

Evaluation of a Personalized Digital Library based on Cognitive Styles: Adaptivity vs. Adaptability

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Abstract

Personalization can be addressed by adaptability and adaptivity, which have different advantages and disadvantages. This study investigates how digital library users react to these two techniques. More specifically, we develop a personalized digital library to suit the needs of different cognitive styles based on the findings of our previous work (Frias-Martinez, et al., in press). The personalized digital library includes two versions: adaptive version and adaptable version. The results showed that users not only performed better in the adaptive version, but also they perceived more positively to the adaptive version. In addition, cognitive styles have great effects on users' responses to adaptability and adaptivity. These results provide guidance for designers to select suitable techniques to develop personalized digital libraries.

Keywords: Digital Libraries, Cognitive Styles, Individual Differences, Personalization

1. Introduction

Digital Libraries (DLs) can be defined as collections of information that have associated services delivered to user communities using a variety of technologies (Callan et al. 2003). In general, DLs are the logical extensions and augmentations of physical libraries in an electronic information society. Such extensions and augmentations offer new levels of access to broader audiences of users (Marchionini, Plaisant and Komlodi, 2003). In other words, users of DLs may have a greater variability, in terms of their background, knowledge and skills. Thus, human factors play an important role in the use of DLs. Among various human factors, cognitive style is one of the pre-search characteristics for information seekers (Spink et al., 2002). Cognitive style refers to tendencies shown by individuals consistently to use a particular type of information processing strategy (Ford, et al., 2002). Previous research has indicated that cognitive styles greatly affect users' information seeking (e.g., Palmquist and Kim, 2000 and Ford, et al., 2005). In particular, our previous work (Frias-Martinez, et al., in press) indicated that different cognitive style groups have different preferences for the use of DLs. Therefore, there is a need to develop personalized DLs based on users' cognitive styles.

Personalization can be addressed by two major approaches. One uses *adaptability* that enables users to adapt the content layout and navigation support to their preferences by themselves while the other requires *adaptivity* to make an automatic adaptation for users (Treiblmaier, et al., 2004). These two approaches provide pros and cons of controllability to users (Jameson and Schwarzkopf, 2002). In order to develop efficient personalized DLs, it is essential to compare their impacts. This issue is especially important to DLs, which is being used by a diverse population. To this end, the study presented in this paper aims to examine how adaptability and adaptivity are experienced by DL users. More specifically, this is a follow-up study, in which a personalized DL was developed based on the findings of our previous work (Frias-Martinez, et al., in press) and then we investigated how users reacted to adaptability and adaptivity provided by the personalized DL.

The rest of the paper is organized as follows. In Section 2, we briefly highlight previous work on cognitive styles in DLs and present related research on personalization. Section 3 describes the methodology used to conduct the study. Subsequently, the results related to users' reactions to adaptability and adaptivity are presented in Section 4, which

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also includes a comparison with the findings of our previous work (Frias-Martinez, et al., in press). Finally, conclusions are drawn and possible directions for future works are identified in Section 5.

2. Related Work

2.1 Digital Libraries

The World Wide Web (Web) enables wide dissemination of information and services (Ivory and Megraw 2005), digital libraries (DLs) being one of the most common mechanisms for this purpose. As DLs become more important in our everyday activities, their contents and services become more varied. The collections of DLs can be business, scientific or medical (Stelmaszewska and Blandford, 2004, Adams and Blandford, 2002) and information can be represented as a digital text, image, audio, video or other media. Due to the amount and great variety of information stored, DLs have become one of the major Web services (Liaw and Huang, 2003). Previous studies indicate that the use of Web services is affected by a number of human factors, among which cognitive styles play an influential role.

There are a variety of dimensions of cognitive style, but among these dimensions, Field Dependence versus Field Independence has great impacts on users' information seeking on the Web, because it reflects how well an individual is able to restructure information based on the use of salient cues and field arrangement (Weller et al. 1994). The key issue of Field Dependence lies within the differences between Field Dependent and Field Independent users, which are presented below:

- Field Independence: the individuals tend to exhibit more individualistic behaviors since they are not in need of external referents to aide in the processing of information. They are more capable of developing their own internal referents and restructuring their knowledge, are better at learning impersonal abstract material, are not easily influenced by others, and are not overly affected by the approval or disapproval of superiors.
- Field Dependence: the individuals are considered to have a more social orientation than Field Independent persons since they are more likely to make use of externally developed social frameworks. They tend to seek out external referents for processing and structuring their information, are better at learning material with human content, are more readily influenced by the opinions of others, and are affected by the approval or disapproval of authority figures. (Witkin et al. 1977).

Previous research showed that Field Independent and Field Dependent users behave differently when they interacted with the Web. Palmquist and Kim (2000) investigated the effects of cognitive styles and online database search experience on Web search performance. The Group Embedded Figures Test (GEFT) was administered to identify the cognitive styles of the 48 undergraduate college students. Their results showed that Field Dependent novices frequently made greater use of embedded links than other users. Additionally, Kim et al. (2004) conducted an experimental study on web searching strategies of 50 elementary students. Likewise, the GEFT was applied to classify the students' cognitive styles. Their finding indicated that Field Independent group preferred the keyword-based style when they perform the alternative searches to improve their precision/recall ratio. On the other hand, Field Dependent group had a preference for changing options and attempting the alternative option features provided by search engines. Furthermore, another study by Ford et al. (2005) sought to discover the effects of human individual differences on Web search strategy. Their sample consisted of 250 master students and the Cognitive Style Analysis (CSA) was used to measure their cognitive styles. The results indicate that there is a link between low levels of Boolean searching and Field Independence and a link between high levels of Boolean searching and Field Dependence.

As showed in these studies, Field Independent and Field Dependent users have different preferences for the use of the Web. DL is one of major services provides by the Web. Therefore, it is necessary to investigate how to develop effective personalized DLs that can accommodate the needs of Field Independent and Field Dependent users.

