RESEARCH ARTICLE

Assessing Aptness of Usability Attributes in VE and UEMs

Kirti Muley*, Maya Ingle
School of Computer Science and IT, Devi Ahilya Vishwavidyalaya Takshashila Campus, Indore, INDIA

Abstract

Usability of any software has become an extremely important issue due to recent competitive era. Thus, highly usable softwares are in the demand from the prospective of development and product both. For evaluation of usability of software, there exists several Usability Evaluation Methods (UEMs) in practice such as cognitive walkthrough, heuristic evaluation, formative evaluation, post-hoc questionnaire, interview, summative evaluation, Testbed evaluation, user task analysis and MAUVE. In general, it has been observed that these methods are applicable for evaluating the usability of software used in Non-Virtual Environment (NVE) except MAUVE. Software products developed in Virtual Environment (VE) gain more popularity as they provides the illusion of real world system. Literature revealed that VE has a wide range of interaction interfaces, which made it difficult to evaluate the user's performance within VE. Traditional evaluation methods have been extended to support the VE evaluation with some limitations. However, an attempt to draw attention towards the role of usability attributes in existing UEMs especially applicable in VE, in this paper. Various existing usability methods have been studied empirically and extracted related information of concerned usability attributes. On the basis of this study, it may be stated that the usability attributes *learnability*, *presence* and *expose* are very important attributes in UEMs in VE whereas attributes *understandability*, *affordance* and *ease of use* are scaled at next level of importance. In contrast, the usability attributes *presence*, *expose* and *efficiency* in NVE and *satisfaction* in VE are missing their importance in UEMs. This study may further be useful to enhance existing UEMs in VE.

Keywords: Attributes, Usability, Usability Evaluation Methods, Virtual Environment

Introduction

In present competitive era, there is an immense need to develop the usable software and to produce usable products. Usable product meets the specified minimum usability criteria. In general, criteria will depend on the specific requirements of the users, tasks and environment used (Scholtz, 2004). Various Usability Evaluation Methods (UEMs) exists for evaluation of usability in software product. Also, UEMs are used to evaluate the interaction of human with computer to identify the areas where interaction can be improved to increase the usability. These evaluation methods range from formal evaluation with large sample size to informal evaluation with small number of participants (Gray and Salzman, 1998). Literature reveals that there exists various categories for UEMs such as Analytical, Empirical, user-based, model-based, expert-based, Automatically, Formally or informally (Gray and Salzman, 1998; Dillon, 2001; Tsai, 2007). These methods include cognitive walkthrough, empirical evaluation, heuristic evaluation, expert review, review against standards, formal lab testing, inquiry methods, inspection methods and testing methods etc. (Rosenbaum, 1989; Ferre *et al.,* 2001; Grice, 2003; Huart *et al.,* 2004; Kock *et al.,* 2009). These methods are able to deal with different usability aspects having their own capabilities and limitations. Also, it has been observed that usability of a software product may be evaluated using more than one UEMs. In practice, only one UEM is used generally due to time and cost constraints. To identify the best suited UEM, there is a need of comparison of UEMs as no standard guidelines are present (Hartson *et al.,* 2003). Also, existing UEMs are basically developed to evaluate the usability of 2-Dimensional or Graphical User Interfaces (GUI) systems. However, there remains a scope of analyzing UEMs and dominance of usability attributes correspondingly in Virtual Environment (VE).

Developing a software product in VE has been a privilege for developers as it provides the illusion of actual system (act in 3-Dimensional world) (Ellis, 1994). In VE applications, there exists a different interaction styles as compare to ordinary user interfaces. The usable interfaces using well known methods in VE seem to be neither appropriate nor effective (Bowman *et al.,* 2002). In Section II, existing UEMs are discussed along with pros and cons. Section III presents the association of usability attributes

*Corresponding Author : Email : kirti_muley13@iisuniv.ac.in

with existing UEMs along with comparison and aptness of usability attributes associated with UEMs in VE and NVE. Finally, Section IV includes results and conclusion.

Existing Evaluation Methods

Cognitive Walkthrough Method

Cognitive walkthrough method particularly focuses on evaluation of usability attribute *learnability* (Scholtz, 2004; HCI Express, 2011). In this evaluation method, interaction between the user and the interface through some pre-defined tasks has been inspected (Bowman *et al.,* 2002; Kock *et al.,* 2009). This approach helps to understand the usability of a system for the naive users (Patel *et al.,* 2006). This method can either be applied at the early stage of interface design or during beta testing phase. Cognitive walkthroughs can be performed by individuals or by groups (Scholtz, 2004; Tsai, 2007; HCI Express, 2011). The evaluation activity may be lengthy and time consuming because of its detail orientation (Tsai, 2007).

