Design of adaptive hypermedia learning systems: A cognitive style approach

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ABSTRACT

In the past decade, a number of adaptive hypermedia learning systems have been developed. However, most of these systems tailor presentation content and navigational support solely according to students' prior knowledge. On the other hand, previous research suggested that cognitive styles significantly affect student learning because they refer to how learners process and organize information. To this end, the study presented in this paper developed an adaptive hypermedia learning system tailored to students' cognitive styles, with an emphasis on Pask's Holist–Serialist dimension. How students react to this adaptive hypermedia learning system, including both learning performance and perceptions, was examined in this study. Forty-four undergraduate and postgraduate students participated in the study. The findings indicated that, in general, adapting to cognitive styles improves student learning. The results also showed that the adaptive hypermedia learning system have more effects on students' perceptions than performance. The implications of these results for the design of adaptive hypermedia learning systems are discussed.

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1. Introduction

Adaptive hypermedia learning system (AHLSs) tailor subject content to individual users by employing a user model built based on parameters derived from human factors (Brusilovsky, 2004, Paternò & Mancini, 1999). These human factors, in an educational context, can range from gender differences (Plumm, 2008; Tsai & Tsai, 2010), through prior knowledge (Greene, Costa, Robertson, Pan, & Deekens, 2010; Lee & Chen, 2009), to cognitive styles (Calcaterra, Antonietti, & Underwood, 2005; Chen & Liu, 2008). Thus, human factors play an important role in the development of AHLSs.

Among the aforementioned human factors, prior knowledge has been widely taken into account in the development of AHLSs. Empirical evidence has suggested that matching students' prior knowledge with AHLSs can improve their learning performance (Dochy, 1992; Moerkerke, 1996; Weibelzahl, 2001). However, recent research has considered cognitive styles as another human factor that can be used to drive adaptation in AHLSs. There has been a mixed reception of cognitive styles in AHLSs because previous studies have not shown consistency regarding its effectiveness in improving student learning. Some studies (Boyle, Duffy, & Dunleavy, 2003; Ford & Chen, 2001; Wang, Wang, Wang, & Huang, 2006) have found that adapting to individuals' cognitive styles can enhance student learning while others (Mitchell, Chen, & Macredie, 2005a, 2005b; Tsianos, Germanakos, & Mourlas, 2006) showed that incorporating cognitive styles is not helpful for the improvement of student learning. Therefore, there is a need to further evaluate the effectiveness of AHLSs tailored to cognitive styles.

Among various dimensions of cognitive styles, Pask's Holist–Serialist is influential to student learning (Bajraktarevic, Hall, & Fullick, 2003; Jonassen & Grabowski, 1993; Riding & Cheema, 1991). Several studies found learning environments that matched with the needs of Holists and Serialists could make them have better performance (Ford, 1985; Ford & Chen, 2001; Kwok & Jones, 1995). Therefore, this study aims to examine the effects of an AHLS that provides an adaptation based on Pask's Holist/Serialist dimension. More specifically, this study aims to prototype an AHLS that adapts to the preferences of Holists and Serialists and compare it with an ordinary hypermedia learning system (OHLS) that does not exhibit any adaptation.

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2. Related research

2.1. Adaptive hypermedia learning systems

AHLSs have evolved from research in adaptive hypermedia, which provides individualized content presentation and navigation support based on users' characteristics, like goals, interests, prior knowledge and other preferences. For example, an AHLS that adapts to students' prior knowledge individualize course content to match with each one's prior knowledge. More specifically, students will be given presentation that is adapted specifically to his or her prior knowledge (De Bra & Calvi, 1998) and a suggested set of most links that are relevant to their current status (Brusilovsky, 2003; Brusilovsky, Eklund, & Schwarz, 1998). To achieve this, the AHLS represents these individual characteristics in a user model for adaptation (Kavcic, 2000). The model is then updated as the user's goals and interests change with time or due to some other factors.