2.2 Personalization

Personalization tailors content, structure, and/or presentation to match the unique and specific needs of each individual (Fink and Kobsa, 2000). Personalization can be delivered by either providing adaptability or adaptivity. In terms of the former, users are allowed to modify the content presentation and navigation facilities by themselves.

On the other hand, the latter automatically adapts to users based on observed behaviors (Stephanidis and Savidis, 1995). In brief, the former is user-driven while the latter is system driven. In other words, these two approaches differ with respect to who takes the initiative (Kay, 2001). Adaptable DLs are *user-controlled* while adaptive DLs are *system-controlled* (Finlater and McGrenere, 2004). Giving the control to the users can reduce the effect of incorrect adaptation. However, the cost of the increased controllability is the additional effort required from the users. The users may need to learn the adaptation component before being able to manipulate it (Tsandilas and Schraefel, 2004).

Although adaptability and adaptivity have different advantages and disadvantages, both of these approaches have been used in DLs. An example of the first approach is that MyLibrary provides basic personalization mechanisms regarding information retrieval and content personalization (Cohen et al., 2000; Winter, 1999), where all those processes are user-driven. There are a lot of different implementations of MyLibrary, such MyLibrary@LANL Research library (Di Giacomo et al., 2001) and My.UCLA (Winter, 1999). The other example of this approach is CYCLADES (Candela and Straccia, 2003), which provides an integrated environment for users and a group of users to search large and heterogeneous archives in a flexible way. An example of the second approach is the study of Semeraro et al. (2000), which presents an agent designed to suggest improved ways to make queries with the DL on the grounds of the documents stored in a personal catalogue. Another example of this approach is the study of McKeown et al. (2003), which presents a personalized information retrieval system for medical literature that re-ranks the results of a search by taking into account the patient record. Such an approach can help the doctor in the process of finding relevant literature to that particular patient.

The aforesaid examples demonstrate that both adaptability and adaptivity are not new techniques for DLs but paucity of comparisons between adaptability and adaptivity has been conducted based on user testing (McGrenere, Baecker, and Booth, 2002). Thus, empirical evaluation becomes paramount because such evaluations can provide concrete prescriptions for selecting a suitable technique for the development of personalized DLs. In this vein, this study addresses this issue by investigating the following two research questions: (1) *whether users perform differently and/or showed different perception to adaptability and adaptivity*; (2) *whether users' cognitive styles have effects on their responses to adaptability and adaptivity*.

3. Methodology

3.1 Research Instruments

The research instruments used include: (1) Cognitive Style Analysis (Riding 1991) to measure participants' cognitive styles, (2) the Personalized DL, which is the focus of the study, and (3) a set of questionnaires for capturing users' perception.

3.1.1 Cognitive Style Analysis

A number of techniques have been developed to measure Field Dependence/Field Independence, from which we chose the Cognitive Styles Analysis (CSA) by Riding (1991). The CSA test includes two sub-tests: (1) the first presents items containing pairs of complex geometrical figures that the individual is required to judge as either the same or different and (2) the second sub-test presents several items each comprising a simple geometrical shape, such as a square or a triangle, and a complex geometrical figure and the individual is asked to indicate whether or not the simple shape is contained in a complex one by pressing one of the two marked response keys (Riding and Grimley 1999). These two sub-tests have different purposes. The first sub-test is a task requiring Field Dependent capacity, while the second sub-test requires the disembedding capacity associated with Field Independence. This provides an important advantage over other methods that only measure one of the factors.

The CSA measures what the authors refer to as a Wholist/Analytic (WA) dimension, noting that this is equivalent to Field Dependence (Riding and Rayner 1998). The WA dimension is a real number between the values of 0.6 and 3.0 that indicates the degree of Field Dependence. Riding's (1991) recommendations are that scores below 1.03 denote Field Dependent individuals; scores of 1.36 and above denote Field Independent individuals; and scores between 1.03 and 1.35 are classified as Intermediate. In this study, the categorizations were based on these recommendations.

3.1.2 Personalized DL

The development of a personalized DL was on the basis of Brunel Library Catalogue (BLC), which is typical DL used to access the bibliographical resources. BLC has two main mechanisms that provide different strategies for finding information: (1) Basic Search: to allow users to run a quick search of the library catalogue using a set of keywords and one of the following commands: “word or phrase”, “author” “title” or “periodical title”; and (2) Advanced Search: to present users with a much broader way of searching for information. According to functionalities provided by the original BLC, two versions of the personalized DL were developed. One is an adaptive version while the other is adaptable version. In respects of the adaptive version, the design was based on the findings of our previous study (Frias-Martinez, et al., in press), which are summarized below:

- Field Independent users utilize *Basic Search (BS)* as the main option and also rely more on *Author/Title/Periodical (ATS)* than on *Word or Phrase (SE)*. There is a relevant use of the *New Search (NS)* button. *Advance Search (AS)* is also used although in a smaller proportion than *Basic Search (BS)*.
- Field Dependent users utilize only the *Basic Search (BS)* option combined with *Author/Title/Periodical (ATS)* and to some extent *Word or Phrase (SE)*. Furthermore, it is notable the use of the *Backward/Forward (BF)* buttons.
- Intermediate users do not have a clear preference for a particular interface feature. It suggests that the combination of various interface features, i.e. the original BLC interface, is a suitable personalized interface for them.

Figures 1, 2 and 3 present the adaptive version of the personalized DL for each cognitive style. Each version was automatically generated according to each cognitive style using Privoxy. In other words, user receives an adaptive version of BLC based on his/her cognitive style through Privoxy, which is a programmable proxy server that can filter the elements that were irrelevant for each cognitive style. More specifically, three filters were defined, one for each cognitive style. Each filter basically removes links that were not to be used by each cognitive style.

