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The value of adaptivity based on cognitive style: an empirical study

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Abstract

Adaptive Hypermedia Systems can be developed to accommodate a variety of individual differences, including learning style and cognitive style. This study investigates the hypothesis that adaptive hypermedia accommodating cognitive styles can be beneficial for the observed learning outcomes. A prototype system, designed to be adapted to individual cognitive styles, was developed as a case study. In order to evaluate the effectiveness of the prototype system, an empirical study was conducted. This paper presents the results of the summative evaluation of the system. Statistical analyses indicated that students in the experimental group performed significantly better than students in a control group. These findings indicate that student performance is mainly affected by adaptivity based on individual cognitive styles.

Introduction

The hypermedia environment is considered to be a flexible instructional environment in which all learning needs can be addressed (Ayersman and Minden, 1995). Many researchers have been working to construct sophisticated hypermedia systems that can identify a user's interests, preferences and needs, and give some appropriate advice to the user throughout the learning process. Adaptive Hypermedia was introduced as one possible solution. Adaptive Hypermedia Systems (AHS) combine hypermedia systems with Intelligent Tutoring Systems to adapt web-based educational material to particular users. AHS build a user model of the goals, preferences and knowledge of the individual user, and use this model to adapt the content of pages and the links between them to the needs of that user. Since the user's goals, preferences and needs may change over time, AHS observe these changes in order to update the user's model (Brusilovsky, 1996).

AHS can be developed to accommodate various learner needs and is the ideal way to accommodate a variety of individual differences, including learning style and cognitive

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will reach the same level of performance as FI ones when studying in the AES-CS environment.

Before discussing the summative evaluation of the AES-CS, it is important to examine the design issues that were considered for the development of the system.

Design issues of AES-CS

The main characteristic of AES-CS is that it can be adapted to the cognitive style and to the level of knowledge acquired by the student. The system is organised in the form of three basic modules: the domain model, the student model and the adaptation module (Triantafillou *et al*, 2003). These three components interact to adapt different aspects of the instructional process, which includes adapting the content according to user's prior knowledge; adapting the presentation of contents through selection and combination of appropriate media; adapting the teaching strategies; modifying the selection of examples and links; and recommending appropriate hyperlinks.

To support adaptivity, AES-CS uses the 'adaptive presentation technique' (Brusilovsky, 1996) that aims to adapt the information presented to the user according to his/her cognitive style and knowledge state. Conditional text and page variants representations are used to accomplish adaptive presentation. With the conditional text technique, a page is divided into chunks. Each chunk of information is associated with a condition indicating which type of user should be presented with it. With the page variants technique, two variants of the pages associated with a concept are prepared. Each variant of the page presents information in a different style according to FD/FI dimension.

Furthermore, AES-CS uses the 'adaptive navigation support' that aims to help users to find an appropriate path in a hypermedia learning environment (Brusilovsky, 1996). AES-CS provides adaptive navigation support by manipulating the selection and the presentation of links through adaptive annotation and direct guidance. Adaptive annotation is the most popular form of adaptive navigation support. It was first used in ELM-ART and has since been applied in several other systems such as Interbook and KBS Hyperbook. Adaptive annotation of hyperlinks supplies the user with additional information about the content behind a hyperlink. The selection and the colour of hyperlinks are adapted to the individual student by taking into account information about the learner's knowledge state and the instructional strategy. Within AES-CS, blue is used for 'recommended' and grey for 'not ready to be learned'. With the direct guidance, the system suggests to the student the next part of the learning material. This technique can be seen as a generalisation of curriculum sequencing, but within the hypermedia context it offers more options for direct guidance. Student's prior knowledge is used by the system in order to provide him/her the most suitable sequence of knowledge units to learn and to work with.

