Cognitive Styles and Adaptive Web-based Learning

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Abstract

Adaptive hypermedia techniques have been widely used in web-based learning programs. Traditionally these programs have focused on adapting to the user's prior knowledge, but recent research has begun to consider adapting to cognitive style. This study aims to determine whether offering adapted interfaces tailored to the user's cognitive style would improve their learning performance and perceptions. The findings indicate that adapting interfaces based on cognitive styles cannot facilitate learning, but mismatching interfaces may cause problems for learners. The results also suggest that creating an interface that caters for different cognitive styles and gives a selection of navigational tools might be more beneficial for learners. The implications of these findings for the design of web-based learning programs are discussed.

1. Introduction

There has been considerable growth in web-based learning (WBL) provision, which employs hypermedia capabilities to offer high-level of flexibility in the delivery of non-linear course material (Federico, 2000). Learners can decide their learning paths, instead of having to follow passively some form of pre-defined linear access (Farrell and Moore, 2000). However, the freedom offered by WBL comes at a price because flexibility increases complexity (Ellis and Kurniawan, 2000). For example, there are problems that are specific to the organisation of hypermedia: some learners who are uncertain of how to

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deal with non-linear learning may meet disorientation problems, disrupting their learning achievement.

One approach to overcoming such difficulties is offered by adaptive hypermedia (AH). AH is hypermedia that can adapt the content presentation and navigation support, to aid users in their search for the information which is most appropriate to them (Wu, et al., 2000). This technique has been widely used is the development of WBL programs. Current adaptive WBL programs have tended to focus on the user's prior knowledge as the basis for adaptation, and research suggests that such programs are useful in aiding learning (Brusilovsky and Pesin, 1998). Recently, another human factor, cognitive style, has been suggested for use in AH systems, for example INSPIRE (Papanikolaou, et al., 2002) and AES-CS (Triantafillou, et al., 2004). However, since these existing programs adapt based on prior knowledge as well as cognitive style, reported benefits cannot necessarily be attributable to the adaptation to cognitive style. In this vein, this study aims to examine whether student learning in a WBL can be enhanced by adapting to cognitive styles alone.

2. Research Rationale

Cognitive styles refer to the way of how users process information. One of the most widely investigated cognitive styles with respect to student learning is field dependence. Field dependence refers to an individual's ability to perceive a local field as discrete from its surrounding field (Witkin, et al., 1977). It is a single bi-polar dimension ranging from Field Dependent (FD) individuals at one extreme to Field Independent (FI) individuals at the other.

Research has indicated differences in the way FD and FI individuals browse through the Web. For example, FD individuals tend to prefer a more restricted interface (Dufresne and Turcotte, 1997) and follow a linear route (Liu and Reed, 1995), whilst the converse is true for FI individuals. In addition, FD users have been found to prefer a breadth-first navigation path, whilst FI users prefer a depth-first path (Ford and Chen, 2001). Further studies have highlighted differences regarding content structure and navigational aid preferences. FD users have been found to perform worse than FI users when there is no explicit structure within the interface (Palmquist and Kim, 2000), becoming confused and disorientated (Wang, Hawk, and Tenopir, 2000). Furthermore, FD users have been shown to prefer using a map as a navigational aid (Ford and Chen, 2000), whilst FI users prefer an index (Liu and Reed, 1995). Such studies are consistent with the conceptual differences between FD and FI individuals. Table 1 describes the relationships between the characteristics of FD and FI users and their navigation preferences.

Table 1. Field Independent vs. Field Dependence navigation preferences

Field Independent		**Field Dependent**	
Characteristic	*Preference*	*Characteristic*	*Preference*
Active approach	Prefer to use index to locate specific items	Passive approach	Rely on map to impose mental structure
Analytical tendency	Prefer depth-first paths	Global tendency	Prefer breadth-first paths
Internally Directed	Prefer non-linear and flexible navigation	Externally Directed	Prefer linear and restricted navigation

Based on Table 1, we developed an adaptive WBL program, which includes two types of interface: FI and FD interfaces (See Section 3.2.1). In addition, a normal interface that incorporated characteristics from these two interfaces was created. Comparing learning performance and perceptions of these three interfaces might help determine whether it is important to consider cognitive styles in the development of adaptive WBL. Therefore, this study aimed to examine this particular issue.

