Towards a Cognitive-Based User Interface Design Framework Development

Natrah Abdullah, Wan Adilah Wan Adnan, and Nor Laila Md Noor

Faculty of Computer and Mathematical Sciences
Universiti Teknologi Mara
Shah Alam, Malaysia
{natrah,adilah,norlaila}@tmsk.uitm.edu.my

Abstract. This paper discusses the theoretical framework underlying the studies of cognitive-based user interface design of heritage tourism website. Multiple Resource Theory under cognitive psychological study is used particularly in developing UI taxonomy of museum website. MRT highlights on three components which are perceptual modality, visual channel and code of processing. Components of MRT are applied extensively into user interface dimensions identification by emphasis on user interface support functions. As a result three components are propose; format, structure and representation. These components can be used to provide insights into area of HCI with taxonomy of UI for museum websites. Cognitive-based UI framework is proposed and presented with aims to assist in the design and development of the taxonomy.

Keywords: User Interface Design, Cognitive.

1 Introduction

User interface (UI) is a new medium to allow museum collections to be exhibited since online museum were being introduced. While Schweibenz [24] emphasis on effective way to display and easy to interact of museum artifact, result from exploratory study on museums website [25] indicates that there is lack of features on presenting and interacting with museum artifact on current museums websites. An absent of the features will effect on learning during exploring museum collections. Therefore, the lacking of capability of UI to educate or to persuade user make UI design in this domain needs to be explored.

The existence of study on user needs and their capability to process information help to design UI. In effect we must understand how people think and reason about cognitive concept before we make decisions about designing UI. The process of identifying of UI may be strongly supported if theoretical grounding is used as a platform [26]. Thus, this paper provides a theoretical study of UI dimensions in heritage tourism website. Besides suggests a foundation related to cognitive, this paper also highlights an important impact on UI design.

The paper is organized as follows. Section 2 discusses literature review to user interface design implemented in web application and we state a problem. Then, we describe the range of reasonable assumptions for the problem. Sections 3 and 4, a

J.A. Jacko (Ed.): Human-Computer Interaction, Part I, HCII 2011, LNCS 6761, pp. 17–24, 2011.

potential UI dimensions for supporting UI design on web application is proposed, based on Multiple Resource Theory. Section 5 outlines the main potential benefits employing such a dimensions in a web application environment and discusses further research and development steps in this direction.

2 Literature Background

In this paper discussion on UI dimensions proceeds from a substantial research literature grounded in cognitive science. Cognitive science provides a unique perspective to the study of UI involving research from psychology and applied in the field of human computer interaction (HCI). This integration will provide new insights into the major factors influencing UI design and, consequently, could result in more efficient searching and browsing in museum website environments.

2.1 User Interface Design

Designing user interface can be done using techniques such as task-based design, model-based design, user-centered design and usage-centered design. Unlike task-based, model-based and usage-centered, which focus on system and process, the user-centered design focuses on user's characteristics in the design of an interface [1] and put an accent on making usable to the user [2]. Discussions on UI based on user characteristic emerged during the 1970s with the development of graphical user interface. Features associates with this type of interface led to major improvements as compared to command-line interface. The success of the innovation, from a cognitive perspective, was based on the finding that humans attempt to understand computers as analogical extensions of familiar activities [3]. This led to availability of desktop interface and direct manipulation interaction.

With internet, a revolution is occurring in the development of user interface. Whilst Welie [4] design interface with aim to allow user to focus on the task at hand and reduce the amount of overhead knowledge required communicating effectively with the website, Langdon and friends [15] emphasize on user capability and limitation during processing information. In addition, Chen et al [5] proposed a theoretical framework of UI underlying cognitive processes. Chen and his colleagues revealed that users' cognitive styles significantly influence their reaction to the user interface in terms of format, accessibility, and structure. These user interface designs are mostly discuss through literature study and there has been little discussion about theoretical studies in the area of UI designs. Thus, this study plan to explore the theoretical foundation for supporting UI design particularly looking at UI in cognitive perspectives.

2.2 Why Cognitive Study?

It has been observed that the goal of user interface design is to reduce the gap between users and system [6] and the cognitive-based design is a good way to achieve this goal [7]. Cognitive-based design can improve recall of information [8] and make applications more satisfying and easier to learn [9]. Callaway and his colleagues [10] report on good recall of information during museum visit based on cognitive aspect. They argue that cognitive aspect is important in designing museum exhibition. In addition [11]

stress on human's cognitive characteristic play a key role in designing satisfy user interface. They concluded that understanding the components and the associated skills becomes a focus of attention and helps in designing usable UI design. Similar conclusion have drawn by Schneiderman [6] and he included cognitive aspect as one of the guidelines to deliver satisfy user interface. Thus, consideration on cognitive aspect is important in enhancing usable user interface.