AHLSs were one of the first application areas of adaptive hypermedia because, in an educational context, users with alternative learning goals and knowledge require essentially different treatments (Brusilovsky, 1996; Brusilovsky, 2001; Brusilovsky & Peylo, 2003). A number of pioneer AHLSs were developed between 1990 and 1996. During that period, most researchers concentrated on building systems that adapt to students' characteristics (De Bra & Calvi, 1998; Hohl, Böcker, & Gunzenhäuser, 1996; Kay & Kummerfeld, 1994; de La Passardiere & Dufresne, 1992). Classical AHLSs, including ELM-ART (Schwarz, Brusilovsky, & Weber, 1996; Weber & Brusilovsky, 2001) and InterBook (Brusilovsky et al., 1998), tailor course material to students' prior knowledge. Numerous studies have concluded that adapting to prior knowledge is an important approach to increase the effectiveness and efficiency of learning courses and might even increase learners' satisfaction (Boyle & Encarnacion, 1994; Weibelzahl & Weber, 2002).

However, recent research has shifted to the exploration of incorporating cognitive styles into AHLSs, such as INSPIRE (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003) and AES-CS (Triantafillou, Pomportis, & Demetriadis, 2003). Cognitive style, which is a term used in cognitive psychology, describes the way individuals think, perceive and remember information, or their preferred approaches to using such information to solve problems (Riding & Rayner, 1998). Several dimensions of cognitive styles have been studied in the past century, including Holist–Serialist (Pask, 1976), Wholist-Analytical (Riding, 1991), Verbaliser-Imager (Betts, 1909), and Field-Dependence/Field-Independence (Witkin, 1962; Witkin, Moore, Goodenough, & Cox, 1977). Among them, Field-Dependence/Field-Independence has emerged as the most widely studied, with the broadest application in education (Chen & Macredie, 2004; Riding & Cheema, 1991; Witkin et al., 1977). Recently, this dimension of cognitive style was considered in the development of AHLSs (Mitchell, Chen, & Macredie, 2005a, 2005b; Triantafillou et al., 2003). The other dimension of cognitive style, i.e., Pask's Holist–Serialist (Bajraktarevic et al., 2003; Jonassen & Grabowski, 1993), has a conceptual link with Field-Dependence/Field-Independence (Chen & Macredie, 2002). Field Dependent individuals typically perceive objects as a whole and approach a task more holistically. Similar to Field Dependent learners, Holists process information in relatively global ways in that they tend to build an overall picture of the subject area. Conversely, Field Independent individuals focus on individual parts of the object and tend to be more serialistic in their approach to learning. Likewise, Serialists take a similar learning pattern of Field Independent learners, tending to maintain a local focus, concentrating on one thing at a time, and on building up procedural understanding step by step. Such conceptual links between Field-Dependence/Field-Independence and Holists/Serialist demonstrate that Holist/Serialist also has some potential for the development of AHLSs. However, this dimension of cognitive style was ignored in the area of AHLSs. To fill this gap, it is, thus, essential to develop an AHLS that tailor to the needs of Holists and Serialists and then evaluate its effectiveness.

2.2. Cognitive style: Holist–Serialist

Messick (1984) defined cognitive styles as consistent individual different preferences of organizing and processing information and experience (Messick, 1984) while learning style refers to individual skills and preferences that affect how students perceive, gather, and process learning materials (Jonassen & Grabowski, 1993). These two terms share similar meanings and are sometimes used interchangeably. However, previous studies found that these two terms are independent and should be treated as separate constructs (Papanikolaou, Mabbott, Bull, & Grigoriadou, 2006; Sadler-Smith, 2001; Zamani-Zarghani, 1988). This may be due to the fact that cognitive styles are seen as stable characteristics and closely linked to fundamental information processing mechanisms whereas learning styles are considered as variable characteristics and are environmentally dependent (Peterson, Rayner, & Armstrong, 2009).

