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Designing a Desktop Virtual Reality-based Learning Environment with Emotional Consideration

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Abstract: Many studies related to the use of virtual reality in education are focused on the cognitive aspects with little consideration given to the emotional domain. Thus, the present study aims to uncover the salient linkages between learners' emotions and design elements of a desktop virtual reality-based learning environment by employing Kansei Engineering concepts. A courseware related to the teaching of road safety skills to young learners was designed and developed to be used as a case for the study. Ten specimens of the courseware, which highlights different design elements, were presented to 90 students from three randomly selected secondary schools. They were required to rate their feelings towards the specimens using the provided checklist that consists of thirty words related to emotions. The gathered data were then analysed using Principal Component Analysis and Partial Least Squares analysis. The results revealed that the most influential design elements in inducing positive emotions are environment richness and coaching. Ultimately, the uncovered linkages could be used to inform future design of emotionally sound desktop VR-learning environments.

Keywords: desktop virtual reality, emotions, Kansei Engineering, instructional design

Introduction

Virtual reality (VR) is one of the many technologies that have become increasingly popular to be used as an educational tool due to the development of low-cost computer graphics technology. With its capability, VR permits users to be immersed in a computer generated virtual world by giving techniques for user orientations in this world [1]. Non-immersive VR or commonly known as desktop VR makes full use of desktop computer to present images in common monitor and allows user interaction with the computer-generated images via generic input devices such as computer mouse and keyboard [2]. The advancement in computer technology has made desktop VR a more popular choice because of the lesser cost that it incurs.

In instructional settings, VR capabilities are often studied in relation to variables related to learners' cognitive capacity using various methodologies [3, 4]. Most evaluations conducted on VR-based learning environments are on common usability issues such as navigation, degree of presence, cognitive load, and interface design [5, 6]. These studies have provided minimal input on aspects of user experience in particular the need to investigate the emotional impacts of VR on the learners. However, with the propagation of instructional models which are derived from the constructivist approach, instructional designers begin to realise that cognitive, social and emotional development cannot be viewed in isolations as each is closely linked with the other [7, 8]. It is generally agreed by educationists that learning is more likely to occur when learners are in a positive state of emotion. Pekrun [9] stipulates that emotions have an immediate effect on learning and achievement as mediated by attention, self-regulation and motivation. They direct a person toward or away from learning matters in learning situations, which eventually leads to self-regulated learning. In addition, previous studies [11, 12] reveal that emotions in computer-supported learning can also affect learners' performance and attainment.

In this paper, the apparent need to investigate the emotional factors of desktop VR-based learning environments is addressed by incorporating Kansei Engineering methods. Specifically, using a VR-based learning environment as a case, this paper demonstrates how Kansei Engineering can be used as part of the evaluation process of such learning environments with the support of empirical findings.

1. ackground

1.1 Emotion and Instructional Design

Emotion is not generally recognised by the disciplines that address the broad issues of understanding complex systems and complex behaviour, especially in the presence of learning as in the case of instructional design [12]. Though there were efforts by researchers such as Martin and Briggs [13] to combine both cognitive and affective domain in creating a more holistic framework for instructions, they were seen as problematic and unpopular due to the lack of proper method to address this gap.

In instructional design, research on emotion in learning context has been conducted actively from two different approaches. One approach has been focused on fostering affective dimensions of human learning and development by designing instruction on affective domain which included emotional development [14]. Emotional development includes understanding own and other's feelings and affective evaluations, learning to manage those feelings, and wanting to do so [15]. The other approach of emotion related studies concentrated on how to moderate emotions that could arise during the learning course. Unlike the first approach, these kinds of study do not consider emotional development, but try to integrate learner's emotion states in learning context aiming at how to handle learner's unstable emotional aspects to be more appropriately maintained during the entire learning course. In this scope of studies, emotions are assumed to be being scattered on some position from positive emotions to negative emotions [12, 16].

