THE EFFECTS OF INDIVIDUAL DIFFERENCES ON LEARNER'S NAVIGATION IN A COURSEWARE

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ABSTRACT
One of the major features of a computer based instruction (CBI) is its non-linear structure allowing learners the opportunity of flexible navigation to accommodate their own needs. However, this non-linear structure may cause problems such as inefficient navigation, being lost or cognitive overhead for some learners. The aim of this study is to determine how individual differences; cognitive styles, prior knowledge and gender influence the navigation pattern in a courseware. The research has the posttest-only, equivalent-groups true experimental design. The sampling is comprised of 84 first year undergraduate students at Gazi University, enrolled in an introduction to computer course. The cognitive styles (field dependent/ field intermediate/ field independent) of the students were measured with the "Group Embedded Figure Test". To determine the navigation pattern of the students, their stratum, compactness and revisit percentage values were computed based on their use of the courseware developed for the research. According to the findings, there is a statistically significant difference between learners' compactness and revisitation scores based on their cognitive styles. Also, there is a significant difference in revisitation scores based on the participants' prior knowledge.
Keywords*:* Cognitive Styles, Navigation, Computer Based Instruction, Stratum, Compactness, Revisitation.

INTRODUCTION

Designing instructional environments according to the user's needs has been the focus of instructional designers (Summerville, 1999; Raven, Cano, Garton, & Shelhamer, 1993). Individual differences are related with how people are similar and how they are differ in their thinking, feeling and behaviour. So educators and instructional designers have to attempt to understand and identify the influences of individual differences on learning to maximize the efficiency of instruction. The effects of individual differences on learning are examined through a large body of educational research. Due to these researches, some learning and/or cognitive styles have been classified over the years. One of the most well known and accepted cognitive style is *field dependence/field independence* developed by Witkin et al. (1977).

Witkin found that individuals are likely to differ considerably in their behaviors from basic perception to career preferences. Witkin and his associates developed the concept of "field dependence/independence" and defined it as the typical method of processing information (Ayersman and Minden, 1995). Field dependence is related to the "degree to which a learner's perception or comprehension of information is affected by the surrounding perceptual or contextual field" (Jonassen and Grabowski, 1993). There are numerous studies on the characteristics of field dependent and field independent learners. For example, Triantafillou, Pomportsis, Demetriadis and Georgiadou (2004) explained these characteristics as field dependent (FD) students are successful regarding interpersonal skills, whereas field independent (FI) learners are more autonomous. Moreover, FD students are globally oriented and have low ability for cognitive restructuring skills. On the other hand, FI students think more analytically and have highly developed cognitive restructuring skills than FD students. There is a continuum between extreme field dependence and independence, with those of intermediate ability being called field intermediate or field neutral (Mancy and Reid, 2004).

Park and Hannafin (1993) emphasized that learning environments can be as functional as to the extent that they are adapted to individual learner needs. Computer based instruction (CBI) provides users a variety of diverse content and learning tools in different contexts matched with learner preferences and knowledge level. Alomyan (2004) defined one of the main features of computer based learning as "the non-linearity where individuals have the freedom to choose their learning paths allowing them to have more control over their learning". These features and many others have increased the popularity of the CBI as a way of delivering instruction" (Shih and Gamon, 2001).

Achieving and processing information in non-linear environments is different from the traditional environments, because non-linearity allows users to jump between units of information in a non-predetermined order (Kim, 1998; Alomyan, 2004). While nonlinearity provides flexibility and freedom, some learners cannot control the pace and sequence of instruction, and find the relevant information on the CBI without getting lost (Chen, 2002). Therefore, educators should be more concerned with "how learners navigate through CBI systems and how individual differences can predict those paths" (Chen and Macredie, 2002). Also, Graff, 2003 found that "Cognitive style is related to an individual's ability to detect his/her spatial location or orientation in space". Therefore, cognitive style is an important factor of one's navigation in computer based instructional systems.

Students with different prior knowledge may be focused on different pieces of content and may choose different navigation path (Brusilovsky, 2003). Prior knowledge shows the learners' knowledge and skills on the content which they acquire from their experiences. Learners try to relate their prior knowledge with new information in learning process (Chi et al., 1989). Educational research insistently claims that what a student previously knows and how this information is organized influences the process of learning new information (Jonassen and Grabowski, 1993). The relationship between a student's prior knowledge and his/her navigation should be considered.