Although cognitive styles are generally considered as an individual's stable learning preferences (Jonassen & Grabowski, 1993), there are some controversies. In particular, it is still unsure whether instruction with students' cognitive styles can enhance their performance. For example, Boles, Pillay, and Raj (1999) developed computer-based instruction that matched with students' cognitive styles and they found that students consistently demonstrated better performance in such a matching environment. On the other hand, Summerville (1999) also examined matching/mismatch and computer-based instruction but the results showed that matching or mismatching with students' cognitive styles had no effect on their performance. The aforementioned findings suggest that the effects of matching or mismatching cognitive styles remain unclear so there is a need to conduct further investigation.

There are a number of dimension of cognitive styles. As mentioned earlier, the dimension of Holist/Serialist was received less attention in the development of AHLSs. Holist–Serialist was identified by Pask (1976). Pask and his colleagues conducted a series of experiments (Pask, 1979, 1988; Pask & Scott, 1972) to determine learners' basic approaches in learning a range of complex academic topics by monitoring routes taken by learners through the topics. The experiments were set up such that the participants used one of two basic approaches, which are the global and the local approaches. In the global learning approach, termed "Holist", learners examined the interrelationships between several topics early in the learning process. They built a broad conceptual overview into which details could subsequently be fitted. In the local learning approach, termed "Serialist", learners examined one thing at a time and concentrated on separate topics and the logical sequence linking them. Pask found that individuals were consistent in their use of strategies of Holists or Serialists. The differences between Holists and Serialists are summarized in Table 1.

A number of studies found that Holists and Serialists showed different preferences to the use of hypermedia systems. For example, Ellis, Ford, and Wood (1992) found significant differences in navigational tools used by Holists and Serialists. The Holists made great use of the

Table 1
Holists vs. Serialists(adapted from Ford, Wilson, Foster, and Ellis, 2002).

Holists	Serialists
• Pick up bits and pieces with a broad framework	• Build up their knowledge sequentially
• May leave gaps, or repeat themselves	• Tend to lose sight of the bigger picture
• May make mistakes about connections between things	• Are impatient with co-workers who" jump around"
• May over-generalize	• Are more comfortable with inherently sequential problem-solving
• May be more comfortable with "topic" based learning	

concept map while the Serialists considerably used the keyword index. Another study by Ford and Chen (2000) found that Holists spent a greater proportion of their time browsing the high level of the subject content probably because they were dependent on a need to grasp a sense of the structure of the subject content. This was different from the browsing strategies displayed by Serialists, which did not appear to be indicative of such a need. A recent study by Clewley, Chen, and Liu (2009) found that Holists felt more difficult to use back/forward buttons than Serialists. Additionally a further study Clewley, Chen, and Liu (2010) found that Holists preferred to have multiple options while Serialists did not demonstrate such a preference. In addition to the aforementioned works, Chen (2000) also identified the differences in the needs of Holists and Serialists in hypermedia learning, which are summarized in Table 2.

As showed in Table 2, Holists and Serialists have different preferences and needs. Thus, it is necessary to develop an AHLS, which matches with the preferences of Holists and Serialists. To this end, based on the different preferences of Holists and Serialists, an AHLS was developed and incorporated two types of interfaces: one that adapts to Holists and the other that adapts to Serialists. In addition, an OHLS that does not exhibit particular adaptation is developed in order to compare with the AHLS. In summary, this study focuses on examining two research questions: (1) Whether adapting hypermedia learning system to an individual's Holist–Serialist dimension shows any differences in learning performance; (2) Whether adapting a hypermedia learning system to an individual's Holist–Serialist dimension shows any differences in perceptions.

3. Methodology design

3.1. Participants

44 participants from an UK university took part in this study and included 23 males and 21 females. The age group of the participants ranged from 18 to 29. The participants had the basic necessary computing and Internet skills to operate an AHLS. The sample represented students from Information Systems and Computing, Mathematics and Engineering that included both undergraduate and postgraduate students. The participants were chosen from such different disciplines and different levels of course so that the bias of a particular type of domain knowledge or course can be reduced.

