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Empirical Investigation on Cognitive User Interface Dimensions

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ABSTRACT.

In line to the introduction of the online museum, a user interface is a new medium to allow museum collections to be exhibited and promoted more effectively. For promoting purposes, this paper stresses on usability of the interface design. It is critical to pay attention to the cognitive design and ensure that the interface is usable in order to help users understand the displayed information. The user interface design for online museum has commanded significant attention from designers and researchers but lacks in the cognitive design perspective. In the effort to formalize the design, this paper is the extension of the initial work on a user interface design dimensions. The individual differences approach is adopted to explore possible user interface design elements. This study also validates the dimensions by conducting empirical investigation. The investigation is to test the hypotheses linkage between cognitive styles and user interface dimensions. The research method involves using Field Dependent and Field Independent as the case study and web-based survey on online museum visitors. The result of the analysis suggests cognitive styles do influence user interface dimensions. These design dimensions contain the implications for cognitive design of user interface development, and the identification of cognitive design of user interface for cultural website. The effort may contribute towards increasing the usability level of the website.

KEYWORDS:

Cognitive design, user interface dimensions, cognitive styles, empirical investigation, structure, format, representation.

1. INTRODUCTION

In the internet era, new type of museum has been introduced to allow more collections to be placed online. With extensive usage of the Internet nowadays, people will no longer have physical space constraints and can get more information about museums from different webs via search engines, or directly visit online museums [1]. A role of museums is beyond preserving a society's cultural heritage collections [2]. Besser [3] noted that online museum increases the public's awareness of and access to traditional physical collections, and serving as a promotional function. Online museums become a center to promote these collections and later persuade a user to visit the physical museum [4]. User Interface (UI) is a new medium to allow museum collections to be exhibited and promoted ever since an online museum was being introduced. For promoting purposes, Fan et. al [5] stress on the establishment of a structure for the digital collection system and the improvement of the interface design for users. The goal to present, and effectively views museum collections for exhibition and promotion, should thus be of emphasis. Otherwise, the promotion of museum collections as to attract more visitors to visit museums will be affected.

Users are easily recognizing information, which matched with their needs [6] and fit with their capability of information processing [7]. Study by Fikkert et. al [8] shows that user differences influence UI design. They concluded that failing to relate with computer users need, and their capability to process information, may result in misinterpretation of the displayed information. Therefore, it is critical to pay attention to user differences and ensure that the interface is usable in order to help users understand the displayed information [9]. Thus, a study on user's differences is significant. By integrating user interface into museum website, museum collections may be presented and views effectively.

Among of the various users' differences, is the cognitive styles, which consider the user's preferred and habitual approach to organizing and representing information [10]. Cognitive styles are proven to have a significant effect on comprehension during the searching and browsing activities [11]. Cognitive styles are also associated with certain personality characteristics that may have important implications to instructional and learning process [12]. As UI design major concern is on how to organize and present information to users, cognitive styles become even significant. In addition, cognitive styles are the most applicable because it is independent of intelligence [13], personality and gender [14]. Moreover, cognitive styles are consistent across domains and stable over time [15]. However, cognitive styles are often overlooked when designing a user interface for museum website. To fill the gap, this study incorporates cognitive styles into the interface elements. The theoretical framework presents the relationship between cognitive styles and user interface dimensions. In this paper users' differences significant to UI design of the cultural website are first presented and discussed before design elements of UI is proposed. A section on research method explains the sample selection, data collection process and statistical analysis. We then provide and discuss the results of the statistical analysis, and followed by conclusion. Finally, this paper would also offer some directions for future research.

2. BACKGROUND STUDY

The success of UI in presenting information via online system from the user perspective is evaluated based on the performance and usability testing. The result suggests UI design can influence user performance and behavior. Thus, a successful UI is a UI that can get better performance in as well presentation as possible. Through understanding of user differences, the potential benefits of UI design could be realized and could contribute towards better performance and usability. The aspects of user difference that influence user comprehension can be categorized into three:

Differences in attention: Most users are capable of using either a visual or verbal content, but they will prefer to use one rather than the other [10]. Imagery and verbal user are grouped according to their preference on content. Imagery style is attracted to ideas, concepts, data and other information, which are associated with images. Imagery users prefer an image or visual content. Visual content reflects the way in which imagery user would represent knowledge in their mental effort. Conversely, verbal users prefer sound and word content [10]. Sound and word content reflects the way in which verbalist represents knowledge in their mental effort. Thus, textual and visual formats have an influence to imagery and verbalist users. In addition, Wickens [15] discusses on imagery user who is at no difficulty in the visual format and verbalize user is, satisfy with textual format.

Differences in accessing information: Holist and serialist users are identified during discussion on helping user find information [10]. According to their capability to explore their environment, holist typical adopts a thematic approach and will often focus on several aspects of the topic at the same time. Holist has a capability to view information as a whole and difficult to identify detail components of the information. However, serialist will adopt a step-by-step approach, built on clearly identified chunks of information, which are used to link concepts and parts of the topic. In addition, serialist will concentrate on detail, procedure and often conceptualize information in a linear structure. The approaches are relations to conclude that user may have a capability to assess information in holist or serialist strategy. The researchers suggest that serialist user accesses information using structured technique and holist user using an unstructured technique. Thus by focusing on the structure dimension as a way to organize information, the researchers hope to allow users move freely within the UI.

