Minsoo Park

INFSCI 3923 Independent Study Paper

Cognitive Factors in Adaptive Information Access

Prof. Peter Brusilovsky

Spring 2005

I. Introduction

Hypermedia has become a major form of information access for many people worldwide in electronic environments. Hypermedia users are freed from the linear flow of printed text (Marchionini, 1988). They are allowed to navigate the huge amount of information, easily accessible, without restraint. However, hypermedia users also require new mental models e.g., navigation strategies for making the best use of their time and effort. Although hypermedia systems offer potentials for creating rich environments for learning any content, some main problems such as disorientation and distraction, are evident for all users (Chen, 2002; Marchionini, 1988; Marchionini, 1995). One cause of disorientation is the quantity of information to which a user has access. Distraction is due to the high level of learner control that hypermedia systems provide. Freedom can be confusing because it increases cognitive load (e.g., attention, decision-making, etc.).

One of the main goals of adaptive hypermedia is to design more user-friendly systems to minimize the problems caused by traditional hypermedia systems. Adaptive hypermedia systems have been built around an individual user's characteristics, such as interests, preferences, knowledge, and goals. Individual differences in the ability to use new information technologies have been an important issue in all fields. Performance differences in utilizing new information technologies are not random; they are sufficiently predictable that we can begin to control them (Borgman, 1989). Therefore, it is necessary to understand psychological mechanisms to explain differences between individuals as well as the levels of performance.

The main purpose of this independent study was to conduct a literature review on cognitive factors, esp., cognitive learning styles, in adaptive hypermedia systems.

II. Cognitive Styles

A style is considered to be a fairly fixed characteristic of an individual, while strategies are the way that may be used to cope with situations and tasks. Strategies may vary from time to time, and may be learned and developed. Styles, by contrast are static and are relatively in-built feature of the individual (Riding and Cheema, 1991).

Cognitive style refers to individual's preferred and habitual approach to organizing and representing information (Riding and Rayner, 1998). The dimension of cognitive style identified by Witkin is field dependence and field independence (Witkin *et al.*, 1977). Field-independent individuals tend to experience the components of a structure field analytically, as discrete from their background, and to impose structure on a relatively unstructured field. By contrast, relatively field-dependent individuals tend to be less good at such structuring and analytic activity, and to perceive a complex stimulus globally as a whole.

Another dimension of cognitive style is the holist-serialist, named by Pask's (1972) studies. Pask's experimental studies show that the holist is cognitively complex, and likes to have several things "on the go" at the same time. In contrast to the steady "brickby-brick" approach of the serialist, the holist adopts what is a comparatively high risk, exploratory strategy, switching attention across a range of tasks before any one is

securely completed and checked as a sure foundation for further progress. The holist progresses in an exploratory fashion compared to the serialist's narrow focus and step-by step logical progression, making sure to build solid foundations for each next move.

Cognitive styles are tendencies displayed by individuals consistently to adopt a particular type of information processing strategy. According to Miyata and Norman (1986), there are two styles of human information processing: task-driven processing and interrupt-driven processing. In a task-driven state, people become engrossed in the task to which they are paying conscious attention and they do not process other events. In an interrupt-driven state, people are usually sensitive to extraneous events, easily distracted by extraneous thoughts and external signals. Individual differences play a role in deciding whether a person is in a state of task or interrupt driven processing. Some people are more easily controlled by task-driven structures; others are more distractible by extraneous events or thoughts.

The dimensions of cognitive style provided by Riding and Rayner (1998) are wholist-analytic and verbal-imagery styles: The wholist-analytic style dimension of whether an individual tends to organize information into wholes or parts; The verbalimagery
style dimension of whether an individual is inclined to represent information during thinking verbally or in mental pictures.

A number of studies have investigated the effect of cognitive styles on hypermedia learning. The studies indicated that different cognitive style groups showed distinct reactions to non-linear interaction, which represents one of the major differences between hypermedia and traditional learning (Chen and Macredie, 2002).

