by "sewing" different local maps together. Consistent with the findings in Stanton, Taylor and Tweedie's study (1992), the no-map subjects in the present study, as its name indicates, had no map to use while browsing through the course, and needed to spend extra mental efforts in reconstructing the map in their minds, especially after they were told they would be tested upon completion. It is interesting to note that the subjects in the local tracking map groups scored significantly lower than those in the global map and all-map group. We hypothesize that subjects in the local tracking groups, unlike their no-map counterparts, did not spend as much mental effort constructing cognitive maps in their minds since they had a map to rely on, but the partial structure of concepts presented in the dynamic, continuous tracking and updating map was not enough for them to construct, or distract them from constructing their own cognitive maps.

From the above discussion, it seems that the local and local tracking maps were not much help in subjects' search performance. This result is consistent with the findings of Stanton, Taylor and Tweedie (1992). Map design in their study was similar to the design of the local map used in the present study, and they found that use of the (local) map resulted in poorer performance on sentence-completion tests. However, there were only 42 screens in their course. This small course did not make maps as absolutely necessary for subjects to use in navigation. Moreover, the inconvenience of using a map seemed to cause poorer subject performance than having no map.

By contrast, the global map in our study provided the most guidance help, while local or local tracking map seemed of no use. However, the number of nodes contained in the course was still relatively small. Using the scroll bar in the global map to search for particular information was not very difficult. However, if the number of nodes in a hypertext course is larger, more than a thousand for example, the global map will be more and more difficult to use, and learners may eventually get lost in the global map itself.

Implications for design and development of navigation map and possible future research directions based on the findings from this study are discussed here. In the present study, the local or local tracking maps showed only a single related one level of super-concept and two levels of sub-concepts concerning the current concept the subject was reading about. In future research, the design of local and local tracking maps can be improved by enlarging their coverages. The coverage may not be limited to concepts hierarchy levels. Instead, the coverage should be decided by the completeness of the knowledge contained in one section. If so, learners can use local and local tracking maps presented in one screen and have a larger overview of the course structure sections.

Future research can also investigate the relationship between various hypertext course scopes and the use of maps having different scope coverages. The terms "global" and "local" used in this study can be taken in a relative sense. It is expected that providing an overview map such as the global map used in this study will help learners navigate and search more efficiently in a relatively small course. Such a map will facilitate not only subjects' reactions to course information, but also help in planning more global progress. When courses are larger, however, a map covering only parts of the course structure will be useful for learners.

Effects of Cognitive Style

In this study, we found that cognitive styles did not have significant effects on subjects' search performances, that is, search steps, search efficiency, and search-task completion. We had expected that field-dependent learners would benefit more when encountering instructional material organized in a structured manner, and when global guidance tools were provided. The results of this study indicate that the search performance of field-dependent learners was equal to that of field-independent learners. Since no interaction effect was found; for example, field-dependent subjects in global map groups outperformed field-independent subjects in local map groups, the results did not support our expectations.

The statistics show that cognitive style had a close to significant main effect on subjects' estimation accuracy. Given that there were few subjects in each cell, the researchers did not reject the research hypothesis stating that cognitive style did not cause significant differences in estimation accuracy. Instead, the researchers in this study suggest more investigation into this topic should be conducted.

Cognitive style caused a significant effect on subjects' cognitive map development. Field-independent subjects scored higher in the cognitive map test than their field-dependent counterparts. This indicates that field-independent individuals were better at constructing their own information structures than field-independent individuals. As discussed previously and reported in related studies, field-independence was proven to be related to learning ability, in particular, structuring and analytical abilities. The test for cognitive map development used in the present study required learners to analyze and construct what they had browsed in hypertext. Thus, differences in cognitive styles led to difference performances on this measure. These results are consistent with the findings in Leader & Klein's study (1996).

It was concluded that cognitive style was significantly related only to the cognitive map development but not to the search performance of the subjects in this study. This finding supports Witkin's (1978) argument that cognitive style is a "process variable" during the learning journey. When given a clearly-defined learning task, such as a search for some particular information, field-dependent individuals and field-independent individuals can do equally well. However, when given no clearly-defined learning task, such as constructing a cognitive map after freely browsing, field-dependent individuals under-performed, while their field independent counterparts did well because of their better analysis and construction abilities.

Time allowed to finish learning tasks and related cognitive-load demands may also provide explanations. In this study, no time limitation was imposed on subjects finishing their 10 search tasks of finding particular node names without reading and digesting the information presented in the course. The result of this study supports Davis' (1991) finding that little or no difference exists between field-independent and field-dependent learners when a limited amount of information is to be processed. By contrast, when a notice of a post-test, and a 30-minute time limit were imposed on subjects browsing the 94 course nodes, the effects of field-dependence showed in their cognitive map development post-test scores. As Leader and Klein (1996) stated, field-independent individuals are consistently more efficient in situations where the information-processing load places heavy demanded. The findings of our study support their observation.

The basic idea behind the aptitude-treatment interaction (ATI) approach is that learners having different aptitudes should be given different treatments to help them learn. In the case of this study, subjects having different field-dependence were given different navigational aids to help them search and browse in a hypertext course. Although the type of navigational aid did not contribute to the performance of field-dependent subjects in their search tasks, the implication of this result is that the time allowance and information loading should be taken into account when designing learning tasks for different field-dependence learners, especially for field-dependent ones, in hypertext learning courses. Continued research into how different learners proceed in hypertext courses, as well as how navigation tools facilitate their progress will help us gain our knowledge on these topics for instructional technologists to use in designing and developing effective and useful hypertext learning environments and courseware.

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