Another impact on the navigation path can be gender of learners. For example, Ford and Chen (2000), in their study, found that relative to males, females made fewer requests for guidance in navigation. According to Lawton (1994), there are gender differences in self-reported use of different way finding strategies. Therefore it is important to point out the effects of gender on navigation paths in CBI.

The most consistent trend in developing a better understanding of users' navigation patterns under hyperdocuments is to analyze the navigation trails (McEeneaney, 2001). The structure of any hyperdocument or a navigation trail can be modeled with some theories as graph theory (Broder et al., 2000). Directed or weighted directed graphs can be constructed based on the visited pages and followed links which represented by nodes and the edges (Herder and Van Dijk, 2004). By using the navigation graphs, some useful numerical metrics (stratum, compactness, revisitation rate, path density etc.) are proposed to help analyze the behaviors of users in their navigations. The measures which can be useful in assessing and modeling users navigation have been examined by some researchers (Gwidzka and Spense, 2007; Herder and Juvina, 2004; McEneaney, 2001; etc.). For example, Herder and Juvina (2004) stated that styles in the navigation paths can be determined using the strategies followed by the users. They used some metrics as stratum, compactness, path density and average connected distance, etc. to characterize user navigation styles. They found two different navigation styles called as flimsy and laborious navigation that predict users' perceived disorientation.

There are also some studies examining the relationship between a student' characteristics (gender, learning style, prior knowledge, cognitive style and computer experience, etc.) and navigation (Alomyan, 2004; Eveland and Dunwoody, 1998; Ford and Chen, 2000; Lawless and Kulikowich, 1998; Reed and Oughton, 1997, etc.) For example, Chen and Macredie (2002) suggested that field independent individuals would prefer free navigation, and field dependent individuals need guided navigation in non-linear learning. Eveland and Dunwoody's study (1998) indicated that novices tend to make use of a linear structure in hypermedia systems, while experts tend to navigate non-linearly. Although Vila, Beccue and Anandakar (2003) found that gender has no effect on the way subjects navigate in Virtual Reality, Ford and Miller (1996) claimed that women were relatively disoriented.

Even though there are many studies about navigation in hyper documents, the relationship among individual differences and navigation patterns has not been researched fully or the implications have been inconclusive. This study aims to examine whether individual differences, cognitive style, prior learning and gender, influence the stratum, compactness and revisitation scores of learners' navigation in CBI. To determine this, the following questions were posed:

1. Are there significant differences among a students' stratum, compactness and revisitation scores based on their cognitive styles (field independent, field intermediate, and field dependent)?
2. Is there a significant difference between the participants with high and low prior knowledge for their stratum, compactness and revisitation scores?
3. Is there a significant difference between male and female learners for their stratum, compactness and revisitation scores?

METHODOLOGY

The design of the research is posttest-only, equivalent-groups true experimental. The true experimental studies are accepted as strongest design even though it is difficult to conduct in school environments. Thus, this design is offered to be used for every research as much as possible (Best and Kahn, 1993).

Subjects

This study was conducted in the Departments of Art Education and History Education in the Faculty of Education at Gazi University with the participation of 84 undergraduate students. The participants consisted of students enrolled in the "*Introduction to Computer*" course during the first semester of the 2006-2007 school year. The sampling includes 34 males and 50 females. 25 students were field dependent, 28 students were field intermediate and 31 students were field independent.

Materials

Computer Based Instruction Program

A computer based instruction tool was developed to teach the word processing software "Microsoft Office Word XP". It included texts, images, captured videos, animations and interactive practices which were combined in a software developed using Microsoft Visual Basic 6.0. Videos were recorded using "Camtasia 2.0" and converted to swf (Shockwave Flash) format for embedding into the tool. The interactive practices and animations were also made using Macromedia Flash MX.

The complete courseware consisted of five chapters and 68 pages which were connected to each other. In the introduction section of the each chapter, there were three screens of advance organizers such as animations presenting the preview of a chapter, identifying texts about the objectives of the chapter and a concept map of the chapter. Another component of the tool was a multiple choice test including twenty items developed to inform learners about their academic achievement.