Differences in action: This group is classified according to task handling used by a user to engage in UI. Active users tend to apply a dynamic strategy. Dynamic strategy encourages users to act and react and generally is more reliable indicators of user intent [16]. Inactive user may be attentive and less obtrusive and have a tendency apply a passive strategy. Passive strategy is described as a situation where the user does not interact with the UI and infrequently applies manipulation task. Passive strategy is common for public displays, such as a cultural website. In cultural website users are allowed to see and listen during viewing cultural collections. These characteristics of passive and active users are then used as the elements to create the representation elements.

By identifying the cognitive background based on the cognitive differences of previous researches, this study uses these user differences as guidance to identify design elements as part of the localization process of UI. This is done with the contextualization process of ‘Format’, ‘Structure’ and ‘Representation’ dimensions of UI, which aims on assisting users on effectively views museum collections around the museum website. In addition, this paper proposes the contextualization process of ‘Content’ dimension of UI that will not only aid the user in information searching but also avoid user from experiencing information overload, which occurs when user deals with too much information. As part of the main contribution of this research which is to maximize user browsing task strategy, the contextualization process of ‘Structure’ dimension of UI may reinforce user positioning and orientation while searching and browsing for information [19]. Furthermore, the localization process of ‘Representation’ dimension of UI is also being imposed. Practical design implication can be seen in the next section where the overall potential effects of cognitive towards the dimensions of 'Format', 'Structure' and 'Representation' of UI are observed.

3. RELATED WORK

3.1 IMPACT OF COGNITIVE OVERLOAD ON PERFORMANCE

Cognitive Load Theory (CLT) as shown is Figure 1 is related to a mental load and mental effort which have an impact on user's performance [17]. While the mental load related to UI design, mental effort refers to cognitive capacities allocated to accommodate with UI demands. Cognitive overload occurs when the user is no longer processing information in the quantities or at the speed which it is being presented. Thus, to minimize cognitive overload, Feinberg and Murphy [18] used consistent page layout, organized information and added audio/visual elements. In addition, they discovered that CLT is consistent with general web design principles for effective design of web-based instruction.

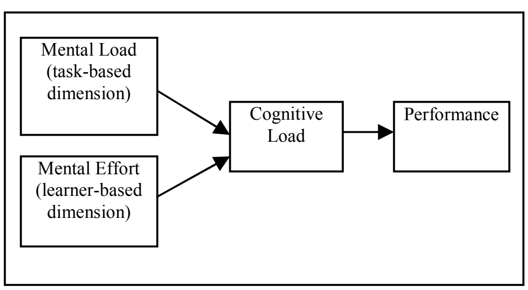


Figure 1: Cognitive Load Theory adopted from Sweller [17]

Another theoretical explanation explains a relationship between cognitive overload and understanding. The relationship between cognitive overloads and understanding is explained by Nikunj [19]. He has stated, when cognitive overloads to ensue; understanding degrades rapidly. In addition, a theoretical explanation on user understanding by Thuring et al. [20] has stressed on limitations of human information processing. According to them, low resources capability available for understanding, less likely a person will understand the information well. They thought a major factor related to user understanding is mental models. Therefore, mental models have an implication on users' understanding during browsing and searching in a website. A performance is determined by how well the UI support in forming quick and clear mental models to turn on understanding. Thus, it can be concluding that performance provides a sign of cognitive overload.

The impact of cognitive overloads on performance has been shown through field and experimental studies. Both field and experimental studies of cognitive overload show a reduced performance [21] [22]. The performance is measured based on various dependent variables. In this, performance is measured by a number of correct answers and time taken to complete tasks.

This research provides a new study on the effects of cognitive load on performance of UI for searching and browsing museum collections. From an experimental study, this research is providing more empirical data on the relationship between cognitive overload and performance. The results of the experiment will provide strong additional evidence for cognitive overload effects on UI design, which may provide an explanation for why UI is so poorly understood in practice.

3.2 RESEARCH ON USER BROWSING PATTERNS

A review of empirical studies on browsing pattern shows that the majority of works concentrated on log file data [23] [24]. Relatively, few studies examined the user navigation to discuss on eye-tracking data. Of those that did consider this factor, many chose to focus on reading style and learning style. A review of empirical studies on user browsing pattern suggests of work concentrated on browsing using direct manipulation task. Effective display designs must provide all the necessary data in a proper representation to explore a web site. This paper is interested in particular, the identification of the browsing style. The researchers propose an approach for the user's activity perception on a museum website to identify the user's styles from observable indicators related to their browsing path and interactions. Their interest relates to the detection of user's browsing styles by the automatic analysis of behaviors through the collection and interpretation of information on the user's activities using eye-tracking data.