3. Methodology Design

3.1 Participants

64 participants took part in this experiment. All were second year Computer Science students at Brunel University and they had the basic computing and Internet skills necessary to operate a web-based instructional program. They were motivated to take part in the experiment by being told that the tutorial might help them to learn the material associated with the course.

3.2 Research Instruments

3.2.1 Adaptive WBL

An adaptive WBL was created to teach the students about computation and algorithms. This was split into two parts, one part of which was a standard tutorial with Normal Interface, the other adapted to suit either a FD or FI user. In order for some students to use the adaptive interface followed by the Normal interface, and others to use the adaptive interface followed by the Normal interface six half-tutorials were created (Normal, FD, FI for each half). The Normal interface was provided with rich links and multiple navigation tools (i.e. a map, an index, and a menu) to aid the participants in their use of the tutorial.

Table 2. The differences between Field Independent and Field Dependent Interfaces

Adaptive Hypermedia	FI Interface	FD Interface
Link Ordering	Depth-first path	Breadth-first path
Link Hiding	Rich Links	Disabled Links
Adaptive Layout	Alphabetical Index	Hierarchical Map

Both FI (Figure 1) and FD (Figure 2) interfaces were developed based on the findings of previous research, summarised in Table 1. As described in Table 2, three types of AH techniques were applied to develop these two interfaces, and their detailed functionalities are described below:

- *Link Ordering:* the system sorts a list of links according to users' cognitive styles. In the FD interface, the links were sorted based on the breadth-first path, which gave an overview of all of the material before introducing detail. In contrast, the FI interface took the depth-first path, whereby each topic was presented exhaustively before the next topic, which was presented in the same way.
- *Link Disabling:* Due to the fact that FD users easily become disorientated and prefer to take a linear navigation strategy, the FD interface provided restricted navigation choices whereby links were disabled. On the other hand, the FI interfaces provided rich links, leaving freedom of navigation to the users.
- *Adaptive Layout:* Because FD and FI users process information in different ways, adaptive layout was applied to identify the relationships of the subject topics by providing different tools. The FD interface provided a hierarchical map, which could help the FD users to understand the content structure. Conversely, the FI

interface used an alphabetical index to facilitate the location of specific information.

