ENHANCING DESIGN CRITERIA FOR NOVICE VIRTUAL ENVIRONMENT DESIGNERS THROUGH THE IDENTIFICATION OF USABILITY PROBLEMS

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Abstract *¾ In this paper we investigate common problems made by novice designers in their virtual environment (VE) designs. Our aim through this study is to alleviate some of the problems encountered by novice designers in their attempts to design and implement their first VEs. The investigation involves the application of usability evaluation techniques as used in Human-Computer Interaction (HCI). Some existing guidelines in VE design are used as a basis for the preliminary work. In our work, we rank usability problems according to how serious they are in the design process. Then, based on this ranking we suggest a set of candidate's criteria for VE design meant specifically for novice designers. The findings from this study highlight the importance of these existing guidelines and the need to modify some of them to suit the requirements of novice designers.*

Index Terms ¾ Human-Computer Interaction (HCI), Usability Evaluation, Virtual Reality (VR), Virtual Environment (VE)

INTRODUCTION

Designing effective and usable content of a virtual environment (VE) is becoming increasingly important with the proliferation of many applications in real-world visualisation. It is essential to look at the usability of the VE application design as not to get users frustrated when exploring the environment. Much groundwork in the domain of evaluating VE application starts from the traditional human-computer interface usability [3,5,6]. Applying Human-Computer Interaction (HCI) concepts which encompass notions from inter-related fields enable one to obtain the immersive feeling in the VE.

In designing an effective VE application, there are many factors that need to be considered. These factors include the technology used, the time, the cost and expertise [4]. To instil the usability elements as part of the design poses another big challenge especially to novice VE designers. The question of how we inform novice designers to incorporate usability in their design is an issue to be discussed.

This paper identifies common problems made by novice designers in their VE design. The intention is to guide designers not to repeat the same mistakes again. The investigation is extended to ranking the usability problems based on how critical or serious they are in the VE design process.

BACKGROUND

Usability issues are concerned with obtaining products which are user friendly or easy to use. International Standards Organisation (ISO) defines usability as '… the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments' (ISO DIS 9241-11). Designing for usability takes into consideration elements which include specifying user characteristics, requirements capture, usability specification and iterative design and prototyping [8]. The integration of usability in design will result in acceptance of the system by the users as reported in many success cases (e.g. [13]).

Evaluation techniques as used in the area of Human-Computer Interaction (HCI) could be applied to virtual reality (VR) especially in designing effective virtual environment. Adopting matured techniques from other disciplines to VR could accelerate the development of virtual environment (VE). This is necessary as a VE is difficult to design and use [14]. VE systems differ from previously computer-centred systems in the extent to which real-time interaction is facilitated. In terms of characteristics, VE systems require a 3-D visual space, a multi-modal interface and an immersive environment [1]. These characteristics are not required by other computer-centred systems as they could be displayed on 2-D. Real-time interactions, which may lead to users' immersive feelings, are not necessary too. One possible way to facilitate development of a VE is through an enhancement on the evaluation technique. Evaluation activity as described in the Star Life Cycle [7] is central to the whole design process. Feedback received from the evaluation process is used to inform the design team about how well the proposed design fits the needs of users.

Reference [2] has formulated some guidelines for evaluating usability of a VE based on HCI. The purpose of her guidelines is to advise developers when designing VE.

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These guidelines contain elements to be considered when designing the objects, user actions and system control of a VE. Reference [5] took a user-centred design and evaluation approach in ensuring the usability of their virtual environments. Their technique is based on user task analysis, expert guidelines-based evaluation, formative and summative evaluation.

In conducting usability evaluation, there are no single techniques which could capture all usability problems. Often, combination of techniques proves to be beneficial [12]. However, at times, a 'quick and dirty' technique is required in order to obtain a fast feedback while maintaining the quality. Usability inspection techniques which include heuristic evaluation meet this requirement and are reported to be cost-effective [11]. Heuristics evaluation conducted by 5 experts could capture 75% of the usability problems [10]. Many researchers (e.g. [9]) have applied this result to their work and reported the same findings in terms of the number of experts and usability problems found. Reference [9] reported that experienced and novice usability specialists differ in terms of judgement in evaluating a graphical user interface. The experienced evaluators were able to use the knowledge of previous user testing results and the knowledge of similar designs to identify problems which were missed by the novices.