3.3 RESEARCH ON INDIVIDUAL CHARACTERISTICS AND UI DESIGN USE

In UI design cases, it is likely that redesigning the interface will be an effective method of dealing with individual differences. Martin et. al [25] have discussed on the three approaches by Egan and Gomez in dealing with individual differences. Firstly, it is necessary to assess the area of the differences. This involves considering what to determine and how to determine them. Once differences have been observed, the essential differences have to be isolated from the confusing factors. Thus, there is a need to consider the features of the UI, features of the users, and the stability of the features. When the important features have been identified it is then necessary to accommodate these features. The researchers' experimental work with cognitive user interfaces embodies the steps. They want to assess, identify and isolate individual differences, which have a significant impact on the human-computer interaction. Some of these differences can be accommodated through format, structure and representation dimensions of UI to improvise the UI design.

Studies on UI design HCI show that there is a wide range of variation in purpose. While cognitive design by Curl et. al [26] provides proper presentation to carry out on database, Clark and Mayer [27] have strengthened important principles covered in e-learning. Both studies included individual differences to their investigation and discussed the impact of their design on performance. As a result Clark and Mayer proposed basic design principles to provide meaningful groupings of items with labels suitable to the user's knowledge, consistent sequences of groups, and orderly formats all support professional users. However, this study be extended to apply to museum users for promoting museum collections, whereby the understanding of museum collection is towards attracting users to later visit the physical museums. In addition to systematic data collection, user behavior approach is monitored. It is aimed to identify any relationship between user behavior and UI elements used. A UI of the National Museum of Malaysia's website is used in order to design accordingly to the identified elements with a goal to persuade users to browse for museum collections.

4. COGNITIVE-BASED USER INTERFACE ELEMENTS

This paper will integrate and extend the above findings by emphasizing the UI design aspects. Instead of ultimately focusing on the relevance dimensions of UI, this paper takes a wider approach by focusing on the elements of UI dimensions that can provide users with better insight and allow greater employment of supportive UI design. The major interest is towards the development of UI dimensions that display information designed primarily for its cognitive impact on the user.

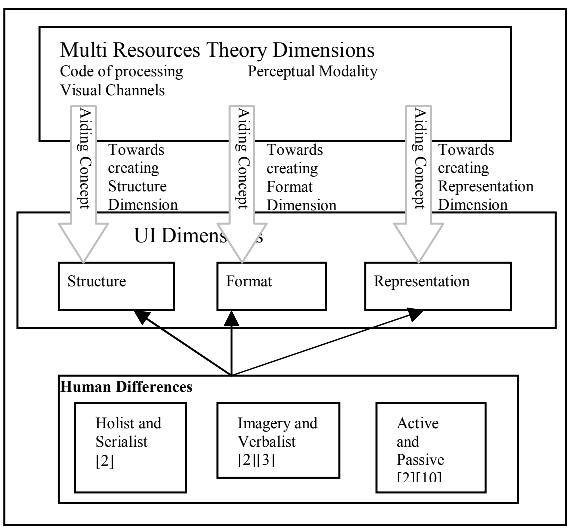


Figure 2: Cognitive Framework of Understanding UI Dimensions (Adapted from Natrah et. al [28])

A theoretical framework of UI design was proposed in a previous study [28]. The framework has three dimensions; format, structure and representation. It is shown in Figure 2. The dimensions are based on Multiple Resource Theory. The Format Dimension is defined as a mode of presentation of content in UI. The Format Dimension is used to get attention from users. User tends to remember content of UI if the format is informative and is able to draw user's attention. The Structure Dimension communicates to users about how to proceed through the UI. The objective of structure dimension is to make information on web sites easy to find and to avoid common browsing errors by users, such as getting lost during finding information. The Representation Dimension is to deliver experiencing and to increase usefulness whiles interacting with the UI.

To extend the format, structure and representation dimensions, cognitive styles are incorporated into the dimensions. Riding and Rayner [10] provide descriptions on groups of cognitive style. They also discuss on the assessment that has been done through series of empirical study [10]. They concluded that imagery-verbal, serialist-holist and active-passive users have significant implications on designing UI. Users browsing and searching in a web environment should be able to form quick and clear mental models. This can be achieved through the use of UI design elements that support the process of mental-model formation. The design dimensions and elements of cognitive-based UI for web environment are outlined below:

Textual or Visual: The study extents the Format Dimension by considering the format, visual and textual format of content. Textual and visual formats have an influence on imagery and verbalist user. The Format Dimension is designed as to get user's attention in order to attract them browsing for museum collection and museum information presented both in a textual and visual format.

Organized, not unorganized: Structure of information content is related to the arrangement of the information content [20]. This study extents the Structure Dimension by considering two elements, structured and unstructured. Structure addresses the interrelationships. It enables users to browse through the UI. The researchers have adopted navigation technique, which consists of two basics: *traveling*, which is the control or motion of the user's viewpoint in the environment, and *way finding*, where the user determines the path based on the knowledge of the virtual environment [9]. These issues are combined to the structure and require a good understanding when designing an effective information organization. However, *traveling* typically is a basic task that enables one to perform a more extensive interaction with the virtual environment. To reduce user's cognitive overhead on structure, Thuring et. al [20], and Storey et. al [29] suggests on providing an overview, table of contents, summaries or headings for holist user as to assist them with the information searching.