Cognitive is an important characteristic that influences the effectiveness of user activity. Graziola and friends [12] have studied on users' reactions to interface design and found that cognitive significantly influence user reaction to user interface in terms of user experience. They concluded that any interactive application played on museum helps in enhancing experience to the users. However, interactivity may effect system performance and the design should consider user cognitive load. Thus, consideration on cognitive aspect is important in enhancing effective communication between user and website.

Research on human cognition can provide established conceptual frameworks toward investigation of the ability to acquire knowledge involved in the use of UI of Web environment. A theory which can support of cognitive aspect is Multiple Resource Theory. Multiple resource theory is used for predicting resource demand when multiple tasks are concurrently executed [13]. These predictions have significant impact in the area of user interface design because most practical applications are carried out in multi-task environments. The main theoretical foundations of MRT originally were established by Wickens' and Baddeley's work [13], which provided the basis and perspective needed to guide the work described in user interface design.

3 Multiple Resource Theory

According to Basil [13] the multiple resource theory (MRT) is proposed by Wickens. The theory helps to identify on UI components which aim to support cognitive aspect. User interface components are identified based on three different dimensions: perceptual modality, visual channels, and code of processing.Three components of MRT and related UI component are discuss in the following subsections.

3.1 Perceptual Modality

In MRT, perceptual modality is associated with the human channels of perception [18]. Perception involves human senses like textual content, visual content, and sound content components [14]. In inter-human communication, modalities are being used to express meaningful conversational contributions include speech, gestures, touch, facial expressions and smell [14]. Fikkert and friends [16] refer modality as defined by Bunt and Beun as an attribute that indicates the mode, manner, or form of something that the human sense employed to process information. Recently, McGAnn [17] discussed on perceptual modality and claimed that perceptual modalities is relate to "mode of presentation" of a particular attention. Thus, perceptual modality is related with form in which the information is presented. For our study, format dimension of UI is proposed to be used as dimension related to perceptual modality.

3.2 Visual Channel

A visual channel is nested dimension within visual resources, distinguishing between focal and ambient vision [13]. Focal vision supports object recognition in reading text and recognizing symbols and ambient vision is responsible for perception of orientation and movement [18]. The focal and ambient vision appears to be associated with different resource structures [13][18] in the sense being associated with different types of information processing. Visual channel is thus used to recognize the information representation. For our study, representation dimension of UI is proposed to be used as dimension related to perceptual modality.

3.3 Codes of Processing

In MRT, code of processing is related to how user process information [18]. Two different methods of processing are recommended by Huthmann [19]. The recommendation is based on spatial ability and categorical ability. While, spatial ability is the capability for processing and imaging movements or other changes in visual object, categorical ability is the capability for processing and imaging movements or changes in verbal information. According to Langdon [14] analog/spatial processing maintains visual materials such as pictures and diagrams, while categorical/symbolic processes sustains verbal information. For our study, structure dimension of UI is proposed to be used as dimension related to code of processing.

4 Research Framework

Based on MRT, cognitive-based research framework is proposed. This research framework consists of three dimensions of UI identify through an aiding concept. The important of each component relate to each of MRT dimension is illustrated in Figure 1.

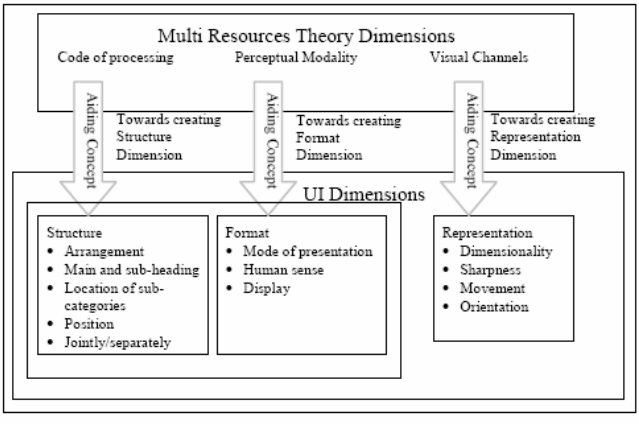

Fig. 1. Research Framework

4.1 Aiding Concept

Aiding concept is introduced by Greef and Neerincx [21]. Cognitive factor, support concept and support function are important in aiding concept. Aiding concept is used to derived UI dimensions. Users benefit from aiding, because the defined UI dimensions can invoke less demand cognitive processing. Table 2 shows the UI dimensions derived through the three levels of requirements.