3.2. Research instruments

3.2.1. Adaptive hypermedia learning system
The AHLS presents an introduction of XML (e**X**tensible **M**arkup **L**anguage). AHA! was utilized in the development of the prototype of the AHLS (De Bra & Calvi, 1998). However, some extensions and changes to the source code of the 'open source' AHA! were created and implemented for suitability of this study

- The pre-test and post-test were incorporated into the AHA! as sub-components.
- The Study Preference Questionnaire (SPQ) developed by Ford (1985) was adopted and implemented as an online component using Javascript and incorporated into the system.

Three types of adaptive hypermedia techniques, including direct guidance, link hiding and adaptive layout, were applied to develop these two versions, and their detailed functionalities are described in Table 3.

- *Direct guidance*: Direct guidance is the most simple adaptive navigation support technique. It is usually implemented through the "next" button to suggest the best next unit to visit according to the user's goals and other parameters in the user model. Pask's studies show that the Holist is cognitively complex and likes to have several things "on the go" at the same time (Pask, 1976). In contrast to the steady "brick-by-brick" approach of the Serialist, the Holist adopts a comparatively exploratory strategy, switching attention across a range of tasks before any one is securely completed. The Holist version, therefore, requires no direct guidance that would restrict their "jumping

Table 2
Preferences of Holists vs. Serialists.

Holists		Serialists	
Characteristic	Preference	Characteristic	Preference
Passive approach	Rely on a map to impose mental structure	Active approach	Prefer to use index to locate specific items
Global tendency	Prefer breadth-first paths	Analytical tendency	Prefer depth-first paths
Internally directed	Prefer non-linear and flexible navigation	Externally directed	Prefer linear and restricted navigation

Table 3
The differences between Holist and Serialist interfaces of AHLS.

Adaptive hypermedia	Holist interface	Serialist interface
Direct guidance	No guidance	Next/previous buttons
Link hiding	Rich links	Disabled links
Adaptive layout	Hierarchical map	Alphabetic index

around" approach. On the other hand, the Serialists have a narrow focus and follow a step-by-step logical progression, making sure to build solid foundations for each next move. Hence, direct guidance using NEXT/PREVIOUS buttons was used for the Serialist version.

- *Link hiding*: Due to the fact that the Serialists become disoriented and prefer a linear navigation strategy, the Serialist version provided users with restricted navigation choices whereby links within the body of the page were disabled, hence displayed as normal text. On the other hand, rich links within the main body of the text are presented in the Holist version so that users are provided with freedom of navigation and can jump to different subject topics.
- *Adaptive layout*: As suggested by Ellis et al. (1992), Holists preferred to use the hierarchical map to understand the content structure while Serialists favored to use the alphabetical index, which can facilitate them to locate specific information. Thus, adaptive layouts were applied to present the subject topics for Holists and Serialists. More specifically, the former was provided with a hierarchical map whereas the latter was given with an alphabetical index in the AHLS.

As described in the previous section, the AHLS includes two versions, which present the same content, but appropriate adaptive hypermedia techniques were employed to adapt the content to the needs of Holists or Serialists. In other words, there are considerable differences between the Holist version and the Serialist version.

3.2.2. The ordinary hypermedia system

Unlike the AHLS, the OHLS comprised of all components that could be adapted to either Holists or Serialists. For example, the OHLS consists of both an alphabetical index and a hierarchical map on the same page. The participants could use either navigation tool. The content is not tailored for any specific cognitive styles. Furthermore, there are no tools which determine the cognitive style of each participant.

3.2.3. Study preference questionnaire (SPQ)

In an attempt to devise a relatively quick and easy measure of Holist and Serialist biases, Ford (1985) developed the Study Preferences Questionnaire (SPQ), which is an 18-item inventory for categorizing learners as Holists or Serialists. To this end, students were provided with two sets of statements. They were asked to indicate their degree of agreement with either statement or to indicate no preferences (Ford, 1985). As the SPQ has been used in several studies (Clarke, 1993; Ellis et al., 1992; Ford & Chen, 2000; Robertson, 1994), it was chosen for this study, which identified Holists and Serialists by using criteria suggested by the original producer (Ford, 1985): (a) if users agree with over half of the statements related to Holists, they are identified as Holists; (b) if users agree with over half of the statements related to Serialists, they are then considered as Serialists, and (c) if users agree with half of the Holist statements and half of the Serialist Statement, they are then considered as Intermediate. This study showed adequate reliability for the SPQ ($\alpha = 0.67$).