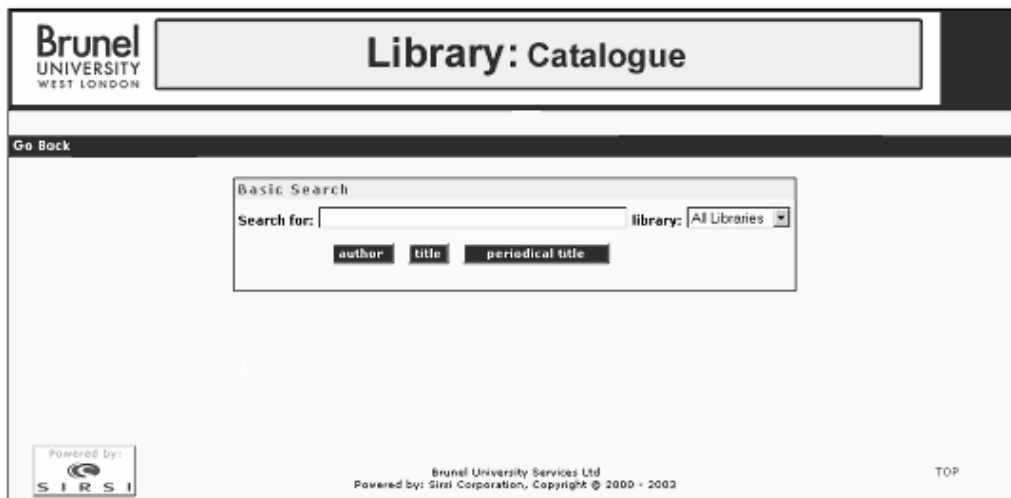


Figure 1: Adaptive version of DL for Field Independent users

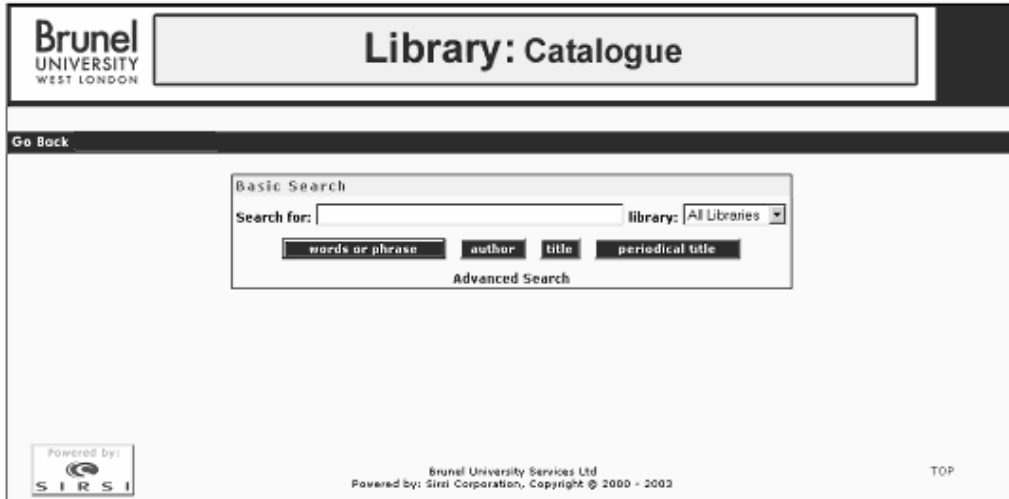


Figure 2: Adaptive version of DL for Intermediate users

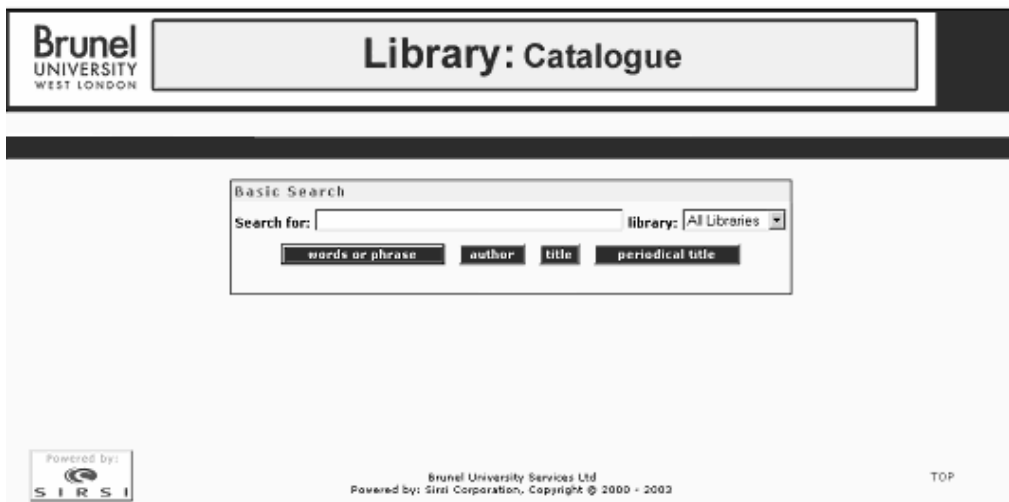


Figure 3: Adaptive version of DL for Field Dependent users

In respects of the adaptable version, users were provided with a menu that allowed for the activation/deactivation of the functionalities offered by the original BLC. In other words, each functionality could be activated or deactivated as desired by the users. Functionalities included: Search by Word or Phrase, Search by Author, Search by Title, Search by Periodical, Advance Search, Limit Search, Back Button, Backward/Forward button and Help button. Figure 4 presents the design of the adaptable version of the personalized DL.