Interactive, not static: The Representation Dimension is defined as a dimension of UI for task handling [28]. In a web environment, task handling involves interaction between user and interface [30]. There are two types of interactions, based on passive and active users. Active user enjoys the element of interactivity because they are flexible in manipulating the UI and passive user rarely involved in the interaction. This study extent the Representation Dimension by proposing two elements, namely passive viewing interaction and active viewing interaction elements as to facilitate a flexible view of UI. Direct manipulation elements in which the machine is viewed as a simple tool, and as a passive collection of objects waiting to be manipulated is suitable for active user. Passive viewing interaction is where the user does not interact with the display and infrequently manipulate during use. Passive viewing applications are common for public displays and small displays. Icons are effective for quickly communicating information on small display. This is corresponding to a requirement of a small space for presenting and manipulating cultural collections in the cultural website. In addition, small display may reduce processing activity, and it will reduce a need for high performance capability of computer processor.

5. EXPERIMENTAL METHOD

The experimental research approach is adopted in the study. The approach is carried out in controlled environment where the independent variable is manipulated. The objectives of the study are to measure user performance on cognitive-based UI dimensions. More specifically the objective is to examine the influence of UI organization, UI format and UI representation on completion time and accuracy for searching and browsing task. Cognitive style and gender are used as dimensions to the individual characteristics. The experimental method consists of collecting data using single factor design. Single factor design in which one independent variable is manipulated to test which factor contributes to better performance. Respondents are assigned within-subjects design in which each subject is assigned to all treatment conditions. In the evaluation of a UI design, the same subjects used the system under seven different treatment conditions. In an ideal experiment only the independent variable should vary from condition to condition. In reality, other factors are found to vary along with the treatment differences. These unwanted factors are called confounding variables and they usually pose serious problems if they influence the behavior under study since it becomes hard to distinguish between the effects of the manipulated variable and the effects due to confounding variables. As indicated by [32], one way to control the potential source of confounding variables is holding them constant, so that they have the same influence on each of the treatment conditions for the study is testing environment. As part of the methodology, experimental design, participants, tasks, interfaces, and the experimental tools are discussed in the next few sections.

5.1 EXPERIMENTAL DESIGN

Measuring on performance and user preferences concerning structure, format and representation, an experiment was conducted on a group of participants. They were examined different types of interfaces and filled out questionnaire for each type of interfaces. Six different types of interface were created based on input from the UI framework. The experimental design within-subject, summarized in Table 1, apply reductionism approach in order to discover number of conditions to be tested. With reductionism method six conditions were tested. We were compared textual and visual of UI format, structured and unstructured of UI organization, and with-interaction and without-interaction of UI representation. Thus, the independent variables were structured, unstructured, textual, visual, three-dimensional without interaction (3DL) and three-dimensional with interaction (3DH). The dependent variables were the completion time and user preferences. The completion time is recorded in log file and the user preferences are recorded using questionnaires. Figure 3 shows the experimental design adopted for this study.

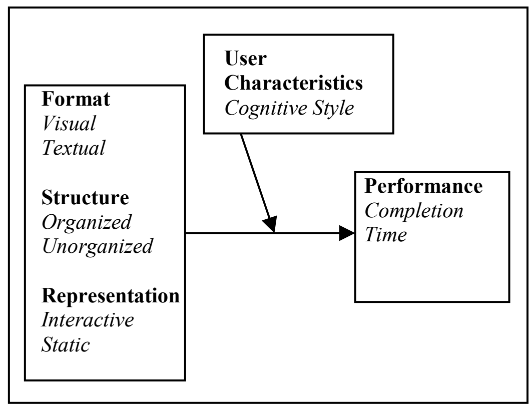


Figure 3: Experimental Design

This study used design as illustrated in Fig. 3, which is adapted from Cognitive Fit Theory. User Characteristics are measured to see the influence of user differences on the UI Dimensions. There were four independent variables: Structure, Format, Representation, and User Characteristics. The dependent variables were completion time and user preferences as shown in Fig 3. Completion time is time allocated to complete a series of task.

5.2 PARTICIPANTS

This experiment is conducted with website users which have an experience visiting museums. Thirty museum visitors were agreed to participate in this laboratory study. The participants were volunteers with roughly equal numbers of Field Dependent (FD) and Field Independent (FD). They were familiar with Web browsing.

5.3 EXPERIMENTAL HYPOTHESES

These hypotheses cover the affects issues of experimental variables. List of research hypotheses to be tested in this experimental study is presented below. Performance is used to test whether the UI dimensions are benefit during browsing and searching activities. By comparing task performance in structured and non-structured conditions; visual and textual format setting; and accompanied by interaction and without interaction features, the benefit can be observed. Thus, the following hypotheses are constructed and will be tested:

- **UI Organization and Performance**

$H1_0$: There is no significant difference in Performance across UI organizations.
$H1_a$: There is a significant difference in Performance across UI organizations.

- **UI Format and Performance**

$H2_0$: There is no significant difference in Performance across UI Formats.
$H2_a$: There is a significant difference in Performance across UI Formats.

- **UI Representation and Performance**

$H3_0$: There is no significant difference in Performance across UI Representation.
$H3_a$: There is a significant difference in Performance across UI Representation.

- **Cognitive style and performance**

$H4_0$: There is no significant difference in performance across cognitive style.
$H4_a$: There is a significant difference in performance across cognitive style.

