Structural and conceptual user interfaces and their impact on learning

David Passig and Liav Nadler

Bar-Ilan University, Israel

David Passig teaches Future Technologies, Educational Futures, and is head of the MM and Virtual Reality Lab at the School of Education, Bar-Ilan University, Israel.
E-Mail: passig@mail.biu.ac.il
Web site: www.passig.com

Liav Nadler is a researcher in the MM Lab at the School of Education, Bar-Ilan University, Israel.
E-Mail: lnadler@zahav.net.il

Correspondence:

Dr. David Passig
School of Education
Bar-Ilan University
52900 Ramat-Gan, Israel
E-Mail: passig@mail.biu.ac.il
Tel: +972-9-8340 042
Fax: +972-3-7384029
Mobile: +972-52-2782377

Running Head: Structural and conceptual user interfaces

Structural and conceptual user interfaces and their impact on learning

Abstract

The purpose of this study was to examine the impact of structural and conceptual user interfaces on learning. Structural interfaces are interfaces which present the learner with the structure of knowledge, while conceptual interfaces present its concepts and main ideas. We hypothesized that interlaced interfaces, which include structural and conceptual elements, would be more effective for learning than any one of the interfaces by themselves.

121 subjects participated in the experiment. Each was given one of six interface formations of a computerized learning environment: a linear browsing interface (control group); a dynamic table of contents (structural interface); a menu-type interface (conceptual); a link-type interface (conceptual); and the interlacing of a structural interface with each of the conceptual interfaces. Each subject responded to two kinds of questions: information-location (superficial processing), and comprehension (deep processing). In this study we found that: a. the interlaced interface table of contents + the menu-type interface was more effective than the menu type interface by itself. However, no difference was found between the formations using the link-type interface. b. no interaction was found between the interface formation and the depth of processing. The conclusion resulting from this study is that the interlacing of interfaces by itself does not contribute to learning; however the interlacing of specific, compatible interfaces can not only make navigation easier (superficial processing), but also enhance deep understanding of content (deep processing).

Keywords: user interface, structural interface, conceptual interface, interlaced interface

Introduction

Over the years, the development of advanced information technologies has seen a growing interest among researchers and educators in learning with the aid of complex hypertext systems. The term *hypertext* was coined in 1965 by Ted Nelson describing his text management system—Xanadu. Nelson referred to hypertext as text which does not form a single sequence, and may be read in various orders (Blustein & Staveley, 2001). Today, the concept describes computer-based systems which enable the user to study large data sources while browsing freely between information units that are related to each other (Unz & Hesse, 1999). Formally, a hypertext system includes at least two elements—nodes and links. A node is an information unit which includes text or any other information, while a link is a logical pathway which connects a node to other nodes. Contrary to linear information systems (such as textbooks), in which the user proceeds from page to page, the hypertext system makes it possible to move freely between linked nodes according to need or interests.

The development of internet browsers in the early 1990's made the World Wide Web the largest hypertext system in the world. At the same time, interest in hypertext for educational purposes was growing. The potential of hypertext waiting to be exploited in education has encouraged many researchers to attempt to discover the relations between the use of these systems and different characteristics of learning.

The first studies of hypertext systems hypothesized that their use would improve learning outcomes in terms of both acquiring knowledge and reading comprehension. Others hypothesized that these systems would improve learning outcomes by reducing time spent on learning, increasing the ability to transfer knowledge to other knowledge domains, and increasing learners' motivation. Nonetheless, the early literature in the field (Chen & Rada, 1996 and Dillon & Gabbard, 1998) found that hypertext systems could not achieve significant advantage over traditional learning tools. Some of the studies even discovered that hypertext systems had restraining effects on learning. In some cases, learners experienced learning systems that were too open. They had to make independent decisions regarding where to navigate and which information units to research. These learners reported experiencing cognitive overload, disorientation, and loss of context. This phenomenon was described as "Lost in Hyperspace" (De-Jong & Van-der-Hulst, 2002).

As a result, in the last decade many studies were conducted to examine the correlation between the use of hypermedia systems and various characteristics of learning. A number of studies focused on the impact of different user interfaces on learning in hypertext environments. The goal of these studies was to find out how to improve the learner's performance while reducing cognitive overload. Researches attempted achieving this goal by improving database characteristics (e.g., type of information, information structure) or by improving the characteristics related to the user interface, such as keywords, navigational maps, indices, tutorials and help systems (Unz & Hesse, 1999).

A common problem observed among various users was the difficulty to create a macro view of the content presented in a document. This kind of difficulty tended to delay their decision regarding the question “Where do I go next”. It led them to navigate to irrelevant pages, or, more importantly, skip over important bits of text. It was also found that many users tended to forget which knowledge nodes they had already visited, or which part of a document they had already scanned. This type of users tended to waste valuable cognitive resources by cruising back and forth from page to page, which caused a sharp drop in learning effectiveness (McDonald & Stevenson, 1999).

In order to resolve this drop in learning effectiveness, different studies suggested the use of spatial interfaces, which present the comprehensive structure of the information, as well as the user’s current location, at any given moment. To fulfill this purpose, a simple spatial interface can suffice—such as a table of contents that includes the names of chapters and sub-chapters. A more complex interface could be a spatial map—a graphic representation of the information nodes and links, listing the documents available to the reader in relation to her current location. In this case, studies have indicated that spatial maps are more effective than simple tables of contents or alphabetical indices in improving the students' abilitiy to navigate the data source and solve problems (McDonald & Stevenson, 1999).