METHODOLOGY

In our work, we replicate Lee *et al.*'s [9] and Nielsen [10] heuristics evaluation approach. Using these approaches, we meant:

i. to identify common problems/ mistakes made by novice designers, and
ii. to rank the problems accordingly using Nielsen's [10] approach to decide how critical the problems are in the design

Subjects

Five usability experts who are members of staff at Universiti Teknologi PETRONAS were selected for this study. An 'expert' is defined to be someone who had three or more years of experience evaluating students' projects. All usability experts chosen have a background in either computer science and/ or IT related disciplines.

Materials

A training document was created for the guidelines described in Deol [2]. This document describes the guidelines and provides examples for each. Three small VE applications developed by final year IT students were selected. This selection was based on their scores obtained during an exhibition on campus during the semester.

Guidelines developed by Deol [2] which are used during the evaluation, specify ways to design objects, how to control them and their interactions in the environment. These guidelines serve as useful checklist to designers in ensuring the usability of the design. They also provide a basis for encouraging usability earlier in the development lifecycle.

Design and Procedure

All five expert evaluators went through the following test procedure:

i. Answer a questionnaire about their background
ii. Learn about the guidelines
iii. Evaluate the VE applications

Evaluators were tested individually. They were asked to think aloud as they carried out the task and were prompted to continue thinking aloud when they fell silent. Evaluators were given a maximum time limit of 1 hour to complete the evaluation. They were encouraged to use all their time even if they had finished early. During the evaluation, evaluators were asked to describe any problems encountered and recommend a possible solution. Their feedback was recorded on hardcopy forms. They were asked to use the guidelines to assist them in identifying those problems.

DATA ANALYSIS

Compilation of Usability Problems

All usability problems reported by evaluators were first analysed by the authors. (A complete listing of usability problem reported by individual evaluators is included in Appendix 1). The process started with counting the total number of usability problems identified by each evaluator. This is shown in Table 1. Each usability problem reported is considered as a major problem by the evaluator as it could hinder users from achieving immersive feeling in the virtual environment. All usability problems were compiled and checked for any similarities among them. Problems which are of the same nature, i.e. sharing a common theme/area are grouped together. From a total of 48 usability problems in Table 1, we have identified only 9 groups of usability problems. These groups of usability problems (in random order) are: objects should look real; objects should behave naturally like in real world; objects should be easy to distinguish; interactions should follow real world convention; allow users to be in control of the application; allow easy navigation as in normal real world; allow users to move freely in the environment; objects should have correct scale as in real world; purpose of objects and environment should be made clear.

TABLE 1
TOTAL NUMBER OF USABILITY PROBLEMS FOUND BY EACH EVALUATOR

Evaluator	Total Usability problem
1	12
2	8
3	14
4	6
5	8
TOTAL	**48**

Ranking the Usability Problems

We presented the 9 groups of usability problems noted in the previous section to the same evaluators where they have a joint discussion. This activity is part of heuristics evaluation developed by Nielsen [10] which is used in Lee *et al.*'s [9]. The objective of this discussion is to gain consensus among all the five evaluators on the findings that we have compiled. It should be noted that the authors only took the facilitators role and were not part of this discussion. During the discussion, the evaluators reviewed the compiled usability problems (those performed by the authors) and suggested that some of the groups could be combined as they are related. This has reduced the groups of usability problems from 9 to 6 only. Each evaluator was asked to rank these 6 new groups on the basis of how critical they are in terms of the effect they may have on reducing the usability in VE design. A rating scale of 1 to 5 was used in which 1 means less critical and 5 means most critical. The average score given by all evaluators for each problem group was calculated and is presented in Table 2.

TABLE 2
RANKING OF USABILITY PROBLEMS

No.	Usability problem groups	Average Score Obtained	
			Most Critical
1	Make the purpose of objects and environment clear	4.67	
2	Allow users to be in control of the application	3.8	
3	Allow easy navigation in which users could move freely (as in real world)	3.4	
4	Make objects behave and interact naturally as in real world	2.4	
5	Make objects look real and have correct scale as in real world	2.0	
6	Make objects easy to distinguish	1.8	
			Less Critical

Table 2 shows the revised version of these six groups of usability problems and how critical they are in the design. Evaluators pointed out that the most important element in designing VE is the sense of purpose of the environment and objects used in it. Users need to understand the goal and objectives of a particular environment. This will give them a mindset of what the environment or objects are trying to imitate or mimic. Once users have realised or understood the environment, it would be easier for them to be in control of the VE application.

Navigations are made easy, as users are able to move freely in the environment. This co-relates with our human characteristics which have been applied in virtual reality such as viewpoint, navigation, manipulation and immersion. The ability to access the environment without restraint could then assist users in achieving the main objective of VE design which is the immersive feeling. Evaluators further suggested that for smooth navigation, there should be indicators to notify the users that certain areas should be restricted. As an example, mouse cursors changed when user collides with objects such as walls or trees.