Adapting instructional strategies

In the ideal educational environment, a tutor with instructional experience with a learning domain can identify students' individual differences, relative to cognitive styles

Table 1: Instructional strategies

Field-dependent learners	*Field-independent learners*
Provide global approach	Provide analytical approach
Provide information from general to specific	Provide information from specific to general
Program control	Learner control
Provide advance organiser	Provide post organiser
Provide maximum instructions	Provide minimal instructions
Provide maximum feedback	Provide minimal feedback
Provide structured lessons	Allow learners to develop their own structure

and acquired knowledge, and thus can provide them with learning material individually selected and structured. In order to simulate, in a sense, an ideal educational environment, an adaptive hypermedia system should provide learners with the ability to use different instructional modes in order to accommodate their individual needs and improve their performance. Therefore, it has to include in its design both issues of cognitive style and teaching strategy. Teaching strategy refers to the instructional material and the instructional strategy. Table 1 presents the instructional strategies adopted in AES-CS that support students according to their cognitive style. Next, we will discuss briefly the most important of these strategies and the way they were implemented in the design of AES-CS.

Global versus analytical approach: AES-CS uses adaptive presentation techniques to provide both global and analytical approaches since FI learners tend to approach things analytically and FD learners tend to approach tasks in a global way. Specifically, conditional text and page variants representations are used to provide information from specific to general for FI learners. On the other hand, the system provides information from general to specific for FD learners.

Program control versus learner control: AES-CS provides both program and learner control options, according to theoretical assumptions in FD/FI dimension. In the learner control option, AES-CS provides a menu from which learners can choose to proceed in the course in any order (Figure 1). In the program control option, there is no menu; the system guides the user through the learning material via adaptive navigation support (see Figure 2).

Instructions and feedback: Studies have shown that FD learners are holistic and require external help, whereas FI individuals are serialistic and possess internal cues to help them solve problems. FD learners are more likely to require externally defined goals and reinforcements, whereas FI ones tend to develop self-defined goals and reinforcements (Witkin *et al*, 1977). In their study, Jonassen and Grabowski (1993) summarised research on the implications of individual differences based on FD/FI dimension. We considered these implications of style characteristics in order to design the instructional support and the instructional environment of AES-CS. As a result, the system provides

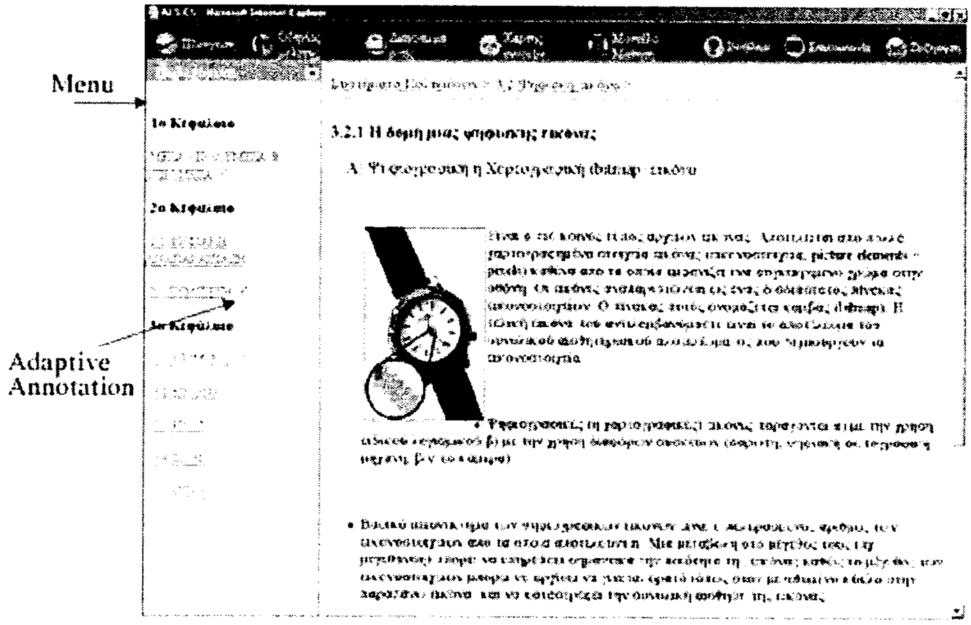

Figure 1: *System screen with the initial adaptation for FI learners*

clear, explicit directions and the maximum amount of guidance to FD learners while it provides minimal guidance and direction to FI learners. Moreover, it provides extensive feedback to FD learners while it provides minimal feedback to FI learners.