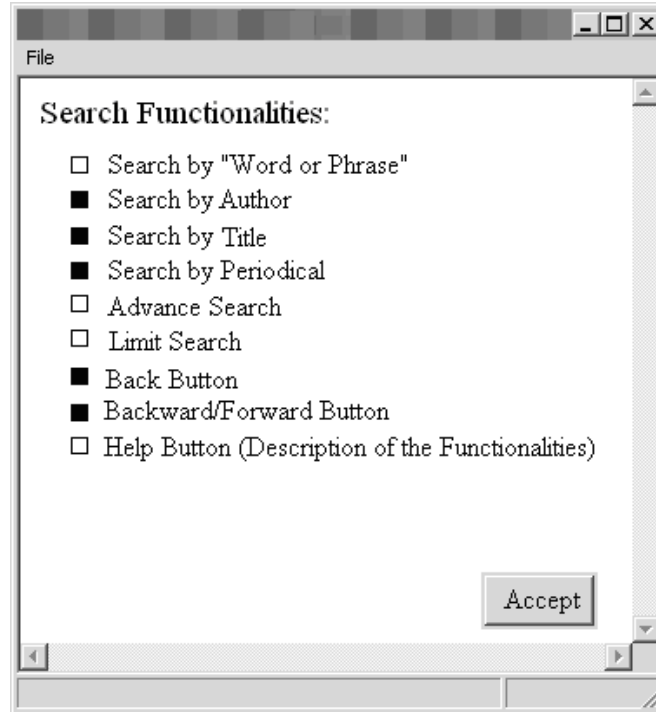


Figure 4: The Adaptable Version of DL

3.1.3 Perception Questionnaires

In order to capture users' perception for the adaptive and adaptable versions of the personalized DL, two questionnaires were used in this study: the Questionnaire for User Interface Satisfaction (QUIS) (Chin et al. 1988) and Computer Usability Questionnaire (CSUQ) (Lewis 1995). QUIS is a tool designed to assess users' subjective satisfaction with specific aspects of the human-computer interaction. Although QUIS is a very complete questionnaire, for the purpose of this study, we used a summarized QUIS test available on-line (<http://www.acm.orf/~perlman>). In this version, the questionnaire is divided into five sections (Overall reaction to the software, Screen, Terminology and System Information, Learning and System Capabilities) with a total of 27 questions. Each area measures the users' overall satisfaction with that facet of the interface, as well as the factors that make up that facet, using a (0-9) scale. CSUQ, developed by IBM, was designed to evaluate the usability of a computer program, not necessarily a web service. It contains 19 questions, each being a statement that the user has to rate on a (1-7) scale ranging from "strongly disagree" to "strongly agree".

3.2 Task Design

When interacting with the adaptive and adaptable versions of personalized DL, the participants were asked to perform eight practical tasks, which are presented in Table 1. The aim was to have tasks at a level of complexity that maintained motivation in the participants (Scanlon, 2000). Furthermore, carrying out these tasks could make the participants experience all functionalities provided by the two versions of the personalized DL. Thus, we were able to identify perception of the participants. Moreover, these tasks were used for the assessment of their performance, including time and transactions required for completing the tasks. One hour was allocated for each participant to complete the tasks.

Table 1. Set of Tasks Designed and Their Type

No.	Task
1	Find the Call Number of the book “The Man in the High Castle”
2	Find the title of any book related to applications of fuzzy logic.
3	Find the number of books written by Aldous Huxley
4	Find a book about how to implement data mining with Java.
5	Find a Java book written by Hugh Vincent.
6	Find a book about 20 th century American Drama.
7	Find the Call Number of the book Homage to Catalonia by G. Orwell
8	Find an IEEE journal on consumer electronics.

3.3 Procedure

This study includes 60 participants, of who 23 are Field Independent, 12 are Intermediate, and 25 are Field Dependent. The study used a within subject design. To avoid an order effect, the participants were divided into four groups, each of which included 15 participants. Two groups used the adaptive version first and then used the adaptable version whereas the other two groups reversed the order. For the two groups that began by using the adaptive version, one group was asked to do the first four tasks described in Table 1 when interacting with the adaptive version. Conversely, the other group was asked to do the last four tasks described in Table 1 when interacting with the adaptive version. The same arrangements were made for the two groups that began by using the adaptable version.

Before the participants interacted with the adaptive version, Riding’s CSA was used to classify their cognitive styles and then each participant interacted with the personalized DL matching with his/her cognitive style. After finishing either the adaptive or adaptable version, the participants needed to fill out the CSUQ and QUIS questionnaires to express their satisfaction with using the personalized DL.

3.4 Data Analyses

Two independent variables are included this study. One is the design of the personalized DL, which includes two versions: adaptive version and adaptable version. The other independent variable is the participants’ cognitive styles, which were classified as Field Dependent, Intermediate, and Field Independent. There are also two dependent variables. One is user performance by measuring an average amount of time and transactions needed to complete a task. The other is user perception by analyzing the participants’ responses to the QUIS and CSUQ questionnaires. Analyzing the semantics of each question in these two questionnaires, in order to avoid similar questions and/or concepts, we reduced the set to 15 questions. These questions are presented in Table 2, which shows the QUIS questions used, and Table 3, which shows the CSUQ questions used.

Table 2. QUIS Questions Selected for this study

Question	Question	Area
1	The interface is: terrible (0) – wonderful (9)	Overall reaction
2	The interface is: Difficult (0) – Easy (9)	Overall reaction
4	The interface has: Inadequate Power (0) – Adequate Power (9)	Overall reaction
6	The system is: Rigid (0) – Flexible (9)	Overall reaction
17	Learning to operate the system is: Difficult (0) – Easy (9)	Learning
18	Exploring New Features is difficult (0) – Easy (9)	Learning
27	The system is designed for all level of users: Never (0) – Always (9)	System Capabilities

Table 3. CSUQ Questions Selected for this study

Question	Question
1	I am satisfied with how easy it is to use the system: 1 (Strongly disagree) – 7 (Strongly agree)
3	I can effectively complete my work using this system: 1 (Strongly disagree) – 7 (Strongly agree)
6	I feel comfortable using this system: 1 (Strongly disagree) – 7 (Strongly agree)
7	It was easy to learn to use this system: 1 (Strongly disagree) – 7 (Strongly agree)
16	The interface of this system is pleasant: 1 (Strongly disagree) – 7 (Strongly agree)
17	I like using the interface of this system: 1 (Strongly disagree) – 7 (Strongly agree)
18	This system has all the functions I expect it to have: 1 (Strongly disagree) – 7 (Strongly agree)
19	Overall, I am satisfied with this system: 1 (Strongly disagree) – 7 (Strongly agree)

4. Results and Discussions

4.1 Overall Responses

4.1.1 User Perception

This section is to evaluate the overall users' perception to the adaptive version and adaptable version of the personalized DL. The results are presented for a selected subgroup of QUIS and CSUQ questions listed in Table 2 and Table 3 respectively. Table 4 and Table 5 show the means and the standard deviations (std) of the users' responses to the selected QUIS and CSUQ questions respectively for the adaptive version while Table 6 and Table 7 present the same information but considering the adaptable version.