3.2.4. Perception questionnaires

The perception questionnaires were created for examining participants' perceptions to the AHLSs and OHLS. In total, the perception questionnaires included 44 statements, which were classified into four categories: "degree of confidence", "functionality and usability", "presentation and navigation" and "overall perceptions". This questionnaire, therefore, allowed for the analysis of a wide range of user perceptions so that a complete understanding of students' perceptions could be obtained. A 5-point Likert-type scale was employed to measure participants' perceptions. For example, for the question "I found the content of the tutorial too detailed", possible responses were "strongly agree", "agree", "neutral", "disagree" and "strongly disagree". Some questions were positively phrased (e.g., "I found that the suggested route through this tutorial is helpful") and others were negatively phrased (e.g., "I felt the structure of the tutorial was not clear"). The number of negative and positive statements was approximately equal to reduce any bias. The reliability of the perception questionnaires was found to be acceptable ($\alpha = 0.88$).

3.2.5. Pre-test and post-test

The pre-test and post-test were conducted to assess participants' levels of knowledge of the subject domain both before and after using the systems. The pre-test gave an objective assessment of the participants' prior knowledge of the subject domain, as opposed to the subjective measure given by their responses to the perception questionnaire. Each test contained 19 multiple-choice questions covering the content of XML. For each question, there were five possible responses: four different answers and a "I don't know" option. The questions were matched on the pre-test and post-test so that each question on the pre-test had a corresponding similar (but not the same) question on the post-test. Creating similar questions was achieved by either re-writing the question or changing the answer options to TRUE/FALSE and "don't know". The questions in the post-test were also shuffled so that the number sequence was different from the pre-test. The item difficulty index was ranging from 0.27 to 0.85 which was of moderate difficulty (Hopkins, 1988 K.D. Hopkins, Educational and psychological measurement and evaluation (8th ed.), Allyn & Bacon, USA (1988).Hopkins, 1988). Overall, the reliabilities of the pre-test and post-test scores were acceptable. The alpha coefficient of the pre-test scores was 0.73 while the alpha coefficient for post-test scores was 0.82.

3.3. Experimental procedures

In order to determine whether or not the AHLS was better than the OHLS, a between-subjects design was used. In other words, each student used either of the systems once but not both. The same content was used for both systems without incurring the practice and fatigue

effects in the study. Furthermore, each participant went through same procedures in order to minimize bias. The following procedures were followed:

- The participants were initially briefed about the functionality of the system and the available tools that can be utilized to aide learning. This briefing was meant to minimize the gap between system experiences of participants as they were from diverse backgrounds and previous research has shown that system experience can have an effect on learning performance and perceptions (Hill & Hannafin, 1997; Mitchell, Chen, & Macredie, 2005b; Torkzadeh & Van Dyke, 2002).
- The participants were then asked to, carefully, go through a pre-test to measure their initial levels of knowledge. To draw participants' attention to details, answers could not be changed once they have been given. The system also allowed participants to proceed to the next activity once all questions had been answered.
- The participants were automatically provided with the SPQ to determine whether the participants are Holists or Serialists. Subsequently, the right version of the AHLS was presented based on the results of the SPQ. On the other hand, the OHLS provided the same interface for both Holists and Serialists after the SPQ test.
- When the participants had studied the material, they then followed a link to do the post-test. Finally, the participants were provided with the perception questionnaire to express their opinions to the use of the AHLS or the OHLS.

3.4. Data analyses

This study aims to compare the differences between the OHLS and the AHLS based on students' learning performance and perceptions. Participants' post-test scores and gain scores were used to determine the differences in their learning performances. The difference between the post-test scores and gain scores lies within the fact that the former are the scores obtained from the post-test while the latter were calculated as the post-test scores minus the pre-test scores. The intention of using the gain scores is to identify how much improvement students have made. On the other hand, their responses to the perception questionnaire were applied to identify the differences in their perceptions of the employed hypermedia system.