Literature shows a difference in performance between FD and FI user, where FD had better performance than FI. FI user processes information using serialist patterns and good in global detail of thinking. The FD user use holist pattern and preferred thinking by image. Thus, it is expected that FD users perform better than FI users.

- **Interaction effects between information organization and cognitive style on performance**

$H5_0$: There is no significant interaction effect between UI organization and cognitive style on completion time.
$H5_a$: There is a significant interaction effect between UI organization and gender on completion time.

A structured UI displays a web content to allow users browse freely across different layers of the web content and help users navigate. Certain users tended to look at the content of a UI and ignore the navigation area. When users with high spatial ability browse, they tend to impose structure on the UI regardless of how unstructured it might be. It was believed the design could lead to higher user performance for certain users. It is expected that differences in performance across UI organizations, is affected by the differences in individual differences. According to users' capability to explore UI, FD typical adopts thematic approach and will often focus on several aspects of the topic at the same time. FD has a capability to view information as a whole and difficult to identify details component of the information. Conversely, FI will adopt step-by-step approach, built on clearly identified chunks of information which are used to link concepts and parts of the topic. In addition, FI will concentrate on detail, procedure and often conceptualize information in a linear structure. The differences on approach adapt by FD and FI are relation to conclude that user may have capability to assess information in different strategy. It is expected that FD user better perform in accessing information using structured technique than FI user.

- **Interaction effects between format and cognitive style on performance**

$H6_0$: There is no significant interaction effect between UI format and cognitive style on completion time.
$H6_a$: There is a significant interaction effect between UI format and cognitive style on completion time.

In words and images, users with intuition style have better performance than with analytical style. People with intuition style could think comprehensively, and the total performance in text is better. Research on spatial memory and design alternatives in text editing revealed performance for individuals, who scored low for spatial memory, increased greatly when using a screen-based editor (Gomez, et al, 1983). Differences were also discovered when cognitive factors, such as strategy selection and recall of operational details. Most users are capable of using either a visual or verbal content, but they will prefer to use one rather than the other [2]. Imagery and verbal user are grouped according to their preference on visual content. Imagery user is attracted to ideas, concepts, data and other information which are associated with images. Visual content reflects the way in which imagery user would represent knowledge in their mental effort. Conversely, verbal users prefer sound and word content [2]. Sound and word content reflect the way in which verbalist represents knowledge in their mental effort. Thus, textual and visual formats have an influence to imagery and verbalist user. In addition, Wickens [3] discusses on imagery user which is at no difficulty in visual format and verbalize user is, satisfy with textual format. Thus, it is hypothesized that FD user is better in performance compared to FI user.

- **Interaction effects between representation and cognitive style on performance**

$H7_0$: There is no significant interaction effect between representation and cognitive style on completion time.
$H7_a$: There is a significant interaction effect between representation and cognitive style on completion time.

This hypothesis has not been tested in the literature before. It is expected that differences in performance across information representation, is affected by the differences in individual cognitive style. FD users are anticipated to perform better using the familiar representation of information than the unfamiliar one. The 3D is considered as a new representation for all participants compared to the 2D. FD users have to restructure new information because they demonstrate fewer proportioning skills [5]. Users with such characteristic show heavy reliance on the use of their memory as well as strongly depend on external references. In contrast, FI students, who employ more active approaches and are better at transferring concepts to new situations, are more comfortable with 3D and 2D in web site. They are characterized as individuals who enjoy working alone, prefer free navigation, more likely to provide organization for unambiguous information and to restructure new information [43].

With this explanation, it is hypothesized that cognitive style performs differently from each other with respect to information representations. Thus, it is anticipated that cognitive style moderates the relationship between information representation and performance.

5.4 TASKS AND PROCEDURE

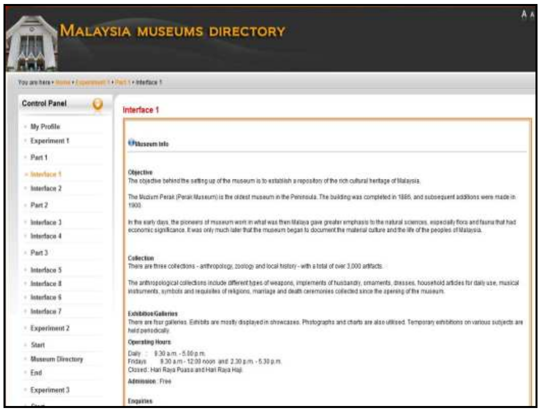
This study seeks to determine if certain features in an interface design is beneficial to certain types of users. In order to determine this, this study will test and compare performance of six interface designs and to investigate the interaction effect of Format, Organization and Representation dimensions. The questions in computer program are related to the content of the program. It concerns about cultural tourism information. Participants were asked about the museum information, direction to museum and collections available in museum and some demographic information about themselves.

Each participant was tested for two sessions. In first session, a ten-minute introduction was given to the participants prior to their tasks. Then the participant was asked to complete the Group Embedded Figures Test (GEFT) [31] to determine the participant's cognitive style. That administration of the GEFT was last twenty minutes. Participants also were asked to provide demographic information (age, gender, etc.) for research purpose only. Answers were recorded via paper-based answer script. Each participant's unique number ID was used to code their answers and selections. The first session was last about forty-five minutes.