Hypermedia gives people the opportunity to control their learning. Hypermedia makes it easy to freely access large amount of information, which may be accessed using different pathways. Even though hypermedia lets people freely navigate, they need to construct both a mental model of the system structure and the knowledge to be assimilated (Dufresne and Turcotte, 1997). The following studies show how cognitive styles play a role in the way people interact with hypermedia systems.

III. Cognitive Styles in Hypermedia Learning

Cognitive styles play a role in creating knowledge with an influence on information behavior. Ford, Miller & Moss's study (2001) investigating the relationship between cognitive styles and problem solving and its associated information seeking showed that field-independent researchers were more analytic and active than their field-dependent counterparts and holists engaged more in exploratory and serendipitous behavior, and were more idiosyncratic in their communication than serialists.

Wang, Hawk, and Tenopir (2000) investigated how users search for factual information on the Web with a focus on individual differences. The user dimension, one of dimensional factors in the study, was influenced by dynamic situational factors, such as the particular task, the information need, and the knowledge state of the user. In addition, certain individual characteristics influenced the human domain, including an individual's cognitive style and affective state before and throughout the interaction process. They found that differences in cognitive styles affected search process; field-

dependent individuals are likely to greater difficult in the Web environment and to get confused more easily than field-independent individuals.

Palmquist and Kim (2000) studied the effects of cognitive styles and experiences on Web searching. Search performance was measured in terms of time required and the number of nodes traversed to locate relevant information. The study showed that there was a relationship of cognitive style and experience on Web searching. Field-dependent novice searchers took longer and traversed more nodes in locating relevant information than field-independent novices.

Kim and Allen (2002) investigated how students with different cognitive and problem-solving styles navigated the Web. They found that cognitive style affected information searching strategies. Field independent students tended to engage in search tasks with more active and analytic strategies. Field dependent students in contrast did not feel comfortable with using tools for jumping around different nodes and navigate the Web in a linear mode.

In summary, cognitive style studies show that there are differences in the way people interact with hypermedia systems. It seems to be clear that everyone cannot be adapted to the same search/navigation routines in hypermedia learning environments. Instead hypermedia systems need to be further built up to better understand individual differences.

IV. Cognitive Learning Styles in Adaptive Hypermedia Systems: Understanding of the Role of Cognitive Learning Styles in Information Access

In the majority of education environments, a general course is provided to the learners and a one-size-fits-all philosophy is imposed with little regard for a users needs or preferences. If the cognitive/learning theories were not taken into consideration, an individual's effective learning would be hindered. Adaptive hypermedia systems are aimed at tackling and overcoming these difficulties by customizing courses to individual users (Conlan et al, 2002). Adaptive hypermedia has the potential to break through traditional educational barriers by allowing the tailoring of applications to specific user needs and requirements by possessing a model of the user (Bruen, 2002).

Adaptive hypermedia systems build a model of the goals, preferences and knowledge of each individual user, and use this model throughout the interaction with the use, in order to adapt to the needs of that user (Brusilovsky, 2001). According to Brusilovsky (2001), there are two areas of adaptation: adaptive presentation and adaptive navigation support. Adaptive presentation is subdivided into text adaptation and multimedia adaptation technologies; adaptive navigation support is subdivided into link hiding, sorting, annotation, direct guidance, and hypertext map adaptation (Brusilovsky, 2001).

User characteristics have been major interests for some researchers in adaptive hypermedia. De Bra (1999) taking into account user preferences as a variable that decides the adaptation, classifies the hypermedia environments or web sites built according to

their capacity to carry out some type of personalization in adaptable hypermedia, adaptive hypermedia and dynamic hypermedia. The following studies show how adaptive hypermedia systems can tailor content presentation and navigation support to an individual user by taking into account a model of the user's cognitive learning style.

Dufresne and Turcotte's study (1997) investigating the effect of cognitive style for navigation strategies provides some implications for the design of adaptive user interface: First, support navigation to minimize cognitive overload by providing navigation aids such as historical cues, index page, and user guide. Second, take into account users experience of computer system by adapting information retrieval and tutorials both to novice and experienced users. Third, provide flexible navigation options to increase usability.