Use of a contextual organiser: Another feature that is embedded in AES-CS is the use of contextual organisers according to FD/FI dimension. Field dependent learners appeared to benefit most from illustrative advance organisers, whereas field independent learners preferred illustrative post organisers (Meng and Patty, 1991). An advance organiser is a bridging strategy that provides a connection between one unit and another. It also acts as a schema for the learner to make sense out of the new concept. A post organiser serves as a synopsis and supports the reconstruction of knowledge. Usually, it is available after the presentation of new information.

Structure: AES-CS provides two navigational tools in order to help learners organise the structure of the knowledge domain: concept map and graphic path indicator (Figure 2). Concept map is a visual representation of a knowledge domain and consists of nodes representing concepts connected by directional links that define the relationships of the nodes. Concept maps may act as tools to aid study and assist in the comprehension of a domain. Furthermore, they are flexible tools that can be used by students to develop their own maps to represent various domains of knowledge and can be used to see the 'forests' and the 'trees', thereby avoiding disorientation. In AES-CS a concept map is used to help FD learners understand the big picture and place detail in perspective. The graphic path indicator can orient users to the surrounding hyperspace and to the content organisation, affecting both cognitive overhead and coherence. The graphic

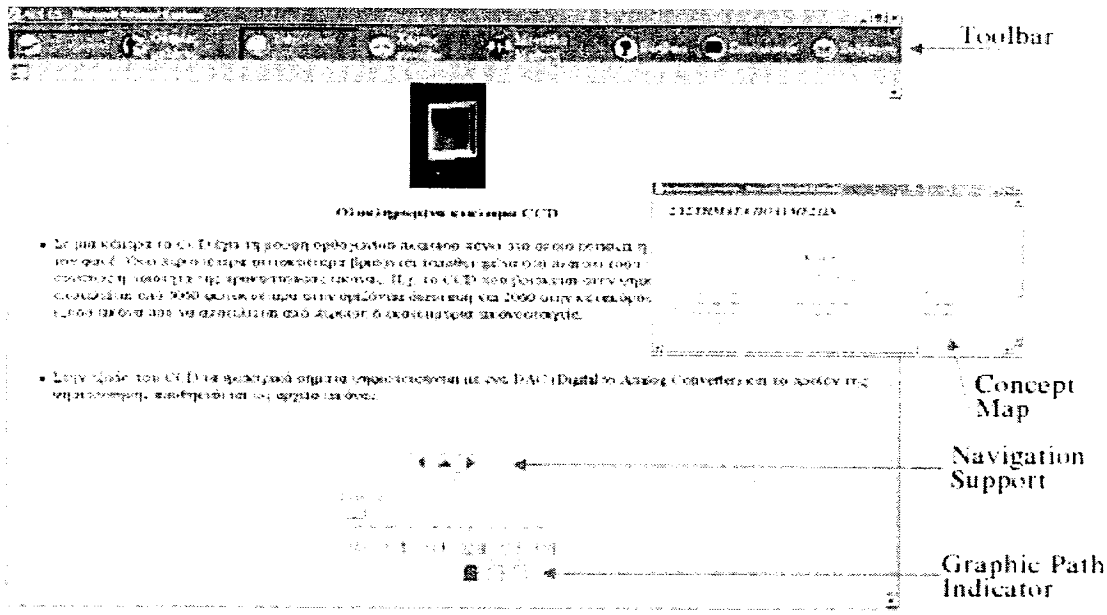

Figure 2: System screen with the initial adaptation for FD learners

path indicator is dynamically created and presents the current, previous and next topic. The graphic path indicator appears at the bottom of each page and illustrates clearly the local neighbourhood of a topic.

Adaptation flexibility

The initial adaptation of AES-CS to FD/FI learners was based on research results (Jonassen and Wang, 1993; Meng and Patty, 1991; Yoon, 1993) and theoretical assumptions in FD/FI dimension (Jonassen and Grabowski, 1993; Witkin *et al*, 1977). According to research results and the theoretical assumptions, AES-CS initially supports FD/FI learners with the respectively instructional strategies (see Table 1). However, users are not simply novice, intermediate or expert but range on a scale of many intermediate values. Furthermore, users are not merely FD or FI learners but instead are some combination of both characteristics. Thus, learners should use a combination of instructional strategies in order to accommodate their individual needs and improve their performance.