Heuristic Method

Heuristic evaluation method can be performed by experts as well as by non-experts. Heuristics are general rules which define common properties of good design (Ferre *et al.,* 2001). On the basis of these rules, evaluators examine the usability related aspects of user interface. Literature reveals that standard set of heuristics does not exist (Perlman, 2015). Heuristic evaluation can be performed by one evaluator. However, it has been observed that effectiveness of method increases with multiple evaluators (Patel *et al.,* 2006). Heuristic methods are quicker and easy to use and hence cost-effective also (Swartz, 2003). At the same time, it has been found that it is highly effective method to find out usability issues in software products. However, effectiveness of method depends mainly on evaluator's skill and experience. It has been observed that proper guidance is not available in method instructions.

Formative Method

Formative evaluation method involves finding and fixing problems as part of an iterative design process to make an interface more usable. Evaluation activity must begin as soon as possible in software development life cycle. Formative evaluation ranges from informal such as user comments, general reactions to very formal and extensive, producing both qualitative and quantitative results (Bowman *et al.,* 2002). Collected data has been analyzed to identify user interface components that diverted from user task performance and user satisfaction. The main purpose of formative evaluation is to improve usability continuously through iterative user's observational studies. It is a time consuming process as it works in iterative manner (Swartz, 2003).

Summative Method

In contrast to formative evaluation method, it is used to judge the complete product against some specific goals. Summative evaluation typically involves a statistical comparison of two or more configurations of user interface design, user interface components and/ or interaction techniques (Bowman *et al.,* 2002; Patel *et al.,* 2006). Generally, it has been performed after user interface design or components are completed. Summative evaluation enables evaluators to measure and subsequently compare the productivity and cost benefits associated with different user interface designs. Summative evaluation is used to obtain measures to establish a usability benchmark or to compare results with usability requirements. This method requires fully functional prototype to evaluate the usability. The result of summative evaluation is an interface that performs the best or is the most usable in a comparative study.

Post-hoc Questionnaire Method

Literature reveals that questionnaire evaluation method is the most frequently used tool to evaluate usability (Bowman *et al.,* 2002). Written set of questions is used to obtain subjective data. It is normally conducted after users have been participated in a usability evaluation session. Method is easy to conduct and compare. For effective evaluation, it is required that questions must be well designed and conducted on large sample size.

Interview Method

Using interview evaluation method, one can gather more information than questionnaire and hence there is a scope to go into deeper level of details (Bowman *et al.,* 2002; Patel *et al.,* 2006). In this method, information can be collected by talking to users directly. Interviews can be categorized as structured interviews and open-ended interviews (Patel *et al.,* 2006). Structured interviews have predefined set of questions and responses. On the other hand, in open-ended interviews, users can provide additional information and interviewers can ask any question to explore the details. Interviews are used to collect qualitative data (Swartz, 2003). This method is flexible and provide in depth investigation. At the same time, it is time consuming and difficult to analyze and compare the results of method.

Testbed Method

This approach involves examining the effect of a primary independent variable such as a particular interaction device or technique (Bowman *et al.,* 1999; 2002; Swartz, 2003; Patel *et al.,* 2006). Also, it considered other potential factors which might have an impact on the experimental results such as frame rate, task, environment characteristics, and user characteristics. Evaluation of interaction is often conducted outside the context of specific applications and thus, produce generalized results (Bowman *et al.,* 2002). Testbed evaluation can be conducted when quantitative, statistical results are required and usually involves large numbers of participants. Evaluation activity observed to be time consuming, complex and costly.

User Task Analysis Method

Task analysis can be conducted to understand the current system and information flows within it (Bowman *et al.,* 2002). Design and allocation of task can be appropriately performed within the new system by using task analysis method. In this method, high level tasks are decomposed and break down into their constituent subtasks and operations (Crystal, 2004). It provides the knowledge of task that user wishes to perform along with features and functions that can be tested. It can be very time consuming activity if used with high degree of detail on complex problems. It has been considered to be most critical activity in usability engineering process but often overlooked.

Multi-Criteria Assement of Usability for Virtual Environment System

MAUVE supports heuristic evaluation, evaluators review the software product and predict its usability. It is a two phase evaluation method. First phase uses traditional usability heuristic method and in second phase, specific usability criteria are evaluated either by questionnaire or by user testing (Swartz, 2003; Hale and Stanney, 2014). This method can be used at various stages in the usability engineering life cycle. It is also used to compare design alternatives.

Materials and Methods

Usability Attributes in VE and NVE Vs UEMs

There are UEMs which are more suitable to VE such as testbed evaluation, user task evaluation, MAUVE etc. In this paper, the association of usability attributes and UEMs is focused. An intuitive approach has been used to extract related information of concerned usability attributes for UEMs.