Table 4. Users' Responses for QUIS questions considering the adaptive version

	<i>QUIS1</i>	<i>QUIS2</i>	<i>QUIS4</i>	<i>QUIS6</i>	<i>QUIS17</i>	<i>QUIS18</i>	<i>QUIS27</i>
Mean	5.84	6.58	5.58	5.36	6.91	6.05	5.67
Std	0.511	0.562	0.829	0.058	0.616	0.011	0.032

Table 5. Users' Responses for CSUQ questions considering the adaptive version

	<i>CSUQ1</i>	<i>CSUQ3</i>	<i>CSUQ6</i>	<i>CSUQ7</i>	<i>CSUQ16</i>	<i>CSUQ17</i>	<i>CSUQ18</i>	<i>CSUQ19</i>
Mean	6.44	5.97	5.60	5.90	4.49	4.52	4.91	4.98
Std.	0.285	0.249	0.158	0.294	0.454	0.607	0.454	0.204

Table 6. Users' Responses for QUIS questions considering the adaptable version

	<i>QUIS1</i>	<i>QUIS2</i>	<i>QUIS4</i>	<i>QUIS6</i>	<i>QUIS17</i>	<i>QUIS18</i>	<i>QUIS27</i>
Mean	5.55	6.39	5.42	4.57	6.74	6.05	5.21
Std	0.759	0.533	0.430	0.261	0.965	0.171	0.021

Table 7. Users' Responses for CSUQ questions considering the adaptable version

	<i>CSUQ1</i>	<i>CSUQ3</i>	<i>CSUQ6</i>	<i>CSUQ7</i>	<i>CSUQ16</i>	<i>CSUQ17</i>	<i>CSUQ18</i>	<i>CSUQ19</i>
Mean	5.05	5.86	5.12	5.70	4.44	4.44	3.62	4.65
Std	0.307	0.457	0.239	0.389	0.563	0.693	0.484	0.344

As showed in Table 4 to Table 7, the users have more positive responses to the adaptive version than to the adaptable version, especially the following items.

- QUIS 6 (The system is rigid or flexible): There is a 0.79 difference between the users' perception to the adaptive version and to the adaptable version. It has to be considered that the adaptive version actually offers less functionality than the adaptable version. It may be due to the fact that the adaptive version provides the functionality based the needs of each cognitive style so the users consider that it is flexible.

- CSUQ 1 (I am satisfied with how easy it is to use the system): The difference between the adaptive version and the adaptable version for this question is 1.39. This indicates that the adaptive version is much simpler to use than the adaptable version. It is probably because the adaptable version needs more effort from the users to choose the suitable functionality.
- CSUQ 6 (I feel comfortable using this system): There is a 1.16 variation between the adaptive version and the adaptable version for this question. This result was somehow expected because the simplicity of the adaptive version might make users feel more comfortable to use. On the other hand, the users feel more uncomfortable to use the complicated adaptable version because the users need to decide the functionality of the DL by themselves.
- CSUQ 18 (This system has all the functions I expect it to have): The variation between the adaptive version and the adaptable version for this question is 1.29. This result is different from our expectation because the adaptive version offers less functionality to the users. This result highlights the fact that the inclusion of functionality not needed or not used by users has a negative impact on the users' perception.

There is another interesting finding, which is related to the standard deviations. In the adaptive version, the average of standard deviation for the QUIS and CSUQ questionnaires was 0.374 and 0.338 respectively, while in the adaptable version it has been increased to 0.591 and 0.434 respectively. These values imply that in the adaptive version users are not only more satisfied but also agree more on their perception.

4.1.2 User Performance

This section is to compare the overall users' performance between the adaptive version and the adaptable version. The average amount of time needed to complete a task with the adaptive version was 51436 milliseconds (standard deviation: 823) while this value was increased to 69223 milliseconds (standard deviation: 1112) with the adaptable version. The average amount of transactions needed to complete a task with the adaptive version was 4.1 (standard deviation: 0.53) whereas this value was increased to 5.1 (standard deviation: 0.95) with the adaptable version. These findings not only suggest that the users perform better in the adaptive version than in the adaptable version, but also reveal that in general the users show a more homogeneous performance in the adaptive version than in the adaptable version.

The results presented in the aforementioned two sub-sections indicate that the users not only had a better performance in the adaptive version, but also they had more positive perception to the adaptive version. These findings are in line with those of previous studies (Frias-Martinez, et al., in press; Chen, 2002), which highlighted that there was a link between users' perception and users' performance. More specifically, positive perception could enhance users' performance.

4.2 Impacts of Cognitive Styles

4.2.1 User Perception

After assessing the overall users' responses to the design of the adaptive version and adaptable version, it is necessary to examine how each cognitive style group reacts to these two types of DL. Table 8 and Table 9 present the means and standard deviations (std) of each cognitive style's responses to the selected QUIS and CSUQ questions for the adaptive version while Table 10 and Table 11 present the same information but for the adaptable version.