From the findings, evaluators have pointed out that issues in designing VE objects are secondary to interaction. They argued that virtual reality is a component of three elements: imagination, interaction and immersiveness. The design of the objects which appear and behave like the conventional situation constitute a step forward towards achieving the immersive feeling in the VE environment. In designing the objects, emphasis should be on 3D modelling which includes lighting, texture, collision detection, choice of colour and scale. These are all important to create the realism aspect in the objects. The behaviour of the objects is another area that needs to be looked into so that they could resemble or function as closely as possible to those in real world.

RESULTS AND DISCUSSION

In our last section, we obtained six usability problem groups, which are resulted from the discussion of the five evaluators in the study. During the study each group was also named accordingly so that these new groups could match the way Deol's [2] set of guidelines is presented. Table 3 shows both Deol's guidelines and our new list of usability problems. It should be highlighted here again that Deol's set of guidelines is used in this study as a basis to identify our new list of usability problems.

TABLE 3
DEOL'S GUIDELINES AND OUR NEW LIST OF USABILITY PROBLEMS

DEOL'S (1998)	OUR NEW LIST	Rank	
DESIGN OF OBJECTS			Most Critical
• Make objects easy to distinguish • Make objects easy to identify • Make the interactivity and significance of objects clear • Make objects easy to access	• Make the purpose of objects and environment clear • Allow users to be in control of the application • Allow easy navigation in which users could move freely as in real world • Make objects behave and interact naturally as in real world • Make objects look real and have correct scale as in real world • Make objects easy to distinguish	4.67 3.8 3.4 2.4 2.0 1.8	
DESIGN INTERACTION DESIGN OF USER ACTIONS • Show what actions are available • Make the purpose of actions clear • Show how to carry out actions • Make actions easy to execute • Show the effect of completed actions DESIGN OF SYSTEM CONTROL • Show that control has begun or ended • Show why control has taken place • Show what actions are available during control			Less Critical

Deol [2] in her work has categorised the guidelines into two: (i) Design of Objects and (ii) Design Interaction. Design Interaction is further segregated into: Design of User Actions and Design of System Control. Each category consists of several criteria. On the other hand, our new list does not have any categories. This list consists of usability problem groups taken from Table 2. It is more condensed in terms of the number of criteria (group) as compared to Deol's. Each group is assigned a value that indicates how critical the group is in the design. A higher value implies that the usability problem group associated to it should be given more priority when designing VE as compared to those assigned with lower values. This approach could be a mechanism to advise novice designers in designing their first VE application.

From Table 3, some observations are made which findings could strengthened the importance of Deol's [2] guidelines in system design but at the same time needing some adjustment to suit novice designers.

- Overlapping of guidelines

There appears to be an overlap in some of our groups with Deol's. Our group overlaps with one or more of Deol's guidelines as shown in Table 4.

TABLE 4
OVERLAPPING OF GUIDELINES

Our Group	Deol's
Make objects easy to distinguish	Make objects easy to distinguish
Make the purpose of object and environment clear	Make the purpose of actions clear
	Make the interactivity and significance of object clear

- Addressing a more higher level issues

Some of our usability problem groups seem to be addressing a more higher level issues when compared to Deol's. A combination of more than one criterion in Deol's could be a subset of our group. This is shown in Table 5.

TABLE 5
ADDRESSING HIGHER LEVEL ISSUES

Our Group	Deol's
Allow users to be in control of the application	Show that control has begun or ended
	Show why control has taken place
Allow easy navigation in which users could move freely as in real world	Show what actions are available
	Make the purpose of actions clear
	Show how to carry out actions
	Make actions easy to execute
	Show the effect of completed actions
	Show that control has begun or ended
	Show why control has taken place
	Show what actions are available during control

- Identification of new groups

There are two other groups identified in our list that are different from Deol's. These groups may seem trivial but could be useful especially for beginners in order to guide them designing appropriate object modelling which resembles real world. The new groups are shown in Table 6.

TABLE 6
NEW GROUPS

Make objects behave and interact naturally as in real world
Make objects look real and have correct scale as in real world

CONCLUSION

In this paper we have highlighted the importance of usability in designing virtual environments (VEs). Concepts in the matured inter-disciplinary fields of Human-Computer Interaction (HCI) could be applied in VE design. The question of how we inculcate and assist young and creative novice designers so that they could integrate usability as early as possible in their development cycle is an issue discussed in this paper. The approach taken in this investigation is by identifying common mistakes made by novice designers. The set of problem groups identified and discussed in this paper are converted to a set of "good design guidelines" for novice users. These guidelines will hopefully eliminate the occurrence of common mistakes during the design of future VE.