Table 1. Proposed UI support Function Dimensions

MRT dimensions	Support concepts	UI support function dimensions
Visual Channels	Support the response selection and response execution	Representation • Sharpness • Dimensionality • Movement • Orientation
Perceptual Modalities	Support perception	Format • Mode of presentation • Human sense • Jointly/separately • Display
Code of processing	Support working memory	Structure • Arrangement • Main and sub-heading • Location of sub-categories • Position

4.3 Format Dimension

Format is a basic unit of the user interface space. In some cases these are sounds or textual and in other cases, images, either static or dynamic. Static type uses to display of electronic text. Dynamic type can serve a wide variety of iconic uses. Individual is tendency to view information either in static or dynamic format. However, to recognize objects, user must have cognitive ability for matching its features to image descriptions. Verbalisers tend to use verbal presentations to illustrate information when thinking, and prefer words rather than images. Imagers tend to use images to illustrate information when thinking, they understand visuals [20]. Verbalizes are superior at working with verbal information whereas imagers are better at working with visual and spatial information. Imager users view information in the form of photographs, diagrams, graphs, charts or basic animations. A verbalizer user tends to choose textual fashion such as written word or spoken.

4.4 Representation Dimension

Representation would be support response selection and response execution during information processing stage. During response selection, user would be attracted to

choose object that directional to appropriate to in choose and easy to be exercised. Implementation on object happens when users choose to manipulate that object. Possible actions of manipulations a visual components include enlarge, zooming and rotation. Visual component permits object with characteristics that describe their structure and behavior [22]. Behavior will be indicated in a form of dimensionality. The dimensionality will determine whether object is 1D, 2D or 3D. Dimensionality will determine manipulation activity of user. Studies on this dimensionality have a comprehensive survey in HCI field and many advantages stated such as performance, experience and preferences.

4.5 Structure Dimension

Structure dimension will take place when user tries to understand a current situation. During processing stages, user will use their knowledge and experience and try to capture any knowledge kept in their mind. If the user have an experienced about the issue then it is easy to them to understand. Graff and [23] discussed on tendency for individuals to process information either as an integrated whole or in discrete parts of that whole. Analytical person process information from parts to the whole; able to establish meaningful structures, sequential, conceptually oriented, and prefer individualized learning. Wholists person process information from the whole to parts, they are factually oriented and affective, not highly organised and less likely to impose a meaningful organisation when there is no structure.

5 Conclusion

This paper explores the important of impact of cognitive aspects in UI design. MRT is explored and research framework is proposed using the MRT. In our proposed we highlight, to identify dimensions is important in museum for presenting object. There are several important implications of our research for research and practice. First, we used some existing concepts of cognitive to understand UI web environment. Second we integrated internal and external perspectives related to cognitive study to offer a holistic view of strategically UI development by using theoretical propositions suggested by MRT in forming the theoretical framework of UI dimensions.

Future work implies that this cognitive understanding of UI design may be further accommodated by the FI/FD dimension influences for the localization process of the UI features. In addition, our framework could be further empirically verified by researchers interested in this area of research. This may be done with the theoretical testing process research method by using practical heuristic UI design guideline relating to theoretical propositions highlighted in this study. Moreover, the theoretical building method reflected in this study that conducted by focusing on inductive reasoning may provide future empirical work toward validating the theoretical propositions for UI dimensions. Our research reflected in this paper is an effort to offer some theoretical understanding of UI dimensions by the adaptation of cognitive aspect. Furthermore, our work could be used as a starting point for conducting empirical studies to uncover the dynamics of UI dimensions.