Table 8: Each cognitive style's responses to the adaptive version (QUIS questions)

<i>Cognitive Styles</i>		<i>QUIS1</i>	<i>QUIS2</i>	<i>QUIS4</i>	<i>QUIS6</i>	<i>QUIS17</i>	<i>QUIS18</i>	<i>QUIS27</i>
Field Dependent	Mean	5.83	7.13	5.88	6.00	8.15	6.62	6.00
	Std	0.267	0.730	0.782	0.082	0.782	0.314	0.193
Intermediate	Mean	5.25	6.73	5.58	4.83	6.58	5.42	5.53
	Std	0.712	0.642	0.832	0.517	0.782	0.975	0.125
Field Independent	Mean	6.21	5.88	5.28	5.25	6.00	6.11	5.48
	Std	0.475	0.268	0.945	0.374	0.453	0.823	0.759

Table 9: Each cognitive style's responses to the adaptive version (CSUQ questions)

<i>Cognitive Styles</i>		<i>CSUQ1</i>	<i>CSUQ3</i>	<i>CSUQ6</i>	<i>CSUQ7</i>	<i>CSUQ16</i>	<i>CSUQ17</i>	<i>CSUQ18</i>	<i>CSUQ19</i>
Field Dependent	Mean	7.07	6.16	6.59	7.14	4.57	4.77	5.47	5.61
	Std	0.288	0.832	0.115	0.084	0.564	0.670	0.730	0.215
Intermediate	Mean	5.88	5.83	5.17	5.32	4.42	4.17	5.00	4.58
	Std	0.832	0.642	0.586	0.564	0.240	0.403	0.603	0.676
Field Independent	Mean	6.37	5.92	5.04	5.24	4.48	4.42	4.26	4.75
	Std	0.124	0.336	0.806	0.098	0.575	0.742	0.628	0.580

Table 10: Each cognitive style's responses to the adaptable version (QUIS questions)

<i>Cognitive Styles</i>		<i>QUIS1</i>	<i>QUIS2</i>	<i>QUIS4</i>	<i>QUIS6</i>	<i>QUIS17</i>	<i>QUIS18</i>	<i>QUIS27</i>
Field Dependent	Mean	5.08	5.08	5.18	4.25	5.42	5.83	4.75
	Std. Deviation	0.311	0.505	0.314	0.454	0.443	0.250	0.485
Intermediate	Mean	5.58	5.67	5.42	4.38	6.17	5.67	5.67
	Std. Deviation	0.621	0.073	0.443	0.234	0.623	0.723	0.670
Field Independent	Mean	5.99	8.42	5.66	5.08	8.63	6.65	5.21
	Std. Deviation	0.105	0.640	0.451	0.116	0.734	0.347	0.218

Table 11: Each cognitive style's responses to the adaptable version (CSUQ questions)

<i>Cognitive Styles</i>		<i>CSUQ1</i>	<i>CSUQ3</i>	<i>CSUQ6</i>	<i>CSUQ7</i>	<i>CSUQ16</i>	<i>CSUQ17</i>	<i>CSUQ18</i>	<i>CSUQ19</i>
Field Dependent	Mean	4.96	5.53	4.03	4.83	4.15	4.25	3.50	4.25
	Std	0.030	0.303	0.030	0.337	0.422	0.712	0.679	0.422
Intermediate	Mean	5.00	5.83	5.08	4.95	4.47	4.33	3.55	4.63
	Std	0.477	0.337	0.165	0.215	0.030	0.155	0.866	0.193
Field Independent	Mean	5.19	6.22	6.25	7.32	4.70	4.74	3.81	5.07
	Std	0.327	0.610	0.165	0.455	0.924	0.797	0.675	0.425

The aforementioned four tables suggest that Field Dependent users have more positive perception to the adaptive version than Field Independent users. In contrast, Field Independent users react more positively to the adaptable version than Field Dependent users. These differences especially demonstrate in how easy to use the interface of the system (QUIS2), how easy to learn to operate or use the adaptive version (QUIS 17/CSUQ7), and how comfortable to use the system (CSUQ6). It may be due to the fact that the adaptive version automatically present suitable functionality based on each user's cognitive style whereas the adaptable version requires users to choose functionality by themselves. Thus, the former is beneficial to Field Dependent individuals, who rely more on external frames of reference and operate best where analyses are already provided (Lyons-Lawrence, 1994). Conversely, Field Independent individuals, who use an internal frame of reference to organize information (Reiff, 1996) and structure problems (Davis and Cochran, 1989) so they are more able to use the latter to process information.

The other interesting finding is related to Intermediate users' responses. In respects of QUIS2, QUIS4, QUIS6, QUIS17, CSUQ1, CSUQ6, CSUQ7, and CSUQ18, they have more positive responses to the adaptive version than to the adaptable version. In respects of the remaining questions, they react more positively to the adaptable version than to the adaptive version. It suggests they are equally comfortable using each version. One possible interpretation is that individuals possessing an Intermediate cognitive style combine the characteristics of both Field Independence and Field Dependence and employ a more versatile repertoire of information seeking strategies. Versatile users have acquired the skill to move back and forth between different information seeking strategies (Ford, 2000) so they are able to adapt themselves to suit the design of a system.

4.2.2 User Performance

This section is to compare the performance of different cognitive style groups between the adaptive version and the adaptable version. Table 12 presents the average amount of time needed to complete a task while Table 13 the average transactions needed to complete a task

Table 12: Average Time for complete a task (millisecond)

	Field Independent Users	Intermediate Users	Field Dependent User
Adaptive Version	52235	48989	53084
Adaptable Version	58112	53441	96116

Table 13: Average Transactions for complete a task

	Field Independent Users	Intermediate Users	Field Dependent User
Adaptive Version	4.1	3.8	4.4
Adaptable Version	4.2	4.1	7.0

As indicated in Table 12 and Table 13, Intermediate users have better performance than other cognitive style groups, in terms of both average time and average transactions for completing a task. Field Independent users slightly performed better than Field Dependent users in the adaptive version. However, Field Independent users greatly perform better than Field Dependent users in the adaptable version. As discussed Section 4.2.1, users need to choose the functionality by themselves in the adaptable version and such an additional effort may hinder the performance of Field Dependent users, who tend to rely on externally provided cues to organize information (Chou and Lin 1997). On the other hand, Field Independent users are less affected because they tend to organize information with internal references (Goodenough, 1976).