These new guidelines include making the purpose of objects and environment clear; allowing users to be in control of the application; allowing easy navigation in which users could move freely as in real world; making objects behave and interact naturally as in real world; making objects look real and have correct scale as in real world; making objects easy to distinguish. In this we have emphasised the importance of existing guidelines in VE design. We believe that additional new set of criteria will help novice designers to focus even more on ensuring usability when building new VEs. This investigation has also laid some groundwork for future research on usability issues in designing VE.

ACKNOWLEDGEMENT

The authors would like to thank Dr Mohamed Benbrahim, Dr Abas Md Said and Mr Halabi Hasbullah for their patient and careful reading of the early drafts of this paper. Also thank you to all evaluators who took part in this study and all students taking VR course during June 2001 and January 2002 sessions at Universiti Teknologi PETRONAS.

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APPENDIX

APPENDIX 1:
USABILITY PROBLEMS FOUND BY EVALUATORS

Evaluator 1

Hit No.	Usability problems
A1	Objects are easy to distinguish but they do not look so real. Adding shadow to object can make them real.
A2	Can walk through walls!
A3	Colour of the objects are too bright
A4	Shelves and cabinet are not easy to distinguish
A5	No interactivity e.g. water running from the tap
A6	No indication to show that control has begun and ended
A7	Objects are not easy to distinguish
A8	Objects in the water are not easy to distinguish
A9	Texture of the grass is not real
A10	No interaction
A11	A small movement of the mouse make the entire environment move
A12	User has less control on the mouse

Evaluator 2

Hit No.	Usability problems
B1	Some objects could not be distinguished/ identified e.g. windows
B2	Effects of lighting should be considered. Some chairs are too affected by lights, some are not
B3	Consider the use of white colour as "wall"
B4	Navigation is not easy. User does not know the restricted area to navigate. There should be some indicators whereby the user should be notified with. For example, the mouse cursors should be changed when the user collides with the restricted area such as walls, trees
B5	Some objects could not be distinguished. For example, windows and doors. It should be designed distinctively with respect to the textures and shapes
B6	The movement of objects – some objects in the application move rapidly for example the canoe and the butterfly. These objects seem to move at specific location and continuously without having any interruptions
B7	The landscape texture and design should be improved in the sense that: 1. the design should be made with less slopes and curves 2. make it more horizontal 3. the structure of the building must be straight with the structure of the land
B8	Scale in comparison with the real world. Objects should be scaled comparatively with the real world

Evaluator 3

Hit No.	Usability problems
C1	Objects are not easily accessed and navigate, there are no doors or exit to enter into the building
C2	Difficult to walk around the environment (mouse control)
C3	The objects are not real (without any shadow)
C4	Click on the mouse, sometimes makes movement forward and backward
C5	Some objects are not easily distinguished
C6	Does not have precise navigation/ movement by the mouse – users cannot navigate through the environment as intended
C7	Movements are too fast and unpredictable
C8	Objects are not real – esp trees, canoes, butterfly (not easily identified)
C9	Does not show the motives of the environment
C10	The interactivities assigned to the objects are not intuitive (e.g. click on the door – result: viewpoint by the lake instead of being inside the building)
C11	The interactivity and significance of the objects are not clearly understood
C12	Actions are not easily executed, effect of the actions was not as users intended to have
C13	Does not indicate the purpose of the object
C14	There are no clear identification whether the objects have interactivities

Evaluator 4

Hit No.	Usability problems
D1	Objects are easy to identify but difficult to distinguish when focus to a particular object
D2	Separation between wall and floor is not smooth (We can see the separated line)
D3	No interactivity – switch button to on/off the light does not work
D4	Selection of shape used – sometime it is not suitable e.g. tree
D5	Combination between 2 objects are not well organised (we can see the space, it is not smooth)
D6	No interactivity. Should have a sun to show the shadow of the object

Evaluator 5

Hit No.	Usability problems
E1	Walls are not easy to distinguish
E2	Interactivity & significant of object is not clear (Pintu tak terbuka masa masuk the room)
E3	Do not portray real environment since you can walk through the walls to access the room
E4	Lights are not easy to distinguish too
E5	Difficult to control the system
E6	Object (butterfly) scale is not appropriate with the actual project scale
E7	Viewpoint (box) is quite irritating to my view!
E8	Shades of objects (grass) is not realistic to show that certain area is higher/lower than others