In the second session, each participant was conducted a series of tasks on six interfaces. For each task, subjects randomly assigned to one of the interfaces in a random order. All participants were required to finish tasks in one hour. After completing with the interfaces participants were given tasks' questions for each interface design type. The task was to search for the correct answers, as accurate as possible, and to complete the task as fast as they can. They were needed to mark the correct answer in the computer. Each task was allocated for six minutes. After completing series of tasks for each interface design type, participants were required to answer a few questions. We were also asked participants few questions at the end of the experiment.

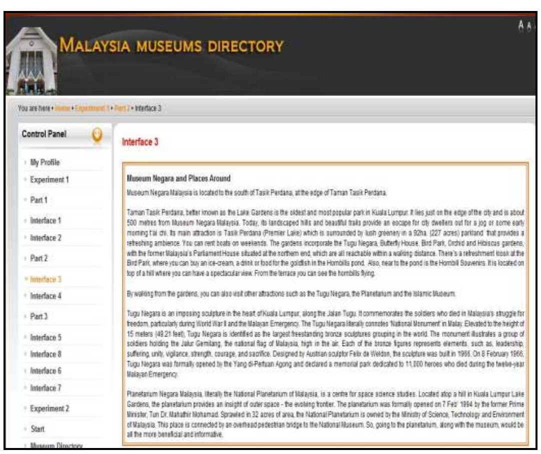
5.5 THE USER INTERFACES

In the experiment one, participants were used seven different interface designs (1, 2, 3, 4, 5, and 6) to perform a series of tasks. A web-based application on Malaysia Museum Directory was used in this experiment. The interfaces are shown in the Fig 4.

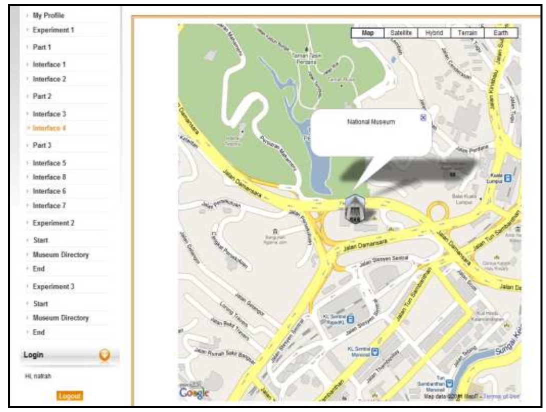


a) Interface 1(structured)

b) Interface 2 (unstructured)



c) Interface 3 (textual)



d) Interface 4 (visual)

e) Interface 5 (2D)

f) Interface 6 (3D)

Figure 4: User Interfaces for the Experiment

5.6 ANALYSIS

A mixed between-within subjects' analysis of variance was conducted to compare score on subjects' completion time with Unstructed and Structured UI. Within-subject effect was measured. There was a significant effects for completion time with large effect size [Wilks' Lambda=.588, F(1,26)=18.20, p<.0005, multivariate partial eta squared=.412.]. The results show that the completion time at structured UI were significantly lower than those at an Unstructured UI. The main effect of subjects on the completion time was significant. This indicated that when the structuring at which UI was measured is ignored, the user completion time was significantly different to the well designed UI. Thus, hypothesis $H1_0$ is rejected. There is a difference in performance between structured and unstructured UI designs.

A between subject analysis of variance was conducted to explore the impact of cognitive style on completion time. Subjects are divided into two groups according to their cognitive styles (Group 1: Field Dependent; Group 2: Field Independent). There was no significant difference in the completion time for the two groups [F (1, 26) =1.31, p>.05, multivariate partial eta squared=.05.] and the effect size of the completion time between-subject was moderate. Thus, hypothesis $H4_0$ is accepted. These findings also show FD doing faster than FI using Structured and Unstructured UI.

A mixed between-within subjects' analysis of variance was conducted to compare score on subjects' completion time with Textual and Visual UI. There was not significant effects for completion time [Wilks' Lambda=.946, F(1,26)=1.45, p>.05, multivariate partial eta squared=.054]. The results show that there was no change in completion time across two UI. This indicated that when the format at which UI was measured is ignored, the user completion time in visual was not significantly different to the textual UI. Thus, hypothesis $H2_o$ is rejected.

The between subject analysis of variance was conducted to explore the main effect of cognitive styles on format dimension. There was a significant difference in the completion time for the two groups [F (1, 26) =4.72, p<.05, multivariate partial eta squared=.154] and the effect size of the completion time between-subject was moderate. The findings indicate that the change in visual UI in the FD group was significant different to the change in the FI group. Thus, hypothesis $H5_0$ is rejected. Specifically, there was a raise in completion time for the FD group and, a drop in completion time for FI group when participant were encouraged to use visual UI. These findings indicate FD doing better when using Textual UI and FI perform faster when using Visual UI.