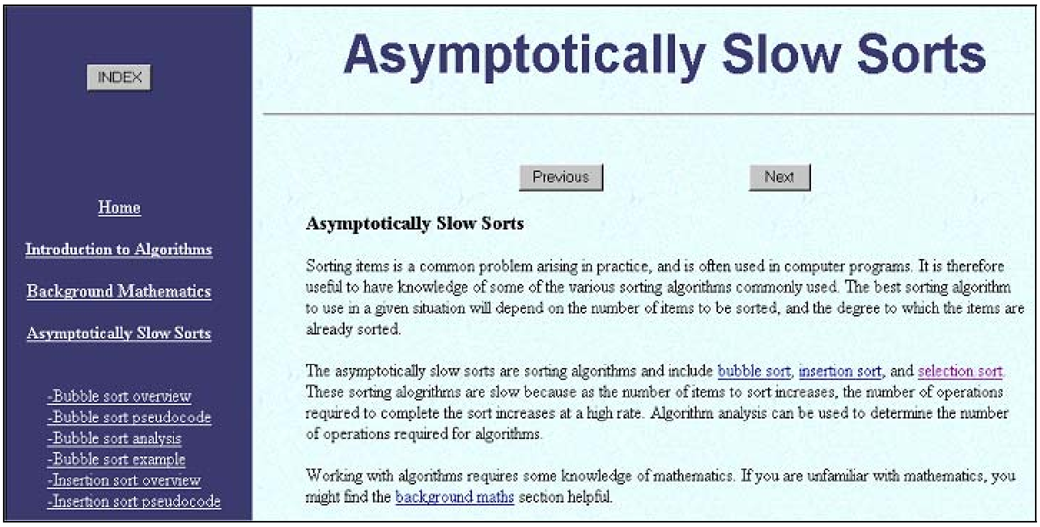

Figure 1 Field Independent Interface

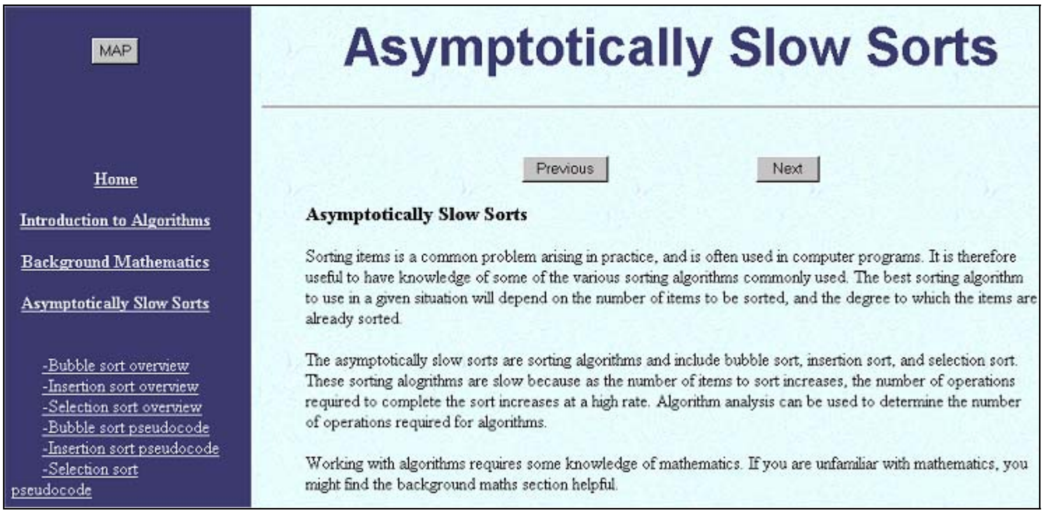

Figure 2 Field Dependent Interface

3.2.2 Questionnaires

Two online questionnaires were created. The first questionnaire asked for background information as well as information regarding the students' levels of prior knowledge of the subject domain. Prior knowledge was measured on a 5-point scale using a series of questions related to the students' level of familiarity with the subject. The second questionnaire asked the students their perceptions of the Web tutorial. This included various questions regarding interface preference between the Normal and Adaptive interfaces, as well as questions regarding the user's ideal interface. This questionnaire, therefore, allowed for the analysis of a number of perceptions of the interfaces and preferences between the two interfaces**.**

3.2.3 Pre- and Post-Tests

Online pre- and post-tests were written to assess the participants' level of knowledge of the subject domain both before and after using the adaptive WBL. Each test contained 20 multiple-choice questions on the subject, 10 of which were related to the first half of the tutorial, and 10 of which related to the second half of the tutorial. For each question, there were five possible responses: four different answers and a "don't know" option. The questions were matched on the pre- and post-tests so that each question on the pre-test had a corresponding similar (but not identical) question on the post-test. Creating similar questions on the post-test was achieved by either re-writing the question or, where appropriate, by substituting different numbers into the questions.

3.2.4 Cognitive Style Analysis

A number of instruments have been developed to measure Field Dependence, including the Group Embedded Figures Test (GEFT) by Witkin et al. and the Cognitive Styles Analysis (CSA) by Riding. The main advantage of the CSA over the GEFT is that FD competence is positively measured rather than being inferred from poor FI capability (Riding and Grimley, 1999). In addition, the CSA offers computerised administration and scoring. Therefore, the CSA was selected as the instrument in this study. In terms of the measures, Riding's recommendations are that scores below 1.03 denote FD individuals; scores of 1.36 and above denote FI individuals; students scoring between 1.03 and 1.35 are classed as Intermediate. In this study, categorizations were based on these recommendations. Table 3 presents the overall range of the scores in this study.

Table 3: The range of style scores in this study

Cognitive Styles	*Mean*	*SD*	*Minimum*	*Maximum*
Field Independent (N=25)	1.5613	.1382	1.36	1.85
Intermediate (N=23)	1.1548	.0095	1.03	1.35
Field Dependent (N=26)	.8182	.1254	.61	1.00
Overall	1.2143	.3243	.61	1.85

3.3 Design

In order to determine whether or not the adaptive interface was better than the normal interface a within-subjects design was used. This meant that each student used both the normal interface and an adaptive interface. To avoid a learning effect, each of these interfaces covered different topics within the tutorial. Since the interfaces were on different topics within the tutorial it was necessary to create both adaptive and normal interfaces for each of the two half-tutorials, so that half of the students used the normal interface for the first half of the tutorial and the adaptive interface for the second half of the tutorial. Similarly, the other half of the students used the adaptive interface for the first half of the tutorial and the normal interface for the second half. This meant that for any student there were four possible experimental conditions: FD interface followed by Normal interface, FI/Normal, Normal/FD, and Normal/FI.