AES-CS allows users to change the initial adaptation based on their individual needs. Specifically, learners have the ability to change the initial stage through the student model and/or appropriate interactive features. Learners may modify the control options between learner and program control, may choose minimal or maximum feedback, may request instructions, and so on. The aim of the flexibility provided is the optimisation of the adaptation under the basic assumption that adaptive systems need to be controllable by the user because they cannot be intelligent enough to appropriately adapt in all possible cases.

The empirical study

The course 'Multimedia Technology Systems' is offered to fourth-year undergraduate students. Typically, the students follow the lectures and study through a hypermedia-based environment. Seventy-six fourth-year undergraduate students volunteered to take part in the study. They were divided into two groups: experimental (36 students) and control (30 students). Students in the experimental group studied through the adaptive educational system AES-CS, while students in the control group studied through the traditional hypermedia-based environment.

Four testing instruments were used in this study. The first was the Group Embedded Figures Test (GEFT) (Witkin *et al*, 1971), which was used to determine the cognitive style of the participants. In this test subjects perceived information (a series of simple figures) independently from the larger complex figure in which the simple figures are embedded. This test describes those who tend to rely on external cues and are less able to differentiate an embedded figure from an organised field as being field dependent in addition to those who tend to rely on internal cues and are more able to differentiate an embedded figure from an organised field as being field independent.

The second testing instrument was a pretest with 10 open-ended items, which was designed to determine the subject's prior knowledge with the domain. The third one was an immediate posttest that consisted of a performance test with the same items as the pretest to verify any increase in understanding at the end of the instruction. The fourth was an attitude and acceptance questionnaire for the experimental group that included items relating to the completeness and ease of use of the system as well as items on the subject's satisfaction and willingness to use the system. In addition, debriefing sessions were used to assess student satisfaction with the instructional and interface designs of AES-CS.

Quantitative data

In order to ensure that both groups had the same prior knowledge with the domain, a test for homogeneity of the pretest data was computed. As expected, the result of the ANOVA presented no significant effects. Hence, only the posttest was computed into the statistical analysis.

A 2-way analysis of variance (ANOVA), with *alpha* level set at .05, was used to test for main effects and the interaction assumption between learning environment and cognitive style. The dependent variable was learner achievement (posttest). The results revealed a significant main effect for the learning environment [$F_A(1,62) = 6.633$, $p = 0.012$]. These findings indicate that students in the experimental group performed significantly better than students in the control group. Furthermore, these results provide evidence that the adaptive educational system AES-CS, which was designed to be adapted to individual cognitive styles, can result in improved student interactions and outcomes. On the other hand, the ANOVA results [$F_B(1,62) = 1.305$, $p = 0.258$] did not show a significant main effect of cognitive style for learner achievement. These results suggest that cognitive style alone did not impact on learner performance. In addition,

Table 2: Performance means on pre and post-test

Dependent variable: POST				
GROUP	Cognitive style	Mean	SD	n
ADAPT	FD	18.00	2.10	15
	FI	18.05	1.43	21
	Total	18.03	1.72	36
HTML	FD	16.27	2.10	11
	FI	17.32	2.00	19
	Total	16.93	2.07	30
Dependent variable: PRE				
GROUP	Cognitive style	Mean	SD	n
ADAPT	FD	1.87	1.77	15
	FI	3.10	2.64	21
	Total	2.58	2.37	36
HTML	FD	1.55	1.44	11
	FI	3.58	2.65	19
	Total	2.83	2.46	30

the results also indicated no significant interaction between learning environment and cognitive style [$F_{A \times B}(1,62) = 1.087, p = 0.301$].