Taking these findings into consideration, various researchers put themselves to the task of understanding the effectiveness of different spatial interfaces. Leader & Klein (1996), for example, examined the influence of four different navigation tools on information searches in a hypermedia environment: a conventional linear browsing (only forward and backward), a keyword search, a spatial map, and an interface that interlaced all of these navigation tools. The study found that there was a significant advantage to linear browsing. In addition, students who used the interlaced interface used linear browsing 70% of the time, the search index 28% of the time, and the map only 2% of the time. The researchers maintained that the spatial map used in their study was ineffective because of two main flaws. First, the number of hierarchies it presented was too large. Second, the map was not available to the users at all times, but only after pressing a button which presented the map in a separate window which concealed the pages behind it.

Another example, Chou & Lin (1998) examined the influence of different navigation maps on the ability to locate information. They used three types of interfaces: a. a global map that presented the entire hierarchical structure of the information; b. a local map that presented only the information nodes linked directly to the user's current location; c. no maps at all—a condition in which the user could choose a navigation tool by himself. In this study as well, the researchers found that the navigation tools had a significant effect on the effectiveness of the learning environment. The results indicated that subjects who used the global map located the requested information in fewer steps, and were generally more effective in locating information. In the forth condition, where the subjects could choose their navigation tools freely, they preferred the global map 84% of the time. Another finding was that subjects who used the local map were not more effective than subjects who didn't received any map. The researchers, therefore, maintained that the ability to see the whole information structure in one window enables a user to create a better mental image of the data source structure, and thereby to locate information more easily.

From this kind of studies, it can be concluded that the use of spatial interfaces assists students in orienting themselves in the information space and in locating information effectively, provided that: a. the interfaces present the entire scope of information, and b. the interfaces do not cause cognitive overload. These interfaces, however, do not contribute to deeper learning abilities, such as reading comprehension and uncovering deeper relations between concepts. For that, McDonald and Stevenson (1999) proposed to use a conceptual map. The conceptual map is a navigation tool, which presents the key concepts of the text and the connections between them, unlike a spatial map, which presents only its structure. Thus, the researchers suggested that a conceptual map can help students create a mental map of the material and better connect the newly presented information with the existing knowledge.

The study they conducted included three interfaces: a spatial map, a conceptual map, and plain hypertext links. They hypothesized that using the spatial map would improve navigation, while using the conceptual map would improve understanding. In general, their findings supported the hypothesis claiming that the spatial map is more effective than the conceptual map, which is more effective than plain hypertext links. They also found a correlation between achievements and the type of questions the learner was asked. The spatial maps and the conceptual maps were more effective for factual questions (questions about facts appearing in the text) than hypertext links. In a measurement which was taken some time after the learning took place, they found that the conceptual map was more effective than the two other interfaces. For idea-related questions (questions about ideas expressed in the text) they found that the conceptual map and hypertext links were more effective. The researchers concluded that the conceptual map, despite its weakness in improving navigation, was more helpful to the students in crystallizing and remembering ideas conveyed in the text. Following studies supported this result (for example, Chang, Sung, & Chiou, 2002).

After reviewing the existing literature described above, we designed our study to further examine the impact of structural and conceptual navigation tools on learning in hypertext environments. Unlike other studies, our study focused primarily on interlacing interfaces. Since spatial navigation tools were found to be effective in locating information, while conceptual navigation tools were found to have the potential of increasing comprehension, we hypothesized that interlacing these two would improve learning. We suggested that an interlaced interface would make it possible to locate the desired information quickly using spatial navigation, and then enable deeper investigation by using conceptual navigation. Our assumption was that this kind of learning would not only be likely to encourage the understanding of ideas and propositions posed in the text, but would also create a more complete mental model of the knowledge concerned.

To further strengthen our hypothesis, we used dynamic interfaces, which change in reaction to events occurring in the system. In recent years new markup and scripting languages have been developed (e.g., Dynamic HTML, .Net, XML, JavaScript), which broadened the capabilities of plain HTML. These changes transformed HTML from an instrument for mere transmission of data to an instrument that enables an "information experience" through dynamic interfaces.

In conclusion, our study was designed to examine the effect of interlaced structural and conceptual user interfaces on the effectiveness of information location and comprehension in dynamic hypertext environments.

Method

Our study examined students' knowledge on a specific subject after using a dynamic hypertext learning system. The domain of knowledge chosen for this study was social psychology. Each subject received access to one of six online hypertext environments, and was asked to respond to questions about this subject. Research design and experimental groups appear in table 1.

Table 1. Research design and experimental groups

The independent variables in this study were the type of interface (between subjects variable) and the depth of processing (within subject variable). The depth of processing variable included two values: surface processing (location of information) and deep processing (comprehension). The dependent variable was the percentage of success in the knowledge test, standardized to a one hundred points scale.

Additional variables that were examined included: gender, age, subject's experience in surfing the internet, prior domain knowledge and prior experience with psychometric tests. We also measured the period of time needed for learning, and the subjects' initial ability in reading-comprehension.

Interfaces

In our study we used three different navigation tools: a dynamic table of contents (a spatial interface), a dynamic menu, and dynamic links (two conceptual interfaces). Here's a brief description of each.