The courseware had four main parts:

1) A title bar which showed the location of the user in the subject sections, and includes "help" and "close" buttons.
2) An index tool (content outline) which had a hierarchical structure.
3) The main area which presented the contents.
4) A menu bar included all components of the software to access various facilities such as moving between pages, taking notes, and so on.

The general view of the software was showed in Fig. 1.

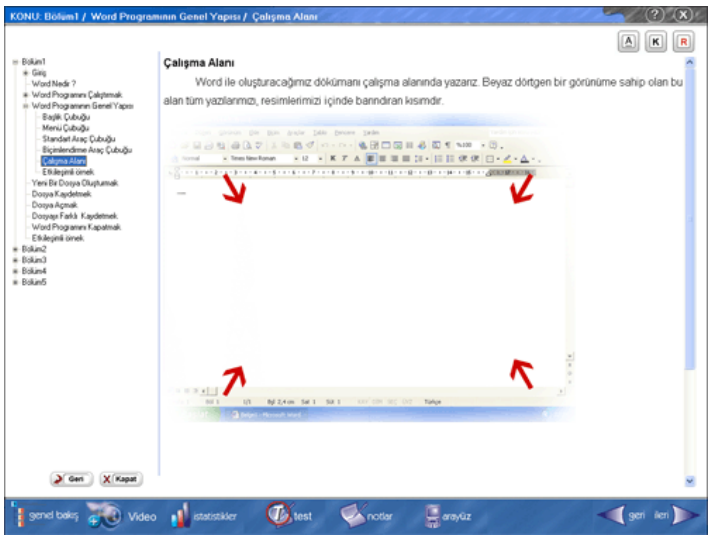

Figure (1). Screenshot of Courseware

The students could follow a linear path through the software using "next" and "previous" buttons on the menu system. The software also included an index tool which made it possible to follow a nonlinear path, and the students were able to jump freely from one page to another. There was also another "back button" on the index tool, which made possible returning to the previous page when a non-linear path had been followed.

Instrument

Cognitive styles analysis

The Group Embedded Figure Test (GEFT) was used to determine the cognitive styles of the students as field dependent, field intermediate or field independent (Witkin, Oltman, Raskin, and Karp, 1971). GEFT was an adaptation of the EFT (**E**mbedded **F**igures **T**est) which was developed in 1950 to determine the field dependence of groups by Witkin, Oltman, Raskin and Karp (1971) and translated to Turkish by Okman Fişek (1979). GEFT had a reliability coefficient of 0.82 and was a standardized paper-pencil test, which measured visual perceptiveness. It was based on the ability to identify a simple geometric shape which was embedded in complex figures, in a limited time, and included 25 items divided into three parts. The first part was for practice and was not evaluated. In this test, there were 7 complex figures in the first section whereas the second and third sections included 9 complex figures. The range of the scores in the GEFT varied from 0 to 18, where each correct answer evaluated by one point. The low and high scores which were determined by using the values of arithmetic mean and standard deviation indicated the individual's field dependence and field independence.

Measurement of stratum, compactness and revisitation percentage

Most of the theoretical studies on the hyperdocuments are often based on the idea of characterizing pages and links between the pages on a hyperdocument with the directed graphs. On such a mathematical model, it is easier to define some useful metrics or measures to make interpretation on the structural attributes of a hyperdocument or a navigation on the hyperdocument such as connectedness or linearity (Blondel and Van Dooren, 2003; Egghe and Rousseau, 2003). It can also be made some iterative computations on the matrix representations of the directed graphs, such as algorithms to determine the hubs and authorities in web searching (Blondel et al., 2004; Kleinberg, 1999).

The stratum and compactness concepts were introduced by Botafago and friends in 1992. They indicate whether a natural order for reading the texts in hypermedia exists by using combined some other metrics for identifying hierarchies in a hyperdocument. If the stratum approaches zero, the hyperdocument goes away from the linear structure, and vice versa. Stratum value of a uniform linear structured hypermedia is 1. The directions of the links have no importance on such a linear structure in terms of stratum. In Figure 2, diagrams of some example hyperdocuments are illustrated with their measured stratum values.