Association of Usability Attributesand UEMs

To determine the association of usability attributes and UEMs in VE and NVE both, total 19 usability attributes were considered which exists in VE (Muley *et al.,* 2014). Most commonly used UEMs are taken into consideration such as cognitive walkthrough method, heuristic evaluation, formative evaluation, post-hoc questionnaire method, interview method, summative evaluation, testbed evaluation, user task analysis evaluation and MAUV evaluation. It has been observed that each UEM focused on evaluating certain usability attributes. On the basis of this, certain usability attributes associated with each of the aforesaid UEMs are identified. Usability attributes in VE and NVE have been associated with UEMs and is shown in Table 1.

Comparing Usability Attributes in UEMs in VE and NVE

Occurrence of each usability attribute was considered for each UEM in VE and NVE, and for both environments. Table 2 depicts the data of occurrence of each usability attribute in UEMs with percentage of aptness in both environments for each usability attribute.

Results and Discussion

The study under consideration reveals the following results

- Usability attribute *learnability* has been evaluated as 20 and 12 respectively in both environments as percentage of use and possess highest aptness in both environment while using UEMs (depicted by * in Table 2).
- *Presence* and *expose* computed as 11.2 as percentage of use and observed to be almost equally important usability attributes as *learnability* in VE (depicted by ** in Table 2).
- Percentage of use of *Understandability* and *ease of use* is computed as 14 and observed to be at the next level of importance for UEMs in NVE (depicted by ** in Table 2).
- At the same time, the percentage of use of *presence, expose and efficiency* computed as 0 and possess lowest importance in NVE .The usability attribute *satisfaction* is computed as 0 during the process of evaluation and possess lowest importance in VE as shown in Table 2.

Above results indicate that UEMs both in NVE and VE are highly interested to evaluate the ease to remember the operations of a software application. Similarly, in VE the UEMs are also interested to measure the aptness of *presence* and *expose* as both of usability attributes are

Table 1. Association of Usability Attributes and UEMs.

S. No	UEMs	Usability Attributes in	
		NVE	*VE*
		Applicability Status/ Usability Attributes	***Applicability Status/ Usability Attributes***
1	*Cognitive Walkthrough Method*	*√(Learnability, Understandability, Affordance)*	*√(Learnability, Memorability, Navigation, Understandability, Presence, affordance)*
2	*Heuristic Evaluation*	*√(Learnability, Navigation, Consistency, Help, Robustness, Memorability, Ease of Use, Interactivity)*	*√(learnability, Navigation, Consistency, Help, Presence, Interactivity, Robustness, Ease of Use, Efficiency, Affordance, Understandability, Memorability)*
3	*Formative Evaluation*	*√(Ease of Use, Learnability, Safety, Memorability, Understandability)*	*√ (Presence, Safety, Ease of use, Learnability, Memorability, Understandability, Expose)*
4	*Post-hoc Questionnaire Method*	*√(Satisfaction, Usefulness, Ease of Use, Robustness, Learnability, Consistency, Memorability)*	*√ (Ease of Use, Navigation, Affordance, Robustness, Helpfulness, learnability, Presence, Expose)*
5	*Interview Method*	*√ (Satisfaction, Usefulness, Ease of Use, Robustness, Learnability, Consistency, Memorability)*	*√ (Ease of Use, Navigation, Affordance, Robustness, Helpfulness, learnability, Presence, Expose)*
6	*Summative Evaluation (both formal and informal)*	*√(Understandability, Learnability)*	*√(Understandability, Learnability, Expose)*
7	*Testbed Evaluation*	*√(Ease of Use, Understandability, Affordance, Learnability*	*√ (Ease of Use, Understandability, Affordance, Learnability, Presence, Expose)*
8	*User Task Analysis Evaluation*	*√(Understandability)*	*√(Understandability, Expose)*
9	*MAUVE (Multi-Criteria Assessment of Usability for Virtual Environment System) Evaluation*	*NIL*	*√(Learnability, Navigation, Consistency, Robustness, Memorability, Ease of Use, Interactivity, Expose, Affordance, Helpfulness, Learnability, Presence)*

building blocks for VE. It is observed that the entire focus of UEMs in VE shifted to assess *presence* and *expose* and that might be the reason that one of the most important usability attribute *satisfaction* missed from the process of evaluation. These results may vary as usability attributes for evaluation may vary from application to application especially in VE. However, this study may be useful to overcome the limitations of existing UEMs in VE. It is suggested to decompose the evaluation process further to make less complex and time consuming. Evaluators may suggest to incorporate the attribute *satisfaction* in the process of evaluation as an important usability attribute.