The dynamic table of contents (TOC) is a list of all the chapters in the learning system, organized by topic. The choice of any topic expands a list of chapters related to it (see table 1). The choice of another topic collapses the previous list of chapters and expands the newly chosen list of chapters. Thus, at any given moment only one topic is visible. Each chapter in the list serves as a link to a specific page in the learning system. In addition, the chosen chapter's heading is marked with a distinctive color, which helps the learner identify her current location.

The dynamic menu is one of the two conceptual interfaces used in the study. It is a menu with permanent categories, where each category contains a list of items depending on the current topic (see figure 1). For example, if the user is reading about social influence, choosing the category "Theory and Research" opens a menu containing links to other text bits, related to that topic. The advantage of this kind of interface lies in its economical nature. The learner works in an uncluttered environment, while retaining the option of further exploring preferred topics.

Figure 1. Sample screen for the *TOC + menu* interface

The dynamic link is another form of a conceptual interface. It is a collection of links embedded in the text, each of which opens a dropdown menu with links to related topics (see figure 2). The dropdown menu does not appear until the user hovers over the link, keeping the workspace uncluttered.

Figure 2. Sample screen for the *links* interface

The main difference between the two conceptual interfaces lies in the navigational workflow. The dynamic menu appears at the top of the window, separating navigation from content. This interface encourages the user to read the entire text, before deciding where to go next. Dynamic links, by contrast, allow the learner to concentrate on the main area of the page without drawing his attention to a separated menu area.

Subjects

142 students between the ages of 15 and 18 participated in this study. The sample was gathered randomly using email addresses of high school students, members of different youth movements. Each student was sent an email message containing a link to the learning system, and one of six access codes providing access to one of the learning environments. The access codes were allocated randomly. In internet based studies this kind of sampling is called "private access," *i.e*., system access is given only to subjects who had been selected in advance. The goal of this sample was to prevent a self choice of participants to the experiment (Nosek, Banaji, & Greenwald, 2002).

In order to diminish the influence of prior domain knowledge, the subjects were asked to respond to the following question: "How would you describe your knowledge in social psychology?" Fifty-one subjects (42.1%) reported no prior knowledge of the topic. Thirty-six subjects (29.8%) reported little knowledge of social psychology, and thirty-four subjects (28.1%) reported some knowledge of the topic. Nine subjects who described themselves as having a great deal of knowledge of social psychology were not included in the final sample. In addition, twelve subjects were removed from the sample because they reported having undergone psychometric tests. This was due to the concern that students who had prepared themselves for the reading comprehension section of the psychometric test would have an advantage over students who had not had that preparation.

In order to confirm that all of the subjects had prior experience in computer use, they were asked to indicate the frequency with which they surf the internet. Fifteen subjects (12.4%) reported they do so occasionally, thirty-five (28.9%) reported surfing "frequently" and seventy-one (58.7%) reported surfing the internet "very often." None of the subjects reported surfing the internet "seldom" or "very seldom."

The final sample included 121 subjects, 86 of whom were girls (71.1%) and 35 (28.9%) boys. The ages of the subjects ranged between 15 and 18, with an average of 16.79, and a standard deviation of 0.92.

Research tools

In this study we used a dynamic hypertext system which was constructed especially for this experiment. The system was based on HTML (Hypertext Markup Language), CSS (Cascading Style Sheets), Java Script, and ASP (Active Server Pages) technologies. The data was gathered using Microsoft Access database. The system simulated an electronic book, where each chapter contained hyperlinks to other blocs of text.

For each of the experimental groups, a unique version of the electronic book was created: without navigation interface, with a dynamic table of contents (on the right side of the screen), with a dynamic menu (on the upper part of the screen), with dynamic links (embedded in the text), and two additional versions which interlaced the interfaces (see figures 1 and 2). All the versions were identical in page content, number of pages, text length, and font size and color.

The domain knowledge chosen for this study was social psychology. The topic was selected because, as a humanistic field, it provides opportunity to examine learner's ability to search information and comprehend text. Additionally, the topic was not a part of the high school curricula, thus diminishing the possible influence of learners' prior knowledge.

The categories used in the menu interface were *Concepts*, *Theory and Research*, and *Related Chapters*. The contents were taken from a series of books called “Social Psychology,” published by an Open University, and were adapted for use in the online system we constructed. The learning program included a total of 24 chapters, which were divided into categories as follows: *Introduction*, *Attitudes*, *Pro-social behavior*, *Interpersonal attraction*, and *The group*.

The principal measuring tool used in this study was the knowledge test, which was written especially for this study. The test included 12 multiple choice questions: 6 information location questions (surface processing), and 6 comprehension questions (deep processing). The questions for surface processing demanded that the learner would search and locate information. For example: *What were Schachter's findings in the study he published in 1959 on anxiety and social affiliation*?

Questions for deep processing demanded a deeper understanding of ideas described in the text and/or integration of information from a number of text blocs. For example: *According to Schachter's bi-factorial theory, which place is the most effective for flirting with the opposite sex,*

a. A romantic movie

b. Rock climbing

c. The local community center

d. A crowded shopping mall

The reliability of the entire test stood at $\alpha = 0.72$, where the reliability of the surface questions was α=0.568, and the reliability of the deep questions was α=0.531.