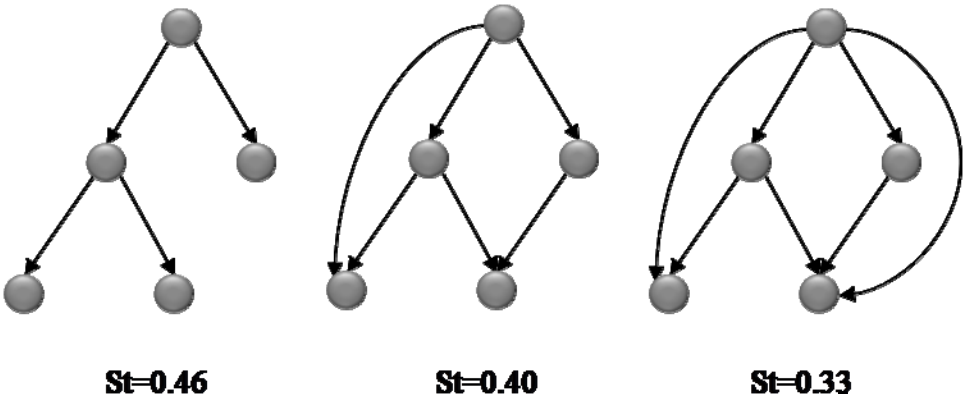

Figure (2). The stratum measure

Compactness measure can be expressed in free of nonessentials, as an indication of the intrinsic connectedness of a hyperdocument. In a complete disconnected hyperdocument, compactness is equal to 0 and this measure approaches to 1 depending on the connection density of the hyperdocument. In a fully connected hyperdocument, the value of the measure is equal to 1. For instance, a cycled hyperdocument constructed with four nodes has the compactness value 0.66 if the directions of the links are one-way. On the other hand, 0.88 is obtained as the value of the measure when the hyperdocument has bidirectional links. In the most complicated situation which is illustrated in the third graph of Figure (3), the hyperdocument has the compactness value 1. It is noted that the measures stratum and compactness are not independent measures each other. It can be seen easily that, when the compactness is equal to 1 for a hyperdocument, the stratum value is 0 for the same hyperdocument.

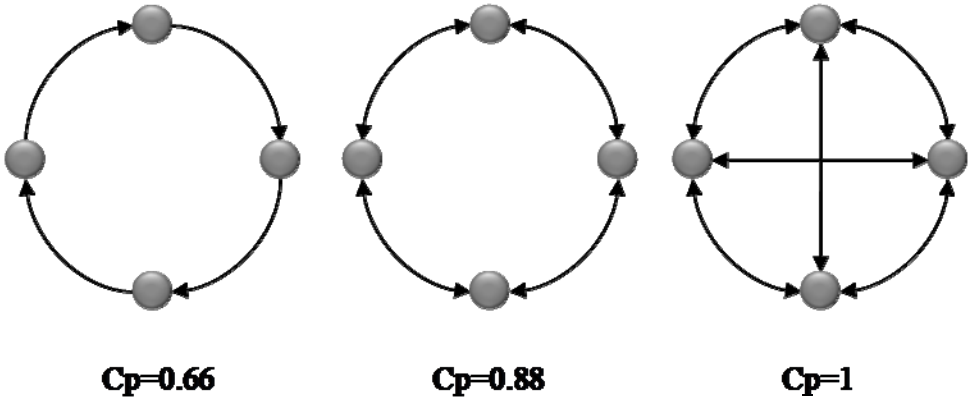

Figure (3). The compactness measure

The revisitation measure is used for calculating the probability that any URL visited is a repeat of a previous visit, using the ratio of the different pages visited to total pages visited, by Catledge and Pitkow (1997). In this study, same formula is used for computing the revisitation scores based on the navigation data of the users.

There is no way to compute easily the stratum and compactness values, or revisitation percentages of the users' navigations in the large graphs such as our hyperdocument which consists of totally connected 68 nodes. Therefore, it is inevitable to use a method to compute the stratum, compactness values and revisitation percentages of the users' navigation graphs using Maple. Applying these procedures to the navigation logs of the users, stratum, compactness and revisitation scores of the users, are obtained, and these scores are formed input data for the statistical analyses.