Chen (2002) studied how students with different cognitive styles react to non-linear learning within hypermedia systems by reviewing the findings of previous studies. She found that field dependent students meet more problems in non-linear learning in hypermedia learning environments. As a solution for them, the author suggests the interface development of adaptive hypermedia learning systems with three types of navigation support techniques: direct guidance, linking hiding, and annotated links. Another study by Chen (2005) explored user's attitudes towards various interface features provided by existing Web directories with an individual differences approach. The findings of the study showed that users' cognitive styles influence their reactions to the organization of subject categories, presentation of the results, and screen layouts. The

authors also provided design guidelines to build a flexible interface, which accommodates the preferences of different cognitive style groups.

Bruen's (2002) study aimed for the corroboration of the premise that the design and delivery of educational technology should depend upon the pedagogic designs conceived by educators rather than depend on the characteristics of the technologies. The study examined the considerations and aspects of learning styles that could make a considerable pedagogical impact on both the narrative selection and the content selection. A descriptive framework was created against pedagogical considerations, for the metadata that would determine the three levels of adaptivity – narrative selection, content group selection, candidate selection. The design of the narrative model was investigated and the relevant changes were made in order to support personalized learning based on the preferred cognitive learning styles of the students.

Adaptive hypermedia tries to deal with the fact that the users are individuals. Most adaptive educational systems take into account learner features like goals/tasks, knowledge, background, hyperspace experience, preferences and interests (Brusilovsky, 2001). However, less attention has been paid in adaptive hypermedia to the fact that people have different approaches to learning, namely that the individuals perceive and process information in very different ways. Recent researches are trying to alleviate this and integrate learning styles in the design of their adaptive applications. One of the difficulties in designing hypermedia software that incorporates learning styles is their actual representation in such an environment. The literature reveals that there have been very few studies, which have set out specifically to investigate the relationship between

learning styles and hypermedia applications, especially adaptive versions (Stash, Cristea, & De Bra, 2004).

Stash, Cristea, & De Bra (2004) in their study introduced a tool to incorporate different learning styles in adaptive educational hypermedia applications. The main purpose of the study was to create a semantically significant interface between classical learning styles and instructional strategies and the modern field of adaptive educational hypermedia. Currently several systems providing adaptation to users' cognitive learning styles have been developed. Most of the adaptive educational systems, which incorporate learning styles, are based on the notion that matching the learning strategies with the learning styles improves learners' performance. Different systems provide adaptation to learning styles in terms of content adaptation, navigation paths, or usage of multiple navigational tools. However the choice of learning styles seems to be limited based on the suitable technology. Also, most of the systems assess the learning styles through questionnaires. The disadvantage of this approach is that the learners are classified into stereotypical groups and the assumptions about their learning styles are not updated during the following interaction with the system (Stash, Cristea, & De Bra, 2004).

In another study by Stash and De Bra (2004), the authors tried to understand aspects of a user's cognitive style by observing his browsing behavior to avoid the questionnaires for identifying cognitive style. The adaptive system (AHA!) developed by De Bra and his colleagues was used to investigate teaching strategies and cognitive styles (e.g., field dependence/independence or verbalizer/imager). AHA! is an example of adaptive systems, which take users' characteristics into account. It allows adaptation of the content

of the web pages shown to the individual users and the links on these pages on the basis of arbitrary user characteristics such as knowledge, interest or preferences. AHA! is a Java servlet based server side extension that provides adaptive presentation and adaptive navigation support (Brusilovsky, 2001). Also, adaptive annotation and link hiding features give the user additional information about the suitability of the destination of a hyperlink.

The popularity of the Web has led to an increasing interest in creating Web-based learning environments. Hypermedia seems to be suitable for supporting active and selfregulated learning. However, empirical studies have shown contradictory results about the efficiency and effectiveness of learning with hypermedia (Triantafillou, Pomportsis, & Georgiadou, 2002). Some studies indicate that hypermedia-based learning may contribute to enhance learning and promote cognitive flexibility when the learning environment is designed task appropriately (Spiro et al., 1991). At the same time, other studies have revealed problems for hypermedia based learning with regards to cognitive overload and disorientation (Marchionini, 1995)

In order to overcome the problems identified, a hypermedia system should be designed in a way that can identify the user's interests, preferences, and needs and give appropriate guidance throughout the learning process. Adaptivitiy is especially important for Web based educational hypermedia, as these systems are expected to be used by several learners without assistance of a physical tutor who usually can provide adaptivitiy in an actual educational environment (Triantafillou, Pomportsis, & Georgiadou, 2002).