The subjects were told that their goal was to correctly answer as many questions as they can within limited time. The subjects had the freedom to decide how much time to dedicate to learning. At the end of the learning period they were asked to press the finish button. The period of time dedicated to learning was measured automatically by the system. On the average, the subjects worked on the learning system for 925.65 seconds (15.42 minutes) with a standard deviation of 831.47. In order to test the power of the correlation between the period of time devoted to learning and achievement on the knowledge test, we performed a *Pearson* correlation test. We found a significant positive correlation between the factors;

r=0.664, p<.01. In other words, the longer the students worked on the learning system, the better they achieved on the knowledge test.

In order to test if there were differences between the interfaces in the time dedicated to learning, we performed a *one-way* ANOVA test. The analysis did not find a significant influence of interface type on the period of time spent on learning: F(5,115)=0.586, p>.05.

Another measuring instrument we used was a short reading comprehension test. This test served as a monitor of the subjects' ability in reading comprehension prior to their exposure to the learning unit. The test included a short text, followed by six multiple choice questions. The text and three of the questions were taken from the verbal reasoning section of a psychometric test published by the national institute for testing and evaluation, (code VE153911H). Three additional questions were written especially for this research, and were similar to the surface questions on the knowledge questionnaire. An *α Cronbach* test of reliability found that the reliability of the questionnaire was α=0.555.

The average score on the reading comprehension test was 83.33, with a standard deviation of 20.18. In order to examine the power of the correlation between the initial ability in reading comprehension and the achievement on the knowledge test, a *Pearson* correlation test was performed. We found that there was a significant positive correlation between the factors: R=0.424, p<.01. In order to test whether there were differences between experimental groups in subjects' initial ability in reading comprehension we performed a *one-way* ANOVA analysis. The analysis did not find a significant difference between groups: F(5,115)=0.750, p>.05.

Procedure

The entire study was carried out over the internet, in the subjects' free time. We began by emailing the students a brief explanation of the experiment and asked for their consent to participate. Several days thereafter, each student received an email with a link to the experiment's website, along with a password to one of the learning systems.

In the first stage, the students responded to a five-item questionnaire: age, gender, frequency of surfing the internet, degree of prior domain knowledge, and prior experience in psychometric tests. In this questionnaire, as in the rest of the questionnaires, the subjects were obliged to answer all the questions in order to advance to the next stage.

In the second stage the subjects were referred to the reading comprehension test. An identical test was administered to all the subjects without a time limit. On finishing the test the subject pressed the *next* button.

In the third stage each participant was referred to a different learning system, according to the password s/he entered at the beginning of the process. All the subjects were able to browse freely through pages and to move from the text area to the knowledge test and back. After finishing the test the subject could push *finish*. One minute before the time was up the subjects received an alert in a pop-up window encouraging them to finish their work. After pressing the *finish* button, subjects' data was collected, including the time spent on the system. The participants were automatically transferred to the summary page on which they could view their scores on the reading comprehension test and the knowledge test. Forty-five minutes after entering the learning system, all subjects were automatically directed to the summary page, including those who had not pressed the *finish* button.

Results

The average score on the knowledge test was 51.38 (out of 100), with a standard deviation of 24.23. On the surface processing questions the students achieved an average score of 58.54, with a standard deviation of 27.05. In the deep processing test the average score was 44.21 with a standard deviation of 27.19. In order to test whether there was a difference between the scores of the surface and deep processing questions, we performed a t test for dependent samples. We found a significant difference between the test results: $t(120)=6.465$, $p<.001$. In other words, taking the entire sample into account, the scores of the surface processing questions were significantly higher than the scores of the deep processing questions.

The average score of male students was 45.95, with a standard deviation of 23.6, while the female average score was 53.59, with a standard deviation of 24.27. In order to test if there was a difference between genders on the knowledge test results we performed a *t* test for independent samples. We found that there was no significant difference between genders: $t(119)= -1.58$, $p>.05$ (with the assumption of equality of variance, according to the *Levine test*: $F=0.662$, $p>.05$). Subjects' scores by group are shown in figure 3.

As noted earlier, no difference was found between the groups, neither as regards the amount of time required for learning nor for the subjects' initial ability in reading comprehension. For this reason we decided not to use these factors as control variables.

In order to determine whether the user interface had any impact on the results in the knowledge test, a *one-way* ANOVA was performed. The analysis found that the interface type had a significant effect on the knowledge test outcomes: $F(5,115)= 2.44$, $p<.05$. A *Scheffe post-hoc analysis* found that subjects in the TOC + menu group were significantly more successful than the subjects in the menu group. No significant difference was found between the other groups.

Figure 3. Knowledge test scores by group

The first hypothesis was that the use of the *structural interface* would bring better scores in the surface processing questions than the use of *conceptual interface*, but that there would be no difference in the deep processing results. In order to test if the type of interface (TOC, menu, links) and the depth of processing (deep, surface) had an impact on the knowledge test scores, we performed a *two-way Repeated Measures analysis*. The analysis found a significant effect of the interface type on the knowledge test outcome: $F(2,57)=3.49$, $p<.05$. A *Scheffe post-hoc analysis* found that the use of the TOC interface yielded significantly better scores in the knowledge test than did the use of the menu interface. No significant differences were found between the TOC interface and the links interface, or between the two conceptual interfaces.