Finally, in order to show that any effects of interface preferences were related to matching with the user's cognitive style rather than just a preference for any adaptive interface, users were randomly matched or mismatched to their cognitive styles: approximately half of the participants used the adaptive interface that was suited to their level of field dependence, whilst the other half used the adaptive interface to which they were not suited and each condition included almost equal number of Intermediate students.

3.4 Procedure

The experiment began by the students taking the CSA to determine their level of field dependence. This was used to automatically provide adaptation of the interface to suit the user's level of field dependence. Students were randomly assigned to an interface that was either matched with their cognitive style or mismatched with it. After taking the CSA, the students completed the first questionnaire. This was followed by the Pre-test. This was timed, allowing the students a maximum of 15 minutes. The Pre-test was followed by using the first interface of the tutorial for 25 minutes, and then the second interface for 25 minutes. This was then followed by the Post-test, again with a 15-minute time limit, before the administration of the second questionnaire.

3.5 Data Analyses

The independent variable was the user's cognitive style as measured by the CSA. The dependent variables were the responses to the various questions about the tutorial from the second questionnaire, as well as learning performance based on the tests. All questionnaire responses, where appropriate, were scored as 5 for "strongly agree", through to 1 for "strongly disagree". Pre- and post-test scores were given as marks out of 20. A "gain score" was calculated as the post-test score minus the pre-test score.

Chi-square tests were used to analyse interface preference in the matched and mismatched conditions, since this data was in the form of frequencies. Pearson's correlations were used to analyse the relationship between field dependence and questionnaire responses, where field dependence was measured on the continuous score as given by the CSA, as opposed to the discrete categories of FD and FI. A significance level of 0.05 was adopted.

4 Results and Discussion

4.1 Interface Preferences

Analysis of participants' interface preferences indicated that there was no significant preference between the Normal interface and the adapted interface for the participants who were matched with their cognitive style. However, those who were mismatched to their cognitive style were significantly more likely to prefer the normal interface over the adapted interface (chi-square = 5.26, df = 1, $p < 0.05$). Figure 3 highlights this finding. This finding suggests that there may be an important interaction between field dependence and interface preference. However, whilst the users were significantly more likely to prefer the Normal interface over the adapted interface when they were mismatched with their cognitive style, there was no significant preference for the adapted interface when the users were matched with their cognitive styles.

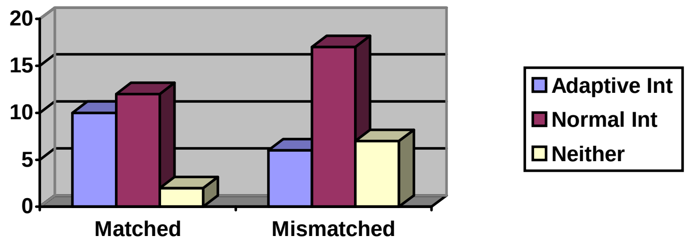

Figure 3. Preferences in matched and mismatched conditions

This suggests that whilst a wrongly adapted interface may cause problems for some users, appropriately adapted interfaces may be no more effective than a well-designed interface for all users. This is consistent with the finding of Ford and Chen, (2001), which showed that mismatched participants experienced more difficulties than matched participants. It is possible that the normal interface in this study contained positive aspects for both FD and FI users. For example, the normal interface provided links within the text that would be suitable for FI users, whilst also having next/previous buttons to provide direct guidance for FD users. Moreover, the normal interface contained both a map and an index. Supporting this conclusion is the fact that 44 of the participants (including seven of FD, seven of Intermediate, and 30 of FI) preferred having a selection of navigation tools. This finding contrasts with previous research indicating that FIs prefer an index and FDs a map (e.g., Liu and Reed, 1995). Whilst it is possible that FDs do prefer a map, and FIs an index, from this study it seems that, overall, users prefer a selection of navigation tools.