The differences between the OHLS and the AHLS were analyzed by using Statistical Package for the Social Sciences (SPSS) for Windows (release 15.0). Following Cohen (1992), effect sizes can generally be defined as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$). The testing of statistical significance for the differences between the OHLS and the AHLS was done by independent t-tests because they are suitable to compare the means of two independent samples (Hatch & Lazaraton, 1991; Stephen & Hornby, 1997). A significance level of 0.05 was adopted for the study.

4. Results and discussion

4.1. Description of the participants

The OHLS was used by 20 participants, of which there were 10 Holists and 10 Serialists. There was an equal distribution of females and males in the sample. With respect to the participants who used the AHLS, 11 were Holists and 10 were Serialists. For the Holist groups, there is no significant difference in the means of pre-test scores between those that used the OHLS (Mean = 36.41) and the AHLS (Mean = 35.25). The same is true for the Serialist groups, as there is no significant difference between those that used the OHLS (Mean = 26.73) and the AHLS (Mean = 28.10).

4.2. Learning performance

Analysis of learning performance was measured by the post-test scores and the gain scores for students using the OHLS and the AHLS. The group means of the post-test and the gain score are shown in Table 4. For Holists, the group means of post-test and gain scores for the adaptive hypermedia group are higher than the ordinary hypermedia group. Similarly, for Serialists, the group means of post-test and gain score for the adaptive hypermedia group are also higher than the ordinary hypermedia group. Whether the differences between the counterpart groups are significant is further examined by the independent t-tests.

Firstly, the differences between Holists using the OHLS and those using the AHLS are analyzed by using independent t tests. With respect to post-test scores, there is a significant difference between Holists using the OHLS and those using the AHLS (Table 5). With respect to gain scores, the results also indicate that there is a significant difference in learning performance between Holists of the OHLS and those of the AHLS. In other words, the findings not only reveal that Holists in the AHLS demonstrate better performance than those in the OHLS based on post-test scores, but also suggest that Holists in the AHLS make significantly bigger improvement than those in the OHLS according to gain scores.

Subsequently, the differences between Serialists using the OHLS and those using the AHLS are investigated. The results indicate that there are significant differences in post-test scores between Serialists of the OHLS and those of the AHLS. This suggests that the performance

Table 4
The means of the post-test and the gain score for Holists and Serialists.

Variable		Holist		Serialist	
		Ordinary hypermedia	Adaptive hypermedia	Ordinary hypermedia	Adaptive hypermedia
Post-test	Mean (SD)	60.43 (13.36)	71.33 (11.48)	54.60 (9.58)	65.40 (10.26)
Gain Score	Mean (SD)	24.02 (12.50)	36.08 (14.67)	27.87 (12.84)	37.30 (13.49)

Table 5
Summary of independent *t*-tests on learning performance.

Learning Performance		Holist	Serialist
Post-test	*t*	3.307	3.330
	p	0.004	0.009
	d	0.33	0.42
Gain	*t*	2.318	2.291
	p	0.041	0.043
	d	0.24	0.21

of Serialists, with respect to the post-test scores, using the AHLS was significantly higher than that of Serialists using the OHLS. With respect to gain scores, the results also indicate that there was a significant difference between Serialists of the OHLS and those of the AHLS. This implies that the Serialists using the AHLS make significantly better improvement those using the OHLS. The results support previous research (Bajraktarevic et al., 2003; Ford, 1995; Ford & Chen, 2001; Pask, 1979), which found that matched interfaces with students' cognitive styles can result in better performance.

In addition to the aforementioned results, which show that the students using the AHLS show better performance and bigger improvement than those using the OHLS, regardless of their cognitive styles, another interesting finding is that the post-test scores of Holists are higher than those of Serialists while the gain scores of Holists are lower than those of Serialists, without respect to the AHLS or the OHLS. These results do not show statistical significance (*p* > 0.05) but they suggest that Serialists can make better improvement than Holists though the Serialists' preliminary understanding of the subject content are not as good as Holists because the former obtained lower pre-test scores than the latter (see Section 4.1).