To supplement the ANOVA analysis, group means and standard deviations of learner achievement were examined (Table 2). Overall, the group mean results show that the students of the experimental group, which studied through the adaptive educational system AES-CS, had higher means. It is important to note that although FD students in the experimental group had lower means in the pretest, they had almost the same posttest performance as FI students in the experimental group. Moreover, FD students in the experimental group demonstrated significantly higher performance than FD students in the control group. Hence, the results provide evidence that adaptivity based on student's cognitive style could be beneficial for the observed learning outcomes, especially for FD students.

The previous perspective constitutes an adaptation of experimental data in a general linear model, which includes two main effects as well as an interaction. From an alternative perspective, in which the experiment includes only one factor (independent variable), which is produced by the combination of two levels of two initial independent variables, statistical analysis of the data can be used to determine which combination of environment and cognitive style has the better results as for the independent variable. In such cases, multiple comparison tests can be used to investigate which categories of the factor variable are significantly different from other categories. Many

Table 3: Statistical results using the Duncan procedure

Treatment	*Mean*	*SD*	*n*
1_1: AES-CS & FD	18.00 a	2.10	15
1_2: AES-CS & FI	18.05 a	1.43	21
2_1: HTML & FD	16.27 b	2.10	11
2_2: HTML & FI	17.32 ba	2.00	19

*The means, which are followed by the same letter, are not significantly different from each other using the Duncan test at a significance level of .05.

multiple comparison procedures are available. They differ in how they adjust the observed significance level. One of the simplest is the Duncan procedure (Toothaker, 1993), which was adopted by this study in order to compare the four pairs (treatments), Environment X Cognitive Style (2 × 2), as for learner achievement (posttest).

Results using the Duncan procedure and a significance level of .05 indicated that groups 1_1 (AES-CS & FD), 1_2 (AES-CS & FI) and 2_2 (HTML & FI) were not significantly different from each other (Table 3). These findings confirm the evidence that adaptivity based on cognitive style influences the performance of FD students in order to reach the same level of performance as FI students.

Qualitative data

An analysis of the data collected showed that overall the subjects were satisfied with the system. In addition, they felt that the system was clear and easy to understand and after working with it they had a better understanding of the area studied. Furthermore, they felt challenged by the instruction and stated that they wanted to use the system again. However, they also stated that they would prefer to use it as support learning material and not as a substitute to the physical lectures.

The data obtained via the attitude questionnaire and the debriefing sessions yielded important information. The students agreed that initial adaptation based on their cognitive style was very helpful but also stated that the ability to change the initial stage through the student model or appropriate interactive features was very useful. The students indicated as very important the adaptation granularity of AES-CS. They felt challenged by the system's flexibility and they were satisfied with the fact that the system was completely controllable by them.

Conclusion

The objective of the overall research was to compile and synthesise findings in the current literature in an effort to develop a prototype adaptive educational system based on cognitive styles. In order to evaluate the effectiveness of the prototype system, an empirical study was conducted. The results from the summative evaluation of the prototype system support the evidence that the adaptivity based on cognitive styles can ensure that all students can learn effectively in a hypermedia environment. Statistical analyses indicated that students in the experimental group (AES-CS) performed significantly better than students in a control group (HTML). These findings indicate that the adaptive educational system AES-CS, which was designed to be adapted to individual cognitive styles, can be an effective tool to support and promote learning.

A secondary purpose of this study was to see if the adaptivity based on cognitive style influences the performance of FD students in order to reach the same level of performance as FI students. The statistically significant findings in this study confirm the evidence that the adaptivity based on student's cognitive style could be beneficial for the observed learning outcomes, especially for FD students. Finally, an analysis of the data collected showed that the subjects were satisfied with the initial adaptation based on their cognitive style. In addition, qualitative data analysis indicated that the adaptation granularity contributed to overall user satisfaction.

In short, this study showed the important role of cognitive style with respect to student success in hypermedia learning environments. Instructors, therefore, might well be encouraged to consider cognitive style as a valuable factor throughout the development of a hypermedia environment. Further research is needed in order to expand the adaptive features of the system focusing on a dynamic detection of student's cognitive style throughout his/her interaction with the system. With these features, the adaptation of the system would be constant and more effective throughout the educational experience.

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