References

1. Brown, S.: Let's Be Specific: Predicting Return On Investment in On-line Learning Activity Design. In: Trant, J., Bearman, D. (eds.) Proceedings of Museums and the Web 2007, Archives & museum Informatics, Toronto (2007)
2. Klett, F.: The Challenge in Learning Design Concepts: Personalization and Adaptation in Virtual Arrangements. In: ITHET 6th International Conference. IEEE, Los Alamitos (2005)
3. Yun, L., Yufen, C., Yingjie, W.: Cognition theory-based research on adaptive user interface for geo-visualization system. In: Proc. 12th Int. Conf. on Geoinformatics – Geospatial Information Research: Bridging the Pacific and Atlantic (2004)
4. van Welie, M.: Task-Based User Interface Design, thesis (2001)
5. Chen, S.Y., Magoulas, G.D., Macredie, R.D.: Cognitive styles and users' responses to structured information representation. International Journal Digital Library 4, 93–107 (2004)
6. Schneiderman, B., Plaisant, C.: Designing the User Interface: Strategies for Effective Human-Computer Interaction, 4th edn. Addison-Wesley, Reading (2004)
7. Fujita, H., Hakura, J., Kurematu, M.: Cognitive Evolutionary Techniques in User Interface Design Based on Human Aspect Modeling. International Journal of Computers 2(1) (2008)
8. Katrina Pariera, B.A.: Information Literacy On The Web: How Visual And Textual Cues Contribute To Website Credibility Assessments. Thesis (2009)
9. Oviatt, S.: Human-Centered Design Meets Cognitive Load Theory: Designing Interfaces that Help People Think. ACM, New York (2006)
10. Callaway, C., Kuflik, T., Not, E., Novello, A., Stock, O., Zancanaro, M.: Personal Reporting of a Museum Visit as an Entrypoint to Future Cultural Experience. In: IUI 2005 and ACM (2005)
11. Fikkert, W., D'Ambros, M., Bierz, T., Jankun-Kelly, T.J.: Interacting with Visualizations. In: Kerren, A., Ebert, A., Meyer, J. (eds.) GI-Dagstuhl Research Seminar 2007. LNCS, vol. 4417, pp. 77–162. Springer, Heidelberg (2007)
12. Goren Bar, D., Graziola, I., Pianesi, F., Zancanaro, M.: Dimensions of Adaptivity in Mobile Systems: Personality and People' s Attitudes. In: Proceedings of Intelligent User Interfaces IUI 2005, San Diego, pp. 223–230, January 200531–62 (2006)
13. Basil, M.D.: Multiple Resource Theory II: Application To Television Viewing. Communication Research 21, 208–231 (1994)
14. Langdon, P., Persad, U., John Clarkson, P.: Developing A Model of Cognitive Interaction for Analytical Inclusive Design Evaluation. Interacting with Computers 22, 510–529 (2010)
15. Jacobson, S.: Learning Style and Lawyering: Using Learning Theory to Organize Thinking and Writing. Journal of the Association of Legal Writing Directors 2, 27–73 (2004)
16. Fikkert, W., Bierz, T., D'Ambros, M., Jankun-Kelly, T.J.: Interacting with Visualizations. In: Kerren, A., Ebert, A., Meyer, J. (eds.) GI-Dagstuhl Research Seminar 2007. LNCS, vol. 4417, pp. 77–162. Springer, Heidelberg (2007)
17. McGann, M.: Perceptual Modalities: Modes of Presentation or Modes of Interaction? Journal of Consciousness Studies 17(1-2), 72–94 (2010)
18. Wickens, C.D.: Multiple Resources and Mental Workload. Human Factors 50(3), 449–455 (2008)
19. Huthmann, A.: Presence-Dependent Performance Differences Between Virtual Simulations And Miniature Worlds, thesis (2009)

20. Riding, R., Rayner, S.G.: Cognitive styles and learning strategies. David Fulton, London (1998)
21. Neerincx, M.A., de Greef, H.P.: Cognitive Support: Extending Human Knowledge and Processing Capacities. Human-Computer Interaction 13, 73–106 (1998)
22. Nguyen, G.T., Rieu, D.: Multiple Object Representations. In: Proc. 20th ACM Computer Science Conference, Kansas City (Mo) (1992)
23. Davies, J., Graff, M.G.: The wholist-analytic cognitive style: A matter of reflection. Personality and Individual Differences 41(6), 989–997 (2006)
24. Schweibenz, W.: The Virtual Museum: New perspectives for museums to present objects and information using the Internet as a knowledge base and communication system. (1998), http://www.informationswissenschaft.org/download/isi1998/14_isi-98-dvschweibenz-saarbruecken.pdf (retrieved September 6, 2009)
25. Natrah, A., Wan Adilah, W.A., Nor Laila, M.N.: A Framework of Web-based Cultural Tourism Information System Evaluation. In: The 2009 International Joint Conferences on e-CASE and e-Technology, pp. 655–665 (2009)
26. Wan Abdul Rahim, W.M.I., Nor Laila, M.N., Shafie, M.: Incorporating the Cultural Dimensions into the Theoretical Framework of Website Information Architecture. In: Aykin, N. (ed.) HCII 2007. LNCS, vol. 4559, pp. 212–221. Springer, Heidelberg (2007)