Procedure

The independent variables in this study were cognitive style (field dependent, field intermediate and field independent), prior knowledge (low and high) and gender. Domain expertise was considered as prior knowledge. The dependent variables were stratum and compactness scores (0 to 1) and revisit percentage. Initially a 25 item multiple choice pretest was given to determine the prior knowledge of students, who were then asked to take the GEFT. Using their GEFT scores, they were categorized into three groups according to their cognitive styles. Firstly, an oral explanation was given to the participants about how to use the CBI tool. During the study, each student worked on a personal computer. The whole treatment was carried out during three weeks for a total of nine hours. Participants were allowed to navigate through CBI in any manner they chose. The nodes which were navigated, and the time period in each node were recorded into a database. At the end of the application, the same 25 item multiple choice test was used as a post test to indicate the students' academic achievement.

Data analyses

Using the template provided by the publisher, the researchers hand scored the GEFT. The scores of the individuals below six were identified as field dependent, the scores in the interval [6-11] were considered as field intermediate, and the students with results more than 11 were identified as field independent. The values of the mean and the standard deviation were 8.97 and 5.08, respectively.

The other data were analyzed by using the Statistical Package for the Social Sciences (SPSS). The research questions were analyzed according to significance level of $p<.05$. Due to the multiplicity of independent variables (high prior knowledge/low prior knowledge, field dependent/field intermediate/field independent, male/female) and dependent variables (stratum scores /compactness scores/ revisit percentage), a 2x3x2 factorial Multivariate Analysis of Variance (MANOVA) was used.

RESULTS

Descriptive Statistics

Table 1 and Table 2 show the descriptive statistics for gender, prior knowledge and cognitive style in the study. Of those 84 participants, 25 students were identified as field dependent, 28 as field intermediate, and 31 as field independent (FI) learners. 72.6% of students (61) were learners with low prior knowledge and 27.4% of students (23) were learners with high prior knowledge. The numbers of the male and female students were 34 and 50, respectively.

Table 1: Student Enrollment by Prior Knowledge and Cognitive Style

FDI	low prior knowledge f %	high prior knowledge f %	Total f (%)
Field Dependent	21 (84)	4 (16)	25 (100)
Field Intermediate	17 (60,7)	11 (39,3)	28 (100)
Field Independent	23 (74,2)	8 (25,8)	31 (100)
Total	61 (72,6)	23 (27,4)	84 (100)

Table 2: Student Enrollment by Gender and Prior Knowledge

FDI	Novice f (%)	Expert f (%)	Total f (%)
Female	34 (68,0)	16 (32,0)	50 (100)
Male	27 (79,4)	7 (20,6)	34 (100)
Total	61 (72,6)	23 (27,4)	84 (100)

Prior Knowledge, Cognitive Style and Gender Effects on Navigation Path

To determine whether there were significant differences in students' stratum scores, compactness scores and revisit percentage based on learners' cognitive styles, levels of prior knowledge and gender, multivariate analysis of variance (MANOVA) was used.

Table 3: The MANOVA Results of Stratum and Compactness Scores According to Prior Knowledge, Cognitive Style and Gender

Dependent variable	Independent variable		N	M	SD	df	F	p
Stratum Scores	Prior Knowledge	High	23	,24	,25	1-82	,041	,840
		Low	61	,25	,23			
	Cognitive Style	FD	25	,26	,26	2-81	1,059	,352
		FM	28	,20	,21			
		FI	31	,28	,23			
	Gender	Male	34	0,21	,19	1-82	,972	,327
		Female	50	0,27	,26			
Compactness Scores	Prior Knowledge	High	23	,61	,24	1-82	2,449	,122
		Low	61	,68	,21			
	Cognitive Style	FD	25	,66	,23	2-81	4,43	,012
		FM	28	,75	,20			
		FI	31	,58	,21			
	Gender	Male	34	,68	,21	1-82	,006	,939
		Female	50	,65	,23			
Revisitation Scores	Prior Knowledge	High	23	50,00	20,30	1-82	4,592	0,035
		Low	61	56,31	15,88			
	Cognitive Style	FD	25	56,56	18,54	2-81	3,437	0,037
		FM	28	58,85	15,23			
		FI	31	49,12	17,15			
	Gender	Male	34	55,65	19,37	1-82	,313	,578
		Female	50	53,86	18,05			

As can seen in table 3, a significant main effect of cognitive styles is observed on users compactness scores ($F(2\text{-}81) = 4{,}43$ $p < 0{,}05$). Field intermediate learners' navigation paths had a higher compactness scores (M=,75) than field independents (M=,58). There are also significant difference in revisitation scores between field intermediate (M=58,85) and field independent (M=49,12) learners. However, no significant main effect of cognitive style were evident on the stratum scores ($F(2,81) = .91$, $p > 0.05$).