The analysis also revealed significant effect of the depth of processing on the knowledge test scores: $F(1,57)=27.09$, $p<.001$. In other words, the scores of the surface processing questions were significantly higher than those of the deep processing questions. No significant interaction was found between the depth of processing and the type of interface: $f(2,57)=1.147, p>.05$. The means and standard deviations appear in table 2.

Table 2. Means and standard deviations of knowledge test by interface (menu, links, TOC) and depth of processing.

The second hypothesis was that the use of an interlaced structural and conceptual interface would yield better test scores, both for surface processing questions and deep processing questions, than the use of any of the interfaces separately. Each of the interfaces which were interlaced was examined separately.

In order to test whether the different interfaces (TOC, menu, TOC + menu) and the depth of processing (surface, deep) had any impact on the knowledge test outcomes, we performed a *two-way Repeated Measures analysis*. The analysis found a significant impact of the depth of processing on the knowledge test scores: $F(1,58) = 17.64$, $p<.001$. In other words, the scores of the surface processing questions were significantly higher than those of the deep processing questions. The analysis also found a significant effect of the type of interface on the knowledge test scores: $F(2,58) = 5.43$, $p<.01$. A *Scheffe post-hoc analysis* found that both the TOC interface and TOC + menu interface produced better scores in the knowledge test than the use of the menu interface alone. No significant differences were found between the TOC interface and the interlaced interfaces. And finally, No significant interaction was found between the depth of processing and the type of interface: $F(2,58) = 2.14$, $p>.05$. The means and standard deviations appear in table 3.

Table 3. Means and standard deviations of the knowledge test by interface (TOC, menu, TOC + menu) and depth of processing.

Also, in order to test whether the interfaces (TOC, links, TOC + links) and the depth of processing (surface, deep) had any impact on the knowledge test outcomes, we performed a *two-way Repeated Measures analysis*. Here, as well, we found a significant impact of the depth of processing on the knowledge test scores: $F(1,55) = 33.28$, $p<.001$. In other words, the scores of the surface processing questions were significantly higher than those of the deep processing questions. The analysis did not find a significant impact of the interface type on the knowledge test scores: $F(2,55) = 0.348$, $p>.05$. Similarly, no significant interaction was found between the type of interface and the depth of processing: $F(2,55) =1.80$, $p>.05$. The means and standard deviations appear in table 4.

Table 4: Means and standard deviations of knowledge test by interface (TOC, links, TOC + links) and depth of processing.

We carried out an additional test to determine whether there were differences between the two conceptual interfaces. In order to examine the impact of the interface type on the knowledge test scores and the time dedicated to learning we performed a *two-way* MANOVA analysis. This time we used two independent variables: the type of interface (menu, links) and the formation in which it appeared (single, interlaced). The analysis revealed that there was no significant impact of the interface type on the simultaneous test (both knowledge test scores and time dedicated to learning): $F(3,70) = 0.65$, $p>0.5$. Nonetheless, the analysis found a significant effect of the formation of the interface on the simultaneous test: $F(3,70) = 3.75$, $p<.05$. A *one-way* ANOVA analysis, which meant to examine the source of this significance, found that the formation had a significant effect on the knowledge test scores: $F(1,72) = 4.08$, $p<.05$. In other words, the interlaced interfaces generated better results in the knowledge test than the sole interfaces, regardless of the specific type of interface. No significant effect was found of the formation of the interface on the amount of time dedicated for learning: $F(1,72) = 0.24$, $p>.05$.

The analysis also found a significant interaction effect between the type of the interface and the formation of the interface in the simultaneous test; $F(3,70) = 2.96$, $p<.05$. A *two-way* ANOVA analysis, which meant to examine the source of this significance, found that there was an interaction effect on the knowledge test score: $F(1,72) = 6.13$, $p<.05$. Using *t* tests for independent samples we found that for the menu interface, the use of the interlaced formation yielded significantly better knowledge test scores than did the use of the single formation. For the links interface, however, there was no difference between the formations. See figure 4. No significant interaction effect was found, on the amount of time dedicated to learning: $F(1,72) = 1.75$, $p>05$.

Figure 4. Knowledge test outcome by interface (menu/link) and formation (single/combined)

Means and standard deviations appear in Table 5:

Table 5. Means and standard deviations of knowledge test and amount of time needed for learning, by conceptual interface (menu/links) and formation (single/interlaced)

Discussion

The interactions between interface type and processing depth

The results indicate that the use of the structural interface (the dynamic table of contents) yielded a significantly higher degree of success than did the use of the menu type of conceptual interface, with no regard to the depth of processing. Even so, no significant difference was found between the structural interface and the conceptual interface of the links type. No significant interaction was found between the type of interface and the depth of processing.

However, the surprising finding for this hypothesis was that the structural interface was found to be more effective than the conceptual interface, not only for questions of surface processing, but also for deep processing questions. It would appear that the correct presentation of a text's structure can help with spatial orientation, as several researchers have suggested (McDonald & Stevenson 1999, Chou & Lin 1998). Moreover, such a presentation would help in building a mental model of knowledge. It is possible that this finding is linked to the interactive nature of the interface. In various studies the subjects received maps passively, without the ability to manipulate them. In this study, on the other hand, the structural interface was built of links which represent categories of information, and the user had to click them in order to expand or collapse the relevant chapter. It may be assumed that the learner's manipulation of the interface increased her/his involvement and control, which contributed to her/his success in the test.