Nonetheless, the lack of appropriate method in uncovering the relationships between emotion and various components in instructions often hinders the development of such studies. Therefore, the present study proposes the incorporation of Kansei Engineering methodology as an alternative approach to bridge the gap between emotion and instructional design particularly in the design of desktop VR-based learning environment. Kansei Engineering serves as a potential method to be included in the instructional design process as it can systematically quantify the relationship between emotion and design attributes of VR-based learning environment.

1.2 Kansei Engineering

Kansei Engineering is a product development methodology, which translate customers' impressions, emotions, feelings and demands of existing products or concepts to design solutions and concrete design parameters [17, 18]. This methodology is capable of quantifying the relationships between user's feelings and design parameter with an intention to create a product that is largely desirable by the users or customers. In a typical Kansei measurement procedure, users are required to rate a product on the Semantic Differential scale, which contains list of words in a pre-determined scale range. These words (known as Kansei words) are compiled from various sources such as target users, experts, pertinent literature and the like. The rating of the product is done specifically on each pre-determined design attributes. Generally, product or design attributes are selected from the existing products available in the market. In some cases, however, the product attributes can be created or designed from scratch by the product designers especially when there are limited designs available within a selected domain. Upon obtaining the evaluation data from Kansei measurement, the correlation between the Kansei words and design attributes (e.g. colour, layout, and size) is then analysed quantitatively using statistical methods.

2. Research Questions

The aim of this study is to examine the relationship between learner's emotion and the design elements of a VR-based learning environment. Specifically, the research questions are:

i. What are the salient design elements of a VR-based learning environment that could influence learner's emotions?
ii. How can the identified relationships be used to inform future design of VR-based learning environments?

3. Methodology

For the purpose of the study, a desktop VR-based learning environment related to the teaching of road safety skills to young learners (aged 13 to 15) known as Virtual Simulated Traffics for Road Safety Education (ViSTREET) was selected as a case for investigation. Each specific skill (or problem) is addressed by a distinct module that consists of VR-based scenarios generated using Virtual Reality Modelling Language (VRML) version 2.0. ViSTREET was designed based on the instructional design theoretical framework by Chen, Toh and Wan [19], which emphasises the constructivist view of VR-based learning environments. The VR learning scenarios were developed fulfilling all the components of the framework. A chosen scenario was then manipulated in order to generate ten different specimens for Kansei evaluation [20]. This is done by removing one major component of the guiding framework from the completed scenario to form one different design specimen as illustrated in Figure 1.

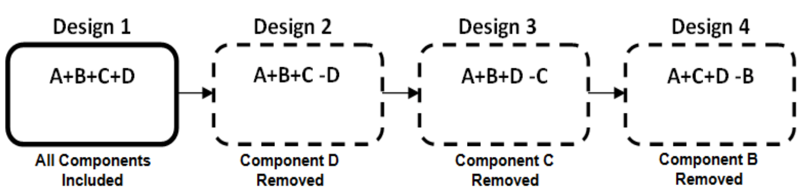

Figure 1: The process of generating design specimens for Kansei evaluation

3.1 Material

Following the step mentioned earlier, ten design specimens were generated. The ten design specimens required participants to perform the same task but the virtual environments differ in terms of salient design elements (according to the elements in the instructional design model). For example, in specimen A01, no element of coaching was provided, in which specific guidance on how to complete a task were removed. Specimen A10 included all components as it was needed to compare the influence of each element when it was removed. Table 1 summarises the generated design specimens and Figure 2 shows a sample screenshot.

Table 1: Specimen codes and descriptions

Code	Specimen Descriptions	Example
A01	Coaching was not given	No feedback messages
A02	Navigational aids were removed	Location map of scenario is excluded
A03	Modelling was not included	No helpful virtual agent
A04	Environment richness was reduced	Reduce the quality of 3D objects
A05	Information resources were removed	No guiding fact sheets/help tips
A06	Narration was removed	No audio narration
A07	No problem representation	Task was given directly as instruction
A08	Objectives were removed	No presentation of objectives
A09	Ignore principles of multimedia design	Font size and font colour
A10	All components included	No manipulation was done.