Triantafillou, Pomportsis, & Georgiadou (2002) in their study introduces the design and development of an Adaptive Educational System (AES) that includes accommodations for cognitive styles in order to improve student interactions and learning outcomes. In this study, A Higher Education module was developed, called AES-CS (Adaptive Educational System based on Cognitive Styles) as an attempt to examine some of the critical variables, which may be important in the design of an adaptive hypermedia system based on student's cognitive style (Field Dependent / Independent Learners). 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. Each page presents information in a different style according to FD/FI dimension. AES-CS also includes adaptive navigation support in the case of program control option (not in learner control option). Adaptive navigation support is a specific adaptive hypermedia technology that aims to help users to find an appropriate path in a hypermedia learning environment (Brusilovsky, 1996). In program control option, AES-CS provides adaptive navigation support by manipulating the selection and the presentation of links through adaptive annotation and direct guidance. The initial adaptation of AES-CS was based on theoretical assumptions in FD/FI dimension. The basic assumption of the study is that adaptive systems need to maximize user control by letting users have the ability to change the initial stage through the user model and appropriate interactive features. Triantafillou, Pomportsis, & Georgiadou's (2002) study describes the design and development of an Adaptive Educational System based on Cognitive Styles (AES-CS), a prototype that includes accommodations for cognitive

styles in order to improve student interactions and learning outcomes but the study does not include any results of learning outcomes.

Research has shown that learning is more likely to occur if instruction is matched to the student's learning style. Examing the instructional system in this perspective, the notion of adaptiveness presupposes that the system will be able to initially determine and subsequently accommodate the specific learning characteristics of each learner (Giouvanaki et al., 2002).

Graff's (2002) study aimed to investigate the effects of hypertext architecture and cognitive style on learning. In this study, a significant interaction was observed between cognitive style and hypertext architecture for recall questions. The results indicate that individual possessing different cognitive styles learn more efficiently from certain hypertext architectures. This finding is in accord with the cognitive styles matching hypothesis. The cognitive style matching hypothesis essentially suggests that when the cognitive style of a learner and the architecture of a system are matched, then the amount of learning will be improved. The author suggests that the results of the study has important implications for e-learning as it is possible that individuals may benefit by using hypertext architecture designed to take account of their particular cognitive styles.

Another study with the cognitive learning style match/mismatch assumption, was done by Giouvanakis et al. (2002). Their study discusses the design and development of an adaptive instructional system that supports individual learning preferences through a web-based learning environment. The authors also introduce the adaptive elements of the system functioning within a semantic Web environment. According to them, the

personalization of the system takes many forms as it adapts content, tasks, feedback, or navigation to match individual progress and performance. The greatest benefit of learning personalization is the ability of the system to make complex instruction easier by presenting only suitable information that a particular learner wants or need according to specific preferences expressed by the learning style.

One of the main aims of adaptive hypermedia is dealing with individual users. People are different in their goals, background and knowledge on the information covered by the hypermedia system. Users with different goals and knowledge may be interested in different pieces of information presented on a regular page and may use different links for navigation. Information and links, which are irrelevant to users, may cause cognitive load, which is unnecessary in the process of learning. A way to overcome this problem is to use the information about a particular user represented in the user model and so to adapt the information and links (Laroussi and Benahmed, 1998). The following studies show how we can design adaptive interfaces with a focus of adaptive presentation to deal with the individuality of users.

Many researchers of educational technology agree that learning materials should be designed for all types of learners and learning styles (Felder and Silverman, 1988). An effective way of achieving this is by using multimedia to target combination of media on the different styles of learner (Beacham et al., 2002). Adaptive presentation technique is partially based on the theoretical assumption of dual coding model. According to dual coding theory, by choosing an appropriate combination of media, learning outcomes can be improved. Information that uses verbal and relevant visual illustrations will likely be

learned better than information that uses text alone, audio alone, a combination of text and audio, or illustrations alone.