This study, thus, poses the question of whether it is possible to create a single interface that can be suitable for both FD and FI users. Whilst it is possible that the adapted interfaces in this study could be further improved to make them better than the normal interface, it is important for further studies to determine whether adapted interfaces can be created that are genuinely beneficial above a single flexible interface used by all. With the findings of this study in mind, it is possibly more beneficial for system designers to concern themselves with an interface that is easy to use for all users, regardless of their level of field dependence. Trying to create distinct interfaces for different levels of field dependence may do more harm than good. Since field dependence is measured on a continuous scale and is only superficially grouped into distinct categories, it is difficult to decide categorically the preferences on any given user. Whilst some users may prefer an interface that is consistent with suggestions of the literature regarding their level of field dependence, others may not. For example, a user at one extreme of the scale may prefer a different interface to a user in the same category, but with a less extreme score. A more suitable interface would be one that was neutral and could support all users, whilst alleviating any particular difficulties that they may have and allowing the user to specify any particular changes that they would like.

Despite the finding that mismatched users preferred the normal interface, Chi-squared tests carried out between FD/intermediate/FI and six other questions referring to aspects of interface preference showed just one significant finding. FI participants found it easier to get lost using the adaptive interface than the Normal interface (chi-square = 4.8, df = 1, $p < 0.05$). However, since significance was not even approached for FD participants or intermediates, nor for the similar questionnaire responses regarding interface navigation, it seems likely that this result is anomalous. Furthermore, analysing gains score showed no significant difference on learning performance using the adaptive interface between those who were matched and those who were mismatched. In fact, the results indicated that those who were mismatched performed marginally better (mismatched mean gain score = 1.1, matched mean gain score = 0.96). In this respect, the experiment is inconsistent with the majority of reported studies (e.g., Ford and Chen, 2000). However, it is consistent with those studies that found no significant differences in learning performance (e.g., Fitzgerald, 1998).

4.2 Ideal Interface Perceptions

Pearson's correlations carried out between CSA score and six questions referring to what the user thought the ideal interface should contain found one significant correlation. The score was correlated with the statement 'how important do you think the following features are to a tutorial: Providing an example of an algorithm first, before giving more detail' ($r = .267$; $p < .05$). This indicated that FD users found providing an example first more important than did the FI users. This result is consistent with previous research (Ford and Chen, 2001) and justifies the FD interface directing the user with an example before giving more detail.

However, it is perhaps surprising that none of the other statements showed any significant correlations, since these were also considered to be characteristics of one or other of the cognitive styles. This suggests that the different preferences between FD and FI users may not be as strong as previously believed. Previous research has suggested that FD users prefer to follow a linear route through hypermedia, whilst FI users prefer to be more flexible (e.g., Dufresne and Turcotte, 1997), yet no such correlation was found in this study. Such results would have important implications for designing WBL programs that tend to adapt to field dependence. Since differences may not be clear cut, adaptation to an interface that is too rigidly 'FD' or 'FI' may not be beneficial, and may not suit the preferences of the individual user. In particular, since only one significant difference was found between FD and FI users in relation to ideal interface design, it is important to determine whether the needs of FD and FI users are as clear-cut as are claimed.

5. Conclusions

In response to the research question, "whether student learning in a WBL can be enhanced by adapting to cognitive styles alone", the answer seems to be that incorporating cognitive styles into adaptive WBL may not be advantageous to students. On the other hand, a single flexible interface that provides multiple options may be useful to all of the students. As results from this study showed, the Normal interface incorporated enough freedom of navigation to suit those who preferred to navigate freely, whilst also providing a suggested route for those who needed structure. It also provided a range of navigation tools that was found to be preferable by the majority of the users to having just one.

This experiment was restricted to the study of field dependence as measured by the CSA. There have been suggestions that the current form of the CSA might not provide reliable measures of cognitive style preference (Peterson, Deary, and Austin, 2003). Future research should therefore re-examine the findings of this study with other cognitive style assessment instruments. Another limitation is that this study adopted a self-developed online survey, so the validity of the questionnaire is questionable. Therefore, testing and modification of the questionnaire are needed in the future. Furthermore, this study was limited in that it provided adaptation to field dependence and field independence in a way considered appropriate for such individuals based on interpretations of previous research into field dependence and WBL. Since some of the findings from this study differ from aspects of pervious research, future studies might consider revising the interpretation used here and re-determine whether different interfaces are needed for FI and FD students, or whether one could satisfy all students regardless of their level of field dependence.

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