Interlaced vs. single interfaces

The second hypothesis assumed that the use of interlaced interfaces would yield higher percentages of success on the knowledge test when compared with the use of single interfaces. The results indicated that the interlaced interface had only a partial advantage. The menu type conceptual interface had only a small marginal addition to the learner's success over the structural interface. Concerning the links conceptual interface, there was no addition at all.

Nonetheless, we feel that it would be incorrect to conclude, on the basis of these results, that it would be prudent to abandon the idea of interlaced interfaces because of their relatively small contribution to learning. We suggest two reasons. First, on examining the average scores it appears that the interlaced TOC + menu group, when compared to the structural interface (TOC) group, had 4.1% better results on the knowledge test, and 12.6% better results on the deep processing questions. Even without statistical significance, the difference in the scores is hard to ignore. It is possible that if we were to use a larger sample the differences within each group would have been reduced, and the differences between the different groups would have been enhanced. Second, it seems to us that, nonetheless, the TOC + menu interlaced interface contributed to the students' deep learning.

Zumbach (2006) maintains that in order to make an effective examination of hypertext systems one must examine their degree of linearity, from completely linear systems (scrolling texts), to hierarchical link systems (similar to the structural interface used in our study). Users prefer linear learning especially because they are more familiar with this way of presenting information. Zumbach refers to this factor as "media literacy." In his opinion, interlaced interfaces are likely to be effective as long as they present various levels of linearity, and create interaction between content and structure. The findings of the current study strengthen Zumbach's point. It seems that by itself, the interlacing of the interfaces does not contribute much to learning, but the interlacing of specific interfaces, which corresponds one another, can improve students' ability both in searching information and in understanding it.

The difference between the conceptual interfaces

In our study we used two types of conceptual interfaces: a dynamic menu and dynamic links. The results indicate that an interface's effectiveness is dependent on whether it appears separately or interlaced with a structural interface. First, the results indicate that the use of the interlaced interface yielded a higher percentage of success in the knowledge test than did the single interface, regardless the specific interface used. Similarly, we found that there is a significant interaction between the type of interface and its formation. The use of the menu interface in the interlaced formation yielded better results in the knowledge test than the use of the single formation by itself, while for the links interface no difference was found between the formations.

One may attribute these findings to the differences which exist between the conceptual interfaces. The basic difference between them is in the location of the interface in relation to the text, *i.e.*, the dynamic menus were separated from the content, offering a cleaner work environment. It is possible that this encouraged the user to read the entire text before deciding where to go next, and helped him/her to better understand the information. In this case, the addition of the structural interface (which was also external to the text) made up for what was lacking and improved the navigation ability. The dynamic links, however, appeared as a part of the text, and were hard to ignore. They encouraged the user to activate them, even if s/he had not read the entire text, and prevented her/him from making logical connections between the pages. It is possible that the addition of the structural interface not only did not help the students, but even caused additional cognitive overload, which undermined their performance in the knowledge test.

It should be noted that despite the attempt to diminish some methodological lapses and biases, which are typical of internet research (see, for example: Nosek, Banaji, & Greenwald, 2002), it is possible that the special nature of this study affected the validity of its findings. For example, in our study there was no control over the actual degree of interface employment made by the subjects. It is possible that there were subjects who made no use whatsoever of the interfaces with which they were presented, or who gave preference to a specific interface over another. In order to get a better understanding of the effectiveness of the interfaces, one would have to perform an in-depth research, including observations or digital recording of users' workflow. Future research in this area could focus on the interlacing of additional user interfaces or on new trends such as social networks (Chen, Lee & Chen, 2004).

The rapid development of the internet is one of the most riveting phenomena of the information age. This phenomenon is not limited to the user's experience alone, but influences the cultural, social, and economical milieu of the modern world. At the same time, it seems that the Web has yet to complete its development, and has yet to realize even a small part of the potential which lies within it. Studies from the field of education indicate the existence of a gap between the internet as an educational tool and the way students actually use it (Nachmias, Mioduser, & Shemla, 2000). In order to breach that gap educators and technology experts must cooperate, so that new learning systems may be developed which combine the imparting of knowledge, as well as the development of skills in diverse, highly effective and interactive environments.

References

Blustein, J. and Staveley, M. S. (2001). Methods of generating and evaluating hypertext. *Annual Review of Information Science and Technology (ARIST), 35*, 299-335.

Chang, K. E., Sung, Y. T. and Chiou, S. K. (2002). Use of hierarchical hyper concept map in web-based courses. *Journal of Educational Computing Research,* 27(4), 335-353.

Chen, C. and Rada, R. (1996). Interacting with hypertext: A meta-analysis of experimental studies. *Human-Computer-Interaction, 11(2),* 125-156.

Chen, C.M., Lee, H.M. and Chen, Y.H. (2004). Personalized e-learning system using item response theory. *Computers & Education, 44(3),* 237-255.

Chou, C. & Lin, H. (1998). The effect of navigation map types and cognitive styles on learners' performance in a computer-networked hypertext learning system. *Journal of Educational Multimedia and Hypermedia*, 7, 151-176.

De Jong, T. and Van der Hulst, A. (2002). The effects of graphical overviews on knowledge acquisition in hypertext. *Journal of Computer Assisted Learning,* 18(2), 219-231.