4.3 Comparison with Non-Personalized DL

As indicated in Section 1, this study is a follow-up study of our previous work (Frias-Martinez, et al., in press) that investigated how cognitive styles influenced users' behavior and perception in a non-personalized DL. After conducting a comparison of users' performance between these two studies, we found that Field Independent users performed better in the personalized DL, regardless of the adaptive version or the adaptable version. On the other hand, the performance of Field Dependent users in the non-personalized DL was better than the performance of Field Dependent users in the adaptable version of the personalized DL. However, it was worse than the performance of Field Dependent users in the adaptive version of the personalized DL. These findings are related to both average time and average transactions for completing a task. For Intermediate users, the personalized DL made them take fewer transactions to complete a task. However, Intermediate users in the adaptable version of the personalized DL spent more time completing a task than those in the non-personalized DL whereas those in the adaptive version of the personalized DL spent less time completing a task than those in the non-personalized DL

After comparing the users' responses to the QUIS and CSUQ questionnaires between these two studies, we found that generally both Field Dependent and Field Independent users have more positive perception to the adaptive version of the personalized DL than to the non-personalized DL, apart from Field Dependent users' responses to QUIS18 and Field Independent users' responses to QUIS2. In addition, Field Independent users also have more positive perception to the adaptable version of the personalized DL than to the non-personalized DL, except their responses to QUIS27 and CSUQ 18. However, the responses of Field Dependent users are diverse. In respects of QUIS1, QUIS2, QUIS6, QUIS17, QUIS18, QUIS27, CSUQ6, CSUQ7, and CSUQ 19, they show more negative responses to the adaptable version of the personalized DL than to the non-personalized DL. In respects of the remaining questions, they show more positive responses to the adaptable version of the personalized DL than to the non-personalized DL. According to the abovementioned comparisons, we may conclude that the adaptive version of the personalized DL seems suitable to both Field Dependent and Field Independent users. On the other hand, the adaptable version of the personalized DL may be useful to Field Independent users, but it may not be helpful to Field Dependent users.

7. Conclusions

Two research questions were examined in this study: (1) whether users perform differently and/or showed different perception to adaptability and adaptivity; (2) whether users' cognitive styles have effects on their responses to adaptability and adaptivity. The answer to the first research question is that the users not only performed better in the adaptive version, but also they perceived more positively to the adaptive version. The answer to the second research question is that cognitive styles have great effects on users' responses to adaptability and adaptivity. Field Independent users react more positively to the adaptable version than Field Dependent users whereas Field Dependent users have more positive perception to the adaptive version than Field Independent users. These findings provide guidance for designers to select suitable techniques for the development of personalized DLs.

This study is a follow-up study of our previous work (Frias-Martinez, et al., in press), where two dimensions of cognitive styles were considered: (a) Field Dependence/Independence; (2) Verbalizer/Imager. However, this study developed the personalized DL by only considering the former. Thus, taking into account the latter to develop a personalized DL is needed in the future. Furthermore, it is necessary for future research to investigate how to develop an integrative personalized DL by considering both dimensions of cognitive styles.

Both our previous work and this study indicated that cognitive styles greatly influence users' preferences for the use of DLs. However, they were only small-scale studies. Further studies need to be undertaken with a larger sample to provide additional evidence. We believe that such evidence cannot only help to improve the design of DLs, but also is useful for the development of other web-based applications, such as search engines and electronic journals.

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References:

- Adams, A. and Blandford, A. (2002) Digital libraries in academia: challenges and changes. *Proceedings of the 5th International Conference on Asian Digital Libraries (ICADL 2002)*, p.392-403.
- Callan, J., Smeaton, A., Beaulieu, M., Borlund, P., Brusilovsky, P., Chalmers, M., Lynch, C., Smyth, B., and Straccia, U. (2003) Personalization and Recommender Systems in Digital Libraries. *Proceedings of the 2nd DELOS Workshop on Personalization and Recommender Systems in Digital Libraries*.
- Candela, L., and Straccia, U. (2003) The Personalized, Collaborative Digital Library Environment CYCLADES and its Collections Management. *Distributed Multimedia Information Retrieval-SIGIR 2003 Workshop on Distributed Information Retrieval, Lecture Note in Computer Science*. 2924, p.156-172.
- Chen, S. Y. (2002) The Relationships between Individual Differences and the Quality of Learning Outcomes in Web-based Instruction. *Proceedings of the ICEB Second International Conference on Electronic Business*, p. 345-351
- Chin, J.P., Diehl, V.A., Normal, K.L. (1988) Development of an Instrument Measuring User Satisfaction of the Human-Computer Interface. *ACM CHI'88 Proceedings*, 213-218.
- Chou, C. and Lin, H. (1997). Navigation Maps in a Computer-Networked Hypertext Learning System. Paper presented at the Annual Meeting of the Association for Educational Communications and Technology, Albuquerque, NM, February 12-16, 1997.
- Cohen, S., Fereira, J., Horne, A., Kibbee, B., Mistlebauer, H., and Smith, A. (2000) MyLibrary Personalized Electronic Services in the Cornell University Library. *D-Lib Magazine*, 6(4), URL <http://www.dlib.org/dlib/april00/mistlebauer/04mistlebauer.html>.
- Davis, J.K. & Cochran, K. F. (1989) An information processing view of Field Dependence - Independence. *Early Child Development and Care*. 51, 31-47
- Di Giacomo, M., Mahoney, D., Bollen, J., Monroy-Hernandez, A., and Ruiz-Meraz, C.M. (2001) MyLibrary, A Personalized Service for Digital Library Environments. *Proceedings of the 2nd DELOS Workshop on Personalization and Recommender Systems in Digital Libraries*,
- Fink, J. and Kobsa, A. (2000) A Review and Analysis of Commercial User Modeling Servers for Personalization on the World Wide Web. *User Modeling and User-Adapted Interaction*, 9(34), 209-249