A mixed between-within subjects' analysis of variance was conducted to compare score on subjects' completion time with 2D and 3D dimension. Within-subject effect was measured. There was a significant effects for completion time with large effect size [Wilks' Lambda=.865, F (1, 26) =4.06, p<.05, multivariate partial eta squared=.135.]. The results show that the completion time at 3D was significantly lower than those at 2D. The main effect of subjects on the completion time was significant. This indicated that when the dynamicity at which UI was measured is ignored, the user completion time was significantly different to the dynamic UI. Thus, hypothesis $H6_0$ is rejected.

The Completion Time x CS Group interaction was no significant [Wilks' Lambda=.998, F (1, 26) =0.058, p>.05, multivariate partial eta squared=.002.], indicating that the change in 2D UI in the FD group was not significant different to the change in the FI group. Specifically, there was a significant raise in completion time in the FI and FD group. These findings indicate that there was a small effect size when participant were encouraged to use dynamic UI. Thus, $H3_0$ is accepted. This shows that using 3D UI accelerate the expected influence in completion time. A between subject analysis of variance was conducted to explore the effect of cognitive style on completion time. There was no significant difference in the completion time for the two groups [$F(1,26)=0.042$, $p>.05$, multivariate partial eta squared=.002.] and the effect size of the completion time between-subject was small. These findings indicate FI doing faster than FD using 2D and 3D. Thus, hypothesis $H7_0$ is rejected.

5.7 DISCUSSION

This study shows a possibility of cognitively adapted UI by connecting cognitive process and UI components. While past studies [11][32] are shown connection between cognitive styles and interface design more related to format, accessibility, structure, interaction flow and menu structure, the results of this study indicates that visual design, structured and 3D dimensions are beneficial to certain types of users. Therefore, the features play an important role in designing user interface.

There is a difference of approach between two groups toward format. The participants having a FD categorization style performed faster in the visual format. Therefore, for FD users who are known to be more dependent on clues, it may be better to work in visual. For example, the system can makes additional features for that user while user viewing the information. The participants having a FI categorization style perform and preferred textual UI. Therefore, for FI users may be better to include textual information in order to help viewing visual information.

There is no difference of approach between two groups toward structured and 3D interfaces. The participants performed the tasks better in the situation where structured and 3D interface were available. Therefore, 3D and structured dimensions are needed to help designing usable UI.

However, there were limitations in the experiment. The subject groups were mostly museums visitors in their early twenties who are more easily adjusting themselves to change so it might be difficult to find clear differences between individuals. Therefore, we will need to capture a big-enough sample with diverse generations to ensure the validity of data. Future research also will combine requirements of FD and FI user toward interactivity in an interface and discover experiment on usability of the user interface design.

6. CONCLUSION

Designing the UI for museum websites is crucial as to make users understand and appreciate cultural collections in museums. This paper aims to understand and establish the relationship between cognitive styles to existing UI framework and of understanding UI. The goal is to understand what do cognitive perspectives may have on UI, in which, the understanding and the theoretical proposition highlighted could bring forward valuable knowledge from a known knowledge into UI domain. An integrated framework, combining these perspectives is presented in Figure 2 as part of the theoretical building process of the UI design framework. This framework is formed by using inductive reasoning research method, which is performed by conducting literature analysis on the related website on UI design and cognitive design elements.

There are several important implications from this research for future research and practice purposes. First, the researchers use some existing concepts of cognitive styles to understand UI design. Second, this study integrate user differences perspectives related to cognitive styles that later offer views for UI design development. This is done by using propositions suggested by cognitive style groups to understand the different cognitive background. Then, this understanding is used as a part of the understanding framework of cognitive UI design. In addition, among the implications and contribution of this research is the identification of cognitive UI design for cultural website that supports user when browsing for museum collections. The effort may contribute towards increasing the usability level of the website.

This study also considers the design dimensions mentioned to evaluate user performance for UI of a cultural website. Evaluation is take place using an experimental approach. The researchers apply reductionism approach where user will be asked to use seven UI, with different elements, and researchers will monitor their performance separately. Results from the experiment provide an empirical support on the important of the proposed UI dimensions in providing usable UI design.