4.3. Participants' perceptions

This subsection analyzes the perceptions of Holists and Serialists towards the AHLS, in terms of overall structure, navigational structure and additional support. The results presented in Tables 6 and 7 are items selected from the perception questionnaire based on the semantic relevance to this study. As shown in Table 6, the group means indicated that both Holists and Serialists using the AHLS possessed more positive perceptions toward structure clarity and logical sequence than those using the OHLS. Similarly, the group means of the former also reveal more positive perceptions toward navigational structure and additional support than the latter. The significant difference of each item is further tested as follows.

4.3.1. Participants' views on overall structure

The AHLS offered a hierarchical map for Holists and an alphabetical index for Serialists. Regarding the former, the content was organized into three levels, with topics, subtopics and pages, presenting a global picture of the entire subject content. Regarding the latter, the content was organized alphabetically with all of the nodes covering the topics, subtopics and pages. The OHLS did not employ adaptive hypermedia techniques to tailor to a specific cognitive style. In comparing the OHLS and the AHLS basing on the structural differences, independent *t*-tests were conducted. As shown in Table 7, the results suggest that there are significant differences in perceptions between the groups.

With respect to Holists, the results of the independent *t*-tests indicate that there are significant differences in perceptions towards the structure of the systems between the Holists of the OHLS and those of the AHLS. This means that participants using the AHLS found the structure to be clearer as compared with those using the OHLS. The results of the independent *t*-test also indicate that there was a significant difference in perceptions towards the sequence of topics between Holists of the OHLS and those of the AHLS. This means that the participants that used the AHLS felt the sequence of topics to be more logical than those that used the OHLS.

The same questions were posed to Serialists to determine their views on the structure of their respective systems. There are significant differences in perceptions between participants that used the AHLS and those that used the OHLS. The *t*-test results show that in terms of clarity of structure, Serialists using the former feel it clearer than those using the latter. Similarly, a significant difference was also found when Serialists were asked about how they felt about the logical sequence of topics. The results show that the Serialists that used the former considered the sequence of topics to be more logical as compared with those that used the latter. In summary, with respect to overall structure, the results of this study support prior research, which indicates that AHLSs which adapt the structure of the content to learners' cognitive styles are perceived as useful and enjoyable tools (Ford, 1985, 1995; Ford & Chen, 2001; Palmquist & Kim, 2000).

4.3.2. Participants' views in terms of navigational structure

In terms of navigational structure, Holists using the AHLS have a higher level of enjoyment while their counterparts using the OHLS feel frustrated because it does not provide a suggested route that suits their cognitive styles. Hence, they are prone to getting lost and confused.

Table 6
The means of participants' perceptions.

Perception aspects		Holist		Serialist	
		Ordinary hypermedia	Adaptive hypermedia	Ordinary hypermedia	Adaptive hypermedia
Overall structure 1: I felt the structure of this tutorial is not clear	Mean(SD)	3.04 (1.17)	2.18 (0.75)	2.30 (1.20)	1.80 (0.31)
Overall structure 2: I found the sequence of topics was logical	Mean(SD)	3.01 (1.16)	4.25 (0.87)	3.42 (0.90)	4.10 (1.03)
Navigational structure: It is hard to find a route for a specific topic in this tutorial	Mean(SD)	2.68 (1.11)	1.92 (0.18)	3.66 (1.00)	2.60 (0.98)
Additional support: Sometimes I found it hard to keep track which bits I had learnt	Mean(SD)	3.62 (1.00)	2.50 (0.98)	3.68 (1.03)	2.80 (0.99)

Table 7
t-test results of participants' perceptions.