Whereas stratum and compactness scores failed to achieve significance according to prior knowledge, there are significant difference in revisitation scores $F(1\text{-}82) = 4{,}59$ $p < 0{,}05$. There are also no significant main effects of gender on learners' stratum, compactness and revisitation scores.

DISCUSSION

Accord with the results, it was seen that there were no significant main effects of cognitive style on users stratum scores. It was expected that, field dependent students may navigate in a more linear structure because of their tendency of studying in a structured educational setting. There are some findings which show that field dependent students prefer to have a fixed path to navigate usually, and field independent students relatively enjoy non-linear navigation in CBI (Reed and Oughton, 1997; Liu and Reed, 1994). There are also some findings which show that there was no statistically significant interaction between field-dependent/independent cognitive styles and navigation (Ford and Chen, 2000; Andris, 1996). The navigation aids such as hierarchical structure of the index tool (content outline) and breadcrumb lists in our courseware may provide enough structure for field dependent students. Moreover, when a non-linear path is followed, the opportunity of returning to the previous page using the back button on index tool may be useful for field dependent students. This study also found that field intermediate learners' navigation paths had a higher compactness scores (M=,75) than field independents. There are two factors effecting the measurements of compactness. The first one is the number of the different pages visited during navigation. The second one is the direction of the navigation among visited pages. For instance, bidirectional navigation on the compactness value has more effect than one directional navigation between two pages. On the other hand, due to the nature of the compactness measure, navigations between two pages repeating more than two times do not affect the value of the measure. Therefore, to determine the source of the effect which increases the value of compactness measure, a third measure, revisitation is needed. When revisitation scores of users analyzed, the revisit percentage of field intermediate users is higher than the revisit percentage of field independent user. Past researches have not suggested clear evidences about the navigation patterns of field intermediate users. The findings of this study suggest that navigation preferences of field intermediate users can be different from navigation preferences of field dependent and/or field independent.

Increases amount of revisitation is interpreted that a user is more likely to be lost (Alonzo, 2002, Smith, 1997). But it may not be exactly true to claim that field intermediate users can be disoriented based on only revisitation scores. To investigate the relationship between cognitive style and disorientation, research studies which include many different disorientation measures (perceived disorientation, etc.) are needed.

The findings of this study indicate that there was significant difference in revisitation scores between learners with low and high prior knowledge. However there was no significant difference in stratum and compactness scores between learners with low and high prior knowledge. It is not surprising that learners with low prior knowledge had a higher revisitation scores (M=56,31) than learners with high prior knowledge (M=50). It was thought that prior knowledge would change the ways of accessing information of individuals. When the literature was examined, it is seen that there is a general agreement about the idea of "prior knowledge would effect the navigation" (Çalışır and Gürel, 2003). This result may be due to the need for repeating of the content or disorientation of learners related to their low prior knowledge.

Another research aim of this study was to investigate if there were gender-related differences in navigation patterns in CBI. A few studies investigated the differences in navigation strategies of females and males (Schwarz, 2001). For example, Reed and Oughton (1997) conducted a study based on linear and nonlinear navigations of different genders. They concluded that females tend towards more linear structured navigation in the hypermedia. The results of this research showed that there is no significant difference between male and female learners based on their stratum, compactness and revisitation scores.

Future Perspectives

Future research is needed to provide information on impact of individual differences on navigation patterns. Following provides a list of potential future studies.

- A similar study, besides the domain knowledge as prior knowledge level, may be repeated by bearing the computer experience in mind.
- Additional research should examine the effects of individual differences as cognitive style on disorientation by using different measures (asking experienced disorientation to learner or measuring learner performance).
- The differences in navigation patterns of learners while students implement different learning tasks in different contexts can be investigate.
- Studies examining the common effect of individual differences and navigation patterns on task success may be conducted.

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