- Finlater, L. and McGrenere, J. (2004) A Comparison of Static, Adaptive, and Adaptable Menus. *Proceedings of CHI 2004*.
- Ford, N. (2000) Cognitive styles and virtual environments. *Journal of the American Society for Information Science*, 51(6), 543-55
- Ford, N., Miller, D. and Moss, N. (2005) Web search strategies and human individual differences: Cognitive and demographic factors, Internet attitudes, and approaches. *Journal of the American Society for Information Science and Technology*. 56, 741-756.
- Ford, N., Wilson, T.D., Foster, A., Ellis, D., and Spink, A. (2002) Information seeking and mediated searching. Part 4: Cognitive styles and individual differences. *Journal of the American Society for Information Science and Technology*. 53(9), 728-735.
- Frias-Martinez, E., Chen, S. Y., and Liu, X. (in press) Investigation of Behavior and Perception of Digital Library Users: A Cognitive Style Perspective. *International Journal of Information Management*
- Goodenough, D. (1976). The role of individual differences in field dependence as a factor in learning and memory. *Psychological Bulletin*, 83, 675-694.
- Kim, H., Yun, M., Kim, P. (2004) A Comparison of Web Searching Strategies According to Cognitive Styles of Elementary Students. *Lecture Note in Computer Science*. 3044, p. 892-901
- Ivory, M. Y., Megraw, R. (2005) Evolution of web site design patterns. *ACM Transactions on Information System*. 23, 463-497.
- Jameson, A. and Schwarzkopf, E. (2002). Pros and Cons of Controllability: An Empirical Study. *Proceedings of Adaptive Hypermedia 2002*. p. 193-202.
- Kay, J. (2001) Learner Control. *User Modeling and User-Adapted Interaction*. 11(1/2), 111-127.
- Lewis, J. R. (1995) IBM Computer Usability Satisfaction Questionnaires: Psychometric Evaluation and Instructions for User. *International Journal of Human-Computer Interaction*. 7, 57-78.
- Liaw, S. S. and Huang, H. M. (2003) An investigation of user attitudes toward search engines as an information retrieval tool. *Computers in Human Behavior*. 19, 751-765.
- Lyons-Lawrence, C. L. (1994) Effects of learning styles on Performance in using computer-based instruction in office systems. *The Delta Pi Epsilon Journal*, 36(3), 166-175.
- Marchionini, G., Plaisant, C., and Komlodi, A. (2003) The people in digital libraries: multifaceted approaches to assessing needs and impact. In *Bishop, A., van House, N. A., Buttenfield, B.P. (Eds.) Digital Library Use Social Practice in Design and Evaluation*. MIT Press, p. 119-160
- McGrenere, J., Baecker, R. M., and Booth, K. S. (2002) An evaluation of a multiple interface design solution for bloated software. *ACM CHI Letters*, 4(1), 163-170.
- McKeown, K.R., Elhadad, N., and Hatzivassigliou, V. (2003) Leveraging a Common Representation for Personalized Search and Summarization in a Medical Digital Library. *Proceedings of the 2003 Joint Conference on Digital Libraries, JCDL03*, 159-173.
- Palmquist, R. A. and Kim, K. (2000) Cognitive style and on-line database search experience as predictors of Web search performance. *Journal of the American Society for Information Science*. 51(6), 558-566.
- Reiff, K. (1996). At-risk middle level or field dependent learners. *Clearing House* 69(4), 231-234.
- Riding R. J., Grimley, M. (1999) Cognitive style, gender, and learning from multimedia materials in 11 year-old children. *British Journal of Education Technology*, 30(1), 43-56.
- Riding, R., Rayner, S. G. (1998) *Cognitive Styles and Learning Strategies*. David Fulton Publisher, London.
- Riding, R. J. (1991) *Cognitive Styles Analysis*. Birmingham: Learning and Training Technology.
- Scanlon, E. (2000) How gender influences learners working collaboratively with science simulations. *Learning and Instruction*. 10, 463-481.
- Semeraro, G., Costabile, M.F., Esposito, F., and Fanzini, N. (1999) Machine Learning Techniques for Adaptive User Interfaces in a Corporate Digital Library Service. *Proceedings of the ACAI-99 Workshop on Machine Learning in User Modelling*, 21-29.
- Spink, A., Wilson, T.D., Ford, N.A., Foster, A., and Ellis, D. (2002) Information seeking and mediated searching. Part I. Background and research design. *Journal of the American Society for Information Science and Technology*. 53(9), 695-703.
- Stelmaszewska, H., Blandford, A. (2004) From physical to digital: a case study of computer scientists' behaviour in physical libraries. *International Journal on Digital Libraries*. 4(2), 82-92.
- Stephanidis, C., Savidis, A., and Akoumianakis, D. (1995) Towards user interfaces for all, *Conference Proceedings of 2nd TIDE Congress*, p 167-170.

- Treiblmaier, H., Madlberger, M., Knotzer, N., and Pollach, I. (2004) Evaluating Personalization and Customization from an Ethical Point of View: An Empirical Study. *Proceedings of the 37th Hawaii International Conference on System Sciences*.
- Tsandilas, T. and Schraefel, M. C. (2004) Usable adaptive hypermedia systems. *New Review of Hypermedia and Multimedia*. 10(1), 5-29.
- Weller, H.G., Repman, J., and Rooze, G.E. (1994) The relationship of learning, behaviour, and cognitive styles in hypermedia-based instruction: Implications for design of HBI. *Computers in the Schools*. 10, 401-420.
- Winter, K. (1999). MyLibrary can help your library. *American Libraries*, 30(7), 65-57.
- Witkin, H. A., Moore, C. A., Goodenough, D. R., and Cox, P. W. (1977) Field-dependent and field independent cognitive styles and their educational implications. *Review of Educational Research*. 47, 1-64.