Dillon, A. & Gabbard, R. (1998). Hypermedia as an educational technology: A review of the quantitative research literature on learner comprehension, control and style. *Review of Educational Research,* 68(3), 322-349.

Leader, L. F. and Klein, J. D. (1996). The effects of search tool type and cognitive style on performance during hypermedia database searches. *Educational Technology Research and Development,* 44(2), 5-15.

McDonald, S. & Stevenson, R. J. (1999). Spatial versus conceptual maps as learning tools in hypertext*. Journal of Educational Multimedia and Hypermedia,* 8(1), 43-64.

Nachmias, R., Mioduser, D. and Shemla, A. (2000). Internet usage by students in an Israeli high school. *Journal of Educational Computing Research, 22(1),* 55-73.

Nosek, B. A., Banaji, M. R. and Greenwald, A. G. (2002). E-Research: Ethics, security, design and control in psychological research on the internet. *Journal of Social Issues*, 58(1), 161-176.

Open University (1996) *Social Psychology*. Tel-Aviv: Open U press.

Unz, D. C. & Hesse, F. W. (1999). The use of hypertext for learning. *Journal of Educational Computing Research,* 20(3), 279-295.

Zumbach, J. (2006). Cognitive overhead in hypertext learning reexamined: overcoming the myths. Journal of Educationa*l Multimedia and Hypermedia, 15(4),* 411-432.

Structural	**Conceptual**		
	none	Dynamic Menus	Dynamic Links
None	no navigation tools (none)	dynamic menus only (menu)	dynamic links only (links)
Table of Content	table of content (TOC)	Table of content + dynamic menus (TOC + menu)	Table of content + dynamic links (TOC + links)

Table 1. Research design and experimental groups

	Surface processing		Deep processing		Total		N
	Mean	SD	Mean	SD	Mean	SD	
menu	44.70	26.92	33.33	26.23	39.02	22.33	22
links	63.33	23.32	45.00	29.67	54.17	23.49	20
TOC	69.44	28.15	45.37	29.60	57.41	26.02	18
Total	58.33	27.87	40.83	28.53	49.58	24.86	60

Table 2. Means and standard deviations of knowledge test by interface (menu, links, TOC) and depth of processing.

	Surface processing		Deep processing		Total		N
	Mean	SD	Mean	SD	Mean	SD	
menu	44.70	26.91	33.33	26.23	39.02	22.33	22
TOC	69.44	28.15	45.37	29.60	57.41	26.02	18
TOC+menu	65.08	28.82	57.94	23.34	61.51	23.20	21

Table 3. Means and standard deviations of the knowledge test by interface (TOC, menu, TOC + menu) and depth of processing.

	Surface processing		Deep processing		Total		N
	Mean	SD	Mean	SD	Mean	SD	
links	63.33	23.32	45.00	29.67	54.17	23.49	20
TOC	69.44	28.15	45.37	29.60	57.41	26.02	18
TOC+links	55.83	23.74	45.83	26.42	50.84	23.40	20

Table 4. Means and standard deviations of knowledge test by interface (TOC, links, TOC + links) and depth of processing.

		testScore		testTime		N
		Mean	SD	Mean	SD	
Menu	single	40.83	22.60	860.3	746.16	20
	combined	64.71	22.54	1016.7	908.67	17
Links	single	54.17	23.49	1115.2	927.64	20
	combined	51.76	23.66	776.0	653.13	19
Total	single	47.50	23.74	987.8	840.91	40
	combined	57.87	23.73	889.7	782.11	36

Table 5. Means and standard deviations of knowledge test and amount of time needed for learning, by conceptual interface (menu/links) and formation (single/interlaced)