With the theoretical foundation of dual coding, Beacham et al. (2002) investigated if different media combinations could be shown to improve students' understanding of computer-based learning materials and to determine whether student learning style affected student understanding for different media combinations using dual coding theory. The results of the study indicate that the sound and diagram combination can improve participants' understanding regardless of their preferred learning style, and that intuitive learns seem to be exceptionally volatile to different media combinations. The study also introduces an approach for developing adaptive user interfaces that change according to styles and media combination.

Another study on adaptive interfaces and cognitive learning styles, was done by Laroussi and Benahmed (1998). The authors applied the concepts of cognitive learning styles and learning strategies into the design of adaptive hypermedia system to generate an educational hypermedia presentation. CAMELEON was introduced. CAMELEON (Computer Aided Medium for Learning On Network) is a system running across the Internet / Intranet allowing teacher introduce his/her course and the learner to study (presentation of the course material, assessments, etc.) via an adaptive interface. The key assumption underlying the study is that learning is the result of conscious interaction between the student and the learning material stored in the system.

The student can navigate through this material in either a free or guided way depending on their learning styles. Hypermedia has the potential of providing many

benefits to the learner, the use of hypermedia is associated with the idea of the learner control, the learner decides which topics they will view and in what order, how topics are related and how long they will spend on each topic, etc. Most previous studies on adaptive systems have only focused on dynamically assembling information and presenting it according to the user's class or knowledge state without including the user's learning procedure in identifying which information to present to students (Laroussi and Benahmed, 1998). To make information presentation in a hypermedia environment effective and its management efficient, it is necessary that text, graphics, and images need to be properly displayed, based on users' cognitive profiles.

References

Beacham, N.A., Elliott, A.C., Alty, J.L., and Al-Sharrah, A. (2002). Media combinations and learning styles: A dual coding approach. In: Barker, P. and Rebelsky, S. (eds.). Proceedings of ED-MEDIA'2002 (Denver, CO, June 24-29, 2002), AACE, 610-611.

Borgman, C. L. (1989). All users of information retrieval systems are not created equal: An exploration into individual differences. *Information Processing & Management, 25*, 237-252.

Bruen, C. (2002). A Development framework for re-useable learning resources for different learning styles and requirements. In: Driscoll, M. and Reeves, T.C. (eds.)

Proceedings of World Conference on E-Learning, E-Learn 2002, AACE, 1238-1241.

Brusilovsky, P. (1996). Methods and techniques of adaptive hypermedia. *User Modeling and User Adapted Interaction, 6,* 87-129.

Brusilovsky, P. (2001). Adaptive hypermedia. *User Modeling and User-Adapted Interaction, 11,* 87-110.

Chen, S. Y. (2002). A cognitive model for non-linear learning in hypermedia programmes. *British Journal of Educational Technology, 33(4),* 449-460.

Chen, S. Y. (2005). A flexible interface design for Web directories to accommodate different cognitive styles. *Journal of the American Society for Information Science and Technology, 56(1),* 70-83.

Chen, S. Y., & Macredie, R. D. (2002). Cognitive styles and hypermedia navigation: development of a learning model. *Journal of the American Society for Information Science and Technology, 53(1),* 3-15.

Conlan, O., Wade, V. P., Gargan, M., & Bruen, C. (2002). Multimodel, metadata driven approach to adaptive hypermedia services for personalized e-learning. Proceedings of 2nd International Conference on Adaptive Hypermedia and Adaptive Web Based Systems. May 29-31, 2002. Malaga, Spain.

De Bra, P. (1999). Design issues in adaptive hypermedia application development, *Proceedings of the 2nd Workshop on Adaptive Systems and User Modeling on the World Wide Web. 29-39.* Toronto, Banff, Canada, 1999.

Dufresne, A., & Turcotte, S. (1997). Cognitive style and its implications for navigation strategies. In B. Boulay & R. Mizoguchi (Ed.), *Artificial intelligence in education knowledge and media learning system* (pp. 287-293). Kobe, Japan: Amsterdam

IOS Press.