Table 2. Comparing Occurrence of Usability Attributes in UEMs

S. No	Usability Attributes	Existence of Usability Attributes in UEMs				Both in NVE & VE
		Occurrence in NVE	*Percentage use in NVE*	*Occurrence in VE*	*Percentage use in VE*	
1	*Learnability*	7	20*	8	12*	7
2	*Understand-ability*	5	14**	6	9.6 ***	5
3	*Affordance*	2	5.7	6	9.6***	2
4	*Navigation*	1	2.8	5	8.06	1
5	*Consistency*	3	8.5	2	3.22	2
6	*Helpfulness*	1	2.8	4	6.4	1
7	*Memorability*	4	11.4***	4	6.4	4
8	*Ease of Use*	5	14**	6	9.6***	5
9	*Interactivity*	1	2.8	2	3.22	1
10	*Safety*	1	2.8	1	1.6	1
11	*Satisfaction*	2	5.7	0	0	0
12	*Presence*	0	0	7	11.2**	0
13	*Expose*	0	0	7	11.2**	0
14	*Robustness*	3	8.5	4	6.4	3
15	*Efficiency*	0	0	1	1.6	0

References

Bowman, A. D., Johnson B. D. and Hodges, F. L. (1999) Testbed Evaluation of Virtual Environment Interaction Techniques. *VKST 99*: 26-33.

Bowman, D., Gabbard, J., and Hix, D. (2002) A Survey of Usability Evaluation in Virtual Environments: Classification and Comparison of Methods. *Presence: Teleop Virt Env* **11(4)**:404-424.

Crystal, A. and Ellington, B. (2004) Task analysis and human-computer interaction: approaches, techniques, and levels of analysis. Proceedings of the Tenth Americas Conference on Information Systems.

Dillon, A. (2001) Usability evaluation. In *W. Karwowski (ed.) Encyclopedia of Human Factors and Ergonomics*, London: Taylor and Francis.

Ellis, R. S. (1994) What are Virtual Environments? *IEEE J Comput Graph Appl* **14**:17-22.

Ferre, X., Juristo, N., Windl, H. and Constantine, L. (2001) Usability basics for software developers. *IEEE software*,**18 (1)**:22 – 29.

Gray, D. W. and Salzman, C. M. (1998) Damaged Merchandise? A Review of Experiments That Compare Usability Evaluation Methods. *Hum Comput Interact* **13**: 203–261.

Grice, R. A. (2003) Comparison of cost and effectiveness of several different usability evaluation methods: a classroom case study. *IEEE, **IPCC*** 140-144.

Hale, S. K. and Stanney, M. K.(2014) Handbook of Virtual Environments: Design, Implementation and Applications, 2nd Edition.Broken South Parkway NW:CRC Press https://books.google.co.in/books?isbn=1466511842

Hartson, H., Andre, T. and Williges R. (2003) Criteria For Evaluating Usability Evaluation Methods. *Int J Hum-Comp Int* **15 (1)**:145-181.

HCI Express. (2011) Experts Review for Usability: Cognitive walkthrough vs Heuristic Evaluation, https://hciexpress.wordpress.com/2011/09/19/cognitive-walkthrough/. Accessed 4 January 2015

Huart, J., Kolski, C. and Sagar, M. (2004) Evaluation of multimedia applications using inspection methods: The Cognitive Walkthrough Case. *Interacting with Computers 2004* **16(2)**:183-215.

Kock, E., Biljon, J. and Pretorius, M. (2009) Usability evaluation methods: Mind the gaps. *SAICSIT'09* 122-131.

Muley, K., Paithankar, K. and Ingle, M. (2014) Comparing Software Usability Attributes in Virtual Environment and Non-Virtual Environment. *IJARCS* **5 (6)**:201-205.

Patel, H., D'Cruz, M., Cobb, S. and Wilson, J. (2006) Initial Report on Existing Evaluation Methodologies Information Society Technologies (IST) Programme.

Perlman, G. (2015) User Interface Usability Evaluation with Web-Based Questionnaires. http://oldwww.acm.org/perlman/question.html. Accessed 4 January 2015

Rosenbaum, S. (1989) Usability Evaluation Versus Usability Testing: When and Why?. *IEEE Trans prof Commun* **32 (4)**:210-216.

Scholtz, J. (2004) Usability Evaluation. *National Institute of Standards and Technology*. http://wwww.itl.nic.gov/iad/IApapers/2004/Usability%20Evaluation_rev1.pdf. Accessed 10 October 2011.

Swartz, O. K.(2003) Virtual Environment Usability Assessment Methods Based on a Framework of Usability Characteristics. Blacksburg, VA.

Tsai, P.(2007) A Survey of Empirical Usability Evaluation Methods. *GSLIS Independent Study*. http://web.simmons.edu/~tsai/Papers/PBartley-empirical-usability-eval.pdf. Accessed 3 January 2015