7. REFERENCES

1. Buhalis, D., & O'Connor, P.: Information Communication Technology Revolutionizing Tourism. Tourism Recreation Research, 30(3), 7-16 (2005)
2. Kateli, B., & Nevile, L.: Interpretation and Personalisation: Enriching individual experience by annotating on-line materials, in J. Trant and D. Bearman (eds.). *Museums and the Web 2005: Proceedings,* Toronto: Archives & Museum Informatics, published March 31, 2005 at http://www.archimuse.com/mw2005/papers/kateli/kateli.html
3. Besser, H.: The Transformation of the museum and the way it's perceived. In K. Jones-Garmil (Ed.). The wired museum. pp.153-169 (1997b)
4. Watkins, J., & Russo, A.:Digital Cultural Communication: Designing Co-Creative New Media Environments in Candy L. (ed.) Creativity & Cognition: Proceedings 2005, ACM SIGCHI, 144-149 (2005)
5. Cheng-Wei F., Jun-Fu H. & Rong-Jyue F.:Development of a learning system for a museum collection of print-related artifacts", Electronic Library, The, Vol. 26 Iss: 2, pp.172 – 187 (2008)
6. White, M.D., & Ivonen, M.: Questions as a factor in web search strategy. Information Processing and Management, 37, 721–740. (2001)
7. Fuji Ren.: Affective Information Processing and Recognizing Human Emotion. *Electron. Notes Theor. Comput. Sci.* 225, 39-50 (2009)
8. Kim, J., Lee, K., You, I.: Correlation between Cognitive Style and Structure and Flow in Mobile Phone Interface: Comparing Performance and Preference of Korean and Dutch Users. In: Aykin, N. (ed.) HCII 2007. LNCS, vol. 4559, pp. 531–540. Springer, Heidelberg (2007)
9. Fikkert, W., T. Bierz, M. D'Ambros, T. J. Jankun-Kelly: Interacting with Visualizations. In: Human-Centered Visualization Environments, volume 4417 of Lecture Notes in Computer Science. Vol. 4417, Chapter 3, p. 257-294 (2007)
10. Riding, R., Rayner,S.G.: Cognitive styles and learning strategies, London CA: David Fulton (1998)
11. Chen, S.Y., Magoulas, G.D. & Macredie, R.D.:Cognitive styles and users' responses to structured information representation. International Journal Digital Library, vol. 4, pp. 93–107 (2004)
12. Sternberg, R. J., & Grigorenko, E. L. Are cognitive styles still in style? American Psychologist, 52(7), 700–712 (1997)
13. Atkinson, S.: Cognitive Styles and Computer Aided Learning (CAL): Exploring Designer and User Perspectives. PATT-11 Conference. Haarlem, the Netherlands 2-14 (2001)

14. Ali Reza R., Katz, L.: Evaluation of the reliability and validity of the cognitive styles analysis. Personality and Individual Differences, 36, 1317–1327 (2004)
15. Wickens, C. D.: Multiple Resources and Mental Workload. Human Factors, Vol. 50, No. 3, pp. 449-455 (2008)
16. Oviatt, S.: Human-Centered Design Meets Cognitive Load Theory: Designing Interfaces that Help People Think. ACM (2006)
17. Sweller, J.: Cognitive load theory, learning difficulty, and instructional design. Learning and Instruction, 4, 295–312 (1994)
18. Feinberg, S. and Murphy, M. Applying cognitive load theory to the design of web-based instruction. In Proceedings of SIGDOC, 353-360 (2000)
19. Nikunj, D., Quible, Z., & Wyatt K.: Cognitive design of home pages: an experimental study of comprehension on the World Wide Web. Information Processing and Management 36(4): 607-621. (2000).
20. Thuring, M., Hannemann, J. & Haake, J.: Hypermedia and cognition: designing for comprehension. Communications of the ACM, Vol. 38 No. 8, pp. 57-66 (1995)
21. Lewis, D., & Barron, A. Animated demonstrations: Evidence of improved performance efficiency and the worked example effect. Proceedings of HCI International 2009, 247–255 (2009)
22. Moody, D. L.: Cognitive load effects on end user understanding of conceptual models: An experimental analysis. In G. Gottlob, A. A. Benczur, and J. Demetrovics, editors, Proceedings of 8th East European Conference on Advances in Databases and Information Systems, ADBIS 2004, LNCS 3255, pg 129–143 (2004)
23. Chen, S. Y., Magoulas, G. D., & Dimakopoulos, D.:A fexible interface design for web directories to accommodate different cognitive styles. JASIST, 56(1), 70-83. (2005)
24. Kim, K.-S.: Information seeking on the Web: effects of user and task variables. Library and Information Science Research, 23(3), 233-255 (2001)
25. Egan, D. E.: Individual Differences in Human-Computer Interaction in M. Helander (Ed.), Handbook of Human-Computer Interaction. New York. Elsevier Science Publishers B.V. (1988)
26. Curl, S. S., Olfman, L., & Satzinger, J. W.: An investigation of the roles of individual differences and user interface on database usability. *Database for Advances in Information Systems, 29*(1), 50-65 (1998)
27. Clark, R. C. & Mayer, R. E.: e-Learning and the Science of Instruction, Hoboken: John Wiley (2002)
28. Natrah, A., Wan Adilah, W.A., Nor Laila, M.N.: Towards A Cognitive-Based User Interface Design Framework Development, accepted to publish in Springer-Verlag (2011)
29. Storey, M.A.D., Fracchiat, F.D. & Muller, H.A.: Cognitive Design Elements to Support the Construction of a Mental Model during Software Visualization, The Journal of Systems and Software, 44(3), 171–185 (1999)
30. Schneiderman, B. & Plaisant, C.: Designing the User Interface: Strategies for Effective Human-Computer Interaction-4th Edition. Addison-Wesley (2004)
31. Witkin, H.A., Oltman, P.K., Raskin, E. & Karp, S.A., A Manual for the Group Embedded Figures Test, Consulting Psychologists Press, Palo Alto, CA (1971)
32. J.H. Kim, K.-P. Lee, and I.K. You, “Correlation Between Cognitive Style and Structure and Flow in Mobile Phone Interface: Comparing Performance and Preference of Korean and Dutch Users”, N. Aykin (Ed.): Usability and Internationalization, part I, HCII 2007, LNCS 4559, pp. 531–540 (2007)