Perception aspects		Holist (ordinary vs. adaptive)	Serialist (ordinary vs. adaptive)
Overall structure 1: I felt the structure of this tutorial is not clear	t	−3.789	−3.751
	p	*0.004*	*0.005*
	d	−0.870	−0.765
Overall structure 2: I found the sequence of topics was logical	t	4.962	2.466
	p	*0.002*	*0.036*
	d	0.94	0.47
Navigational structure: It is hard to find a route for a specific topic in this tutorial	t	−5.129	−3.977
	p	*0.001*	*0.081*
	d	−1.096	−0.15
Additional support: Sometimes I found it hard to keep track which bits I had learnt	t	−3.124	−3.031
	p	*0.009*	*0.012*
	d	−0.717	−0.786

Italic values represent $p < 0.05$.

The results of the independent *t*-test indicate that there is a significant difference in perceptions towards getting lost using the systems between Holists of the OHLS and those of the AHLS. More specifically, the participants that used the AHLS felt it easier to find a route for a specific topic as compared with those that used the OHLS. Although the problem of navigation and getting lost is not as significant for Serialists as it is for Holists. Serialists using the AHLS feel that the navigational structure is better as compared with those using the OHLS. In other words, they feel it easier to find a specific topic when using the AHLS than the OHLS.

These results support previous findings that matching individuals with their preferred navigational features improves the likeability of a hypermedia system. A number of empirical studies have evaluated the effectiveness of different navigation tools for Holists and Serialists. They found that these tools influence users' achievement and attitudes (Ford & Chen, 2000; Liu & Reed, 1994). The AHLS used in this study employed the same principles to adapt the navigational structure to Holists and Serialists.

4.3.3. Participants' view on additional support

Finally, Holists using the OHLS found it harder to track which bits of information they have learnt as compared with those using the AHLS. For the Serialists, the difference was also significant. Serialists using the AHLS feel it easier to track bits they have learnt than did those using the OHLS. The results support previous findings that show that it is essential to provide different additional support based on users' different cognitive styles (Magoulas, Papanikolaou, & Grigoriadou, 2003).

5. Conclusions

Two research questions were examined in this study: (1) *whether adapting a hypermedia learning system to an individual's Holist–Serialist dimension shows any differences in learning performance;* (2) *whether adapting a hypermedia learning system to an individual's Holist–Serialist dimension shows any differences in perceptions.* The answer to the first research question is that the AHLS that adapts to individuals' cognitive styles improves their learning performance. Likewise, the answer to the second research question is that learners exhibited more positive perceptions towards the AHLS that adapts to individuals' cognitive styles. This study has demonstrated that adapting a hypermedia learning system to an individual's cognitive style can improve his/her learning performance and perceptions. This is in contrast with some studies (Mitchell, Chen, & Macredie, 2005a; Tsianos et al., 2006) that did not find any benefits of adapting to cognitive styles.

However, the present study has also shown that adapting to cognitive styles has different effects on learning performance as compared with learning perceptions. According effect sizes, the relative improvement in learning perceptions is significantly higher than that of learning performance when using the AHLS that adapts to learners' cognitive styles. More specifically, the effect sizes for learning performance are between small and medium while those for learning perceptions are between medium and large. Hence, this study recommends that the design of the adaptive hypermedia learning systems not only needs to incorporate cognitive styles to enhance perceptions of use, but also needs to employ mechanisms that are dedicated to improve learners' performance. This type of design could maximize performance and perceptions of learners using AHLSs. Furthermore, there is also a need to incorporate both prior knowledge and cognitive styles and determination of the right blend in order to maximize learning.

The present study shows fruitful results but there are several limitations. Firstly, the present study only incorporated a small-scale sample and learning content. Hence, it is recommended that further studies should be undertaken with a larger sample and content to provide additional evidence. Such evidence will not only be helpful to improve the design of AHLSs, but also will be useful for the development of other personalized applications, such as e-commerce systems and virtual training environments. Secondly, it has to be noted that there is no runtime adaptation. The systems used in this study, are, in most part, pre-adapted based on the results of the conducted SPQ. The design rationale is based on the assumption that a cognitive style is a trait so it will not be changed during interacting with the system (Witkin et al., 1977).

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