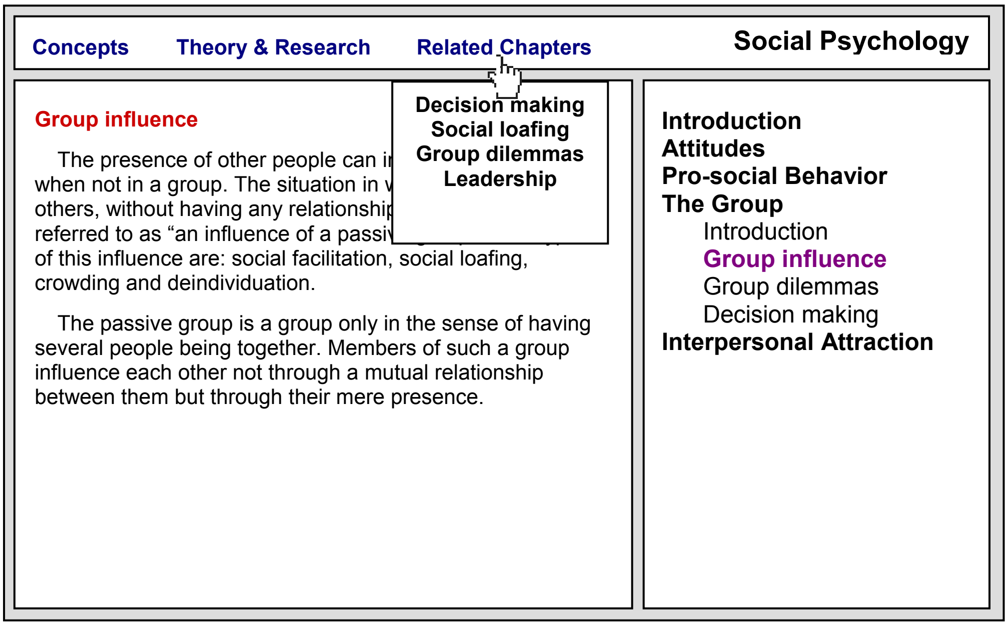

Figure 1. Sample screen for the "TOC + menu" experimental

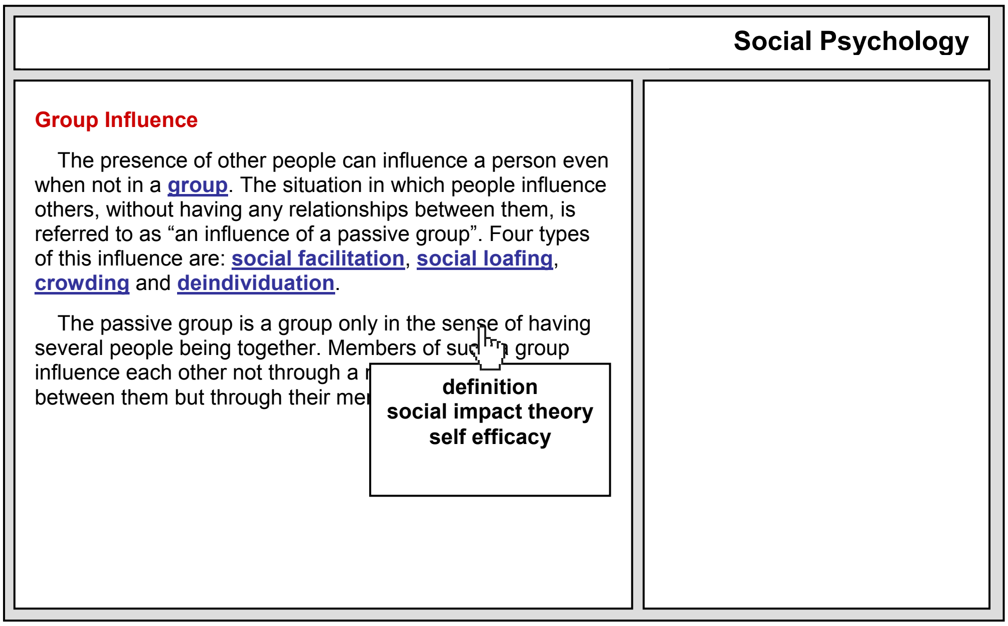

Figure 2. Sample screen for the "links" experimental group

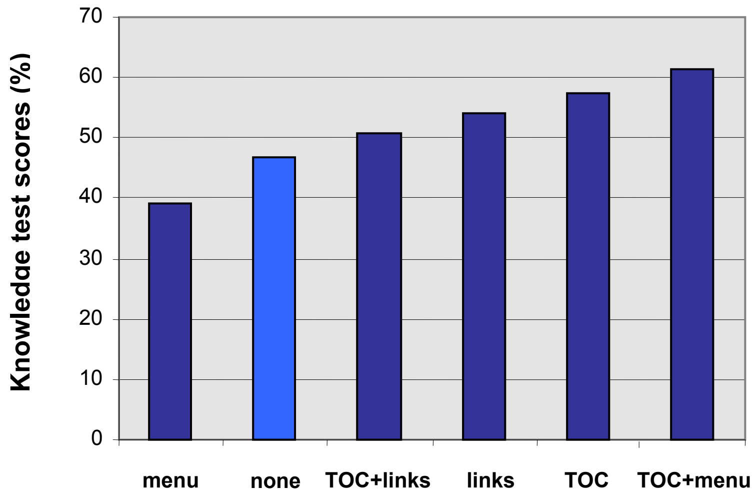

Figure 3. Knowledge test scores by group ("none" group marked)

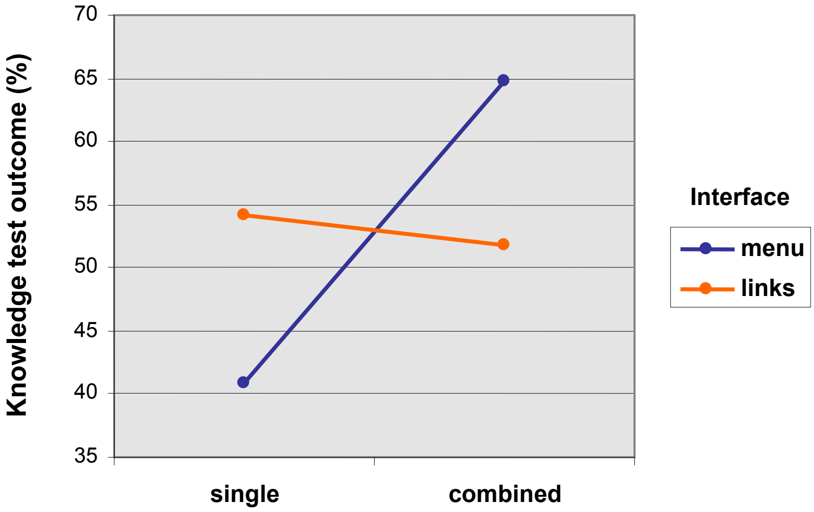

Figure 4. Knowledge test by interface (menu/link) and formation