Felder, R.M., & Silverman, L.K. (1988). Learning and teaching styles in engineering education. *Journal of Engineering Education, 78(7),* 674-681.

Ford, N., Miller, D., & Moss, N. (2001). The role of individual differences in Internet searching: An empirical study. *Journal of the American Society for Information Science and Technology, 52(12),* 1049-1066.

Giouvanakis, T., Tarabanis, K., Bousiou, D., and Samaras, H. (2002). Exploring the strengths and limitations of learning styles towards the design of an adaptive web-based instructional system. In: Barker, P. and Rebelsky, S. (eds.). Proceedings of EDMEDIA' 2002 (Denver, CO, June 24-29, 2002), AACE, 1707-1712.

Graff, M. (2002). Learning from hypertext and the analyst-intuition dimension of cognitive style. In: Driscoll, M. and Reeves, T.C. (eds.). Proceedings of World Conference on E-Learning, E-Learn 2002, (Montreal, Canada, October 15-19, 2002), AACE, 361-368.

Kim, K. S. & Allen, B. (2002). Cognitive and Task Influences on Web Searching Behavior*, Journal of the American Society for Information Science and Technology, 53(2),* 109-119.

Laroussi, M. and Benahmed, M. (1998). Providing an adaptive learning through the Web case of CAMELEON: Computer Aided MEdium for LEarning on Networks. In: Alvegård, C. (ed.). Proceedings of CALISCE'98, 4th International conference on Computer Aided Learning and Instruction in Science and Engineering, (Göteborg, Sweden, June 15-17, 1998), 411-416.

Marchionini, G. (1995). *Information seeking in electronic environments:*

Cambridge series on human-computer interaction. Cambridge: Cambridge University Press.

Miyata, Y., & Norman, D. A. (1986). Psychological issues in support of multiple activities. In D. A. Norman, & S. W. Draper (Eds.), *User-centered design* (pp. 265-284). NJ: Lawrence Erlbaum.

Palmquist, R. A., & Kim, K. S. (2000). Cognitive style and on-line database search experience as predictors of Web search performance. *Journal of the American Society for Information Science and Technology, 51(6),* 558-566.

Pask, G. (1972). A fresh look at cognition and the individual. *International Journal of Man-Machine Studies, 4*, 211-216.

Riding, R., & Cheema, I. (1991). Cognitive styles: an overview and integration. *Educational Psychology, 11*, 193- 216.

Riding, R. & Rayner, S. (1998). *Cognitive styles and learning strategies: Understanding style differences in learning and behavior*. London: David Fulton Publisher.

Spiro, R.J., Feltovich, R.J., Jacobson, M.J., & Coulson, R.L. (1991). Cognitive flexibility, constructivism and hypertext: Random access instruction for advanced knowledge acquisition in ill structured domains. Educational Technology, 31, 24-33.

Stash, N., Cristea, A., and De Bra, P. (2004). Authoring of learning styles in adaptive hypermedia: Problems and solutions. In: Proceedings of The Thirteenth International World Wide Web Conference, WWW 2004 (New York, NY, 17-22 May, 2004), ACM Press, 114-123.

Stash, N., & De Bra, P. (2004). Incorporating cognitive styles in AHA!.

Proceedings of the IASTED International Conference. Web-Based Education. February 16-18, 2004. Innsbruck, Austria. 378-383.

Triantafillou, E., Pomportis, A., and Georgiadou, (2002). E. AES-CS: Adaptive educational system based on cognitive styles. In: Brusilovsky, P., Henze, N. and Millán, E. (eds.). Proceedings of Workshop on Adaptive Systems for Web-Based Education at the 2nd International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2002) Proceedings, (Málaga, Spain, May 28, 2002), 1-11.

Wang, P., Hawk, W. B., & Tenopir, C. (2000). Users' interaction with World Wide Web resources: an exploratory study using a holistic approach. *Information Processing and Management, 36*, 229-251.

Witkin, H .A., Moore, C. A., Goodenough, D. R., & Cox, P. W. (1977). Fielddependent and field-independent cognitive styles and their educational implications. *Review of Educational Research, 47(1),* 1-64.