Figure 2: Screenshot from one of the specimens

3.2 Instrument

The instrument of the present study consisted of a checklist of 30 Kansei words. These Kansei words were chosen from the pertinent research papers and journals related to learning process [12, 16, 21] added with general Kansei words which were considered important to describe learning environment. Some of these words include “frustrated”, “appealing”, “curious”, “calm”, “lost”, “annoyed”, “safe”, etc. The synthesised Kansei words were then organised in 5-point Semantic Differential scale to form the checklist for data collection.

3.3 Sample

The sample for the main study was comprised of 90 participants from three daily schools in the Kuching division, Malaysia (30 from each school). The schools were chosen using simple random sampling method from a list of 15 identified schools in the division with sufficient computers. As for the participants, they were from lower-secondary classes as the VR-based learning environment is designed for this group of learners. They were first filtered based on their computing background such as familiarity with common input devices and software. From the filtered students, they were then randomly selected to meet the required number of participants for each school.

3.4 Data Collection Procedures

Prior to each Kansei evaluation session, the participants were explained on the purpose of the evaluation and what they were required to do. Explanation on the set of Kansei words was also carried out to avoid confusion of meaning. The Kansei evaluation session in each school were carried out in the computer lab with the use of 30 computers of similar specifications such as screen size, audio volume and quality and screen colour. To avoid a sudden surge of excitement, the participants were first presented with a sample VR-based scene (exploration of a house and its surrounding area). This sample scene also served as a navigational training for them to familiarise with the controls needed for the exploration of the actual VR-based learning environment.

During the evaluation session, the ten specimens were presented one by one to participants on each of their computer screen. The participants were allowed to navigate and explore the given virtual scenario and were required to complete the task required. They were given a maximum of 10 minutes to explore each specimen. Then, 3 minutes were given to the participants to rate their feelings towards the specimens using the provided checklist without discussions with their peers. The whole session took approximately two hours to be completed.

4. Results and Discussion

The results of the study are essentially based on two main analyses: i) Principal Component Analysis and Partial Least Squares [17]. Principal Component Analysis is used to reveal the Kansei semantic space as well as the major factors of the specimens that influence the emotion (represented by Kansei words). On the other hand, Partial Least Squares is used to uncover the relationship between the emotion and specific design elements of each specimen.

4.1 Kansei Semantic Space

The semantic space is analysed by Principal Component Analysis [17] using the averaged evaluation value for each specimen. This step is pertinent in finding out the salient factors that could uncover the implicit relationship between the Kansei words and design element. The Principal Component Analysis results produced three major axes. Table 2 lists the three groups of Kansei words (with highest positive factor loadings) for each principal component.

Table 2: Three groups of Kansei words for each principal component

PC1	PC2	PC3
Confident	Interesting	Comfort
Curious	Lively	Calm
Satisfied	Fun	Fresh
Safe	Enjoyable	Thrilled
Motivated	Appealing	Lost

The first principal component (PC1) provided a contribution ratio of 64.5% while the second principal component (PC2) provided 22.1%. The third principal component (PC3), on the other hand, gave a contribution ratio of 8.7%. Clearly, majority of the data structure can be captured in the first two components as they represent a total of 86.6% of the total variability. This would mean that the structure of the Kansei words is highly influenced by the first two components. The remaining principal components account for a very small proportion of the variability and are considered as unimportant or not significant.

4.2 Indentifying the Salient Linkages

Using Partial Least Squares analysis, the coefficient values between emotion and design elements of each specimen were obtained. Design elements with the high coefficient value are considered to be influential on each of the ten emotions (as identified in PC1 and PC2). Table 3 shows the partial view of the tabulated data.

Table 3: Sample tabulated results from the Partial Least Squares analysis

Design elements	**Kansei**		
	Satisfied	**Safe**	**Motivated**
Coaching	0.11281	0.11408	0.11921
Navigational aids	0.10393	0.10634	0.04115
Modelling	0.02714	0.09982	0.03347
Environment Richness	0.03429	0.04291	0.12851
Information Resources	0.03241	0.09113	0.05492
Narration	0.03610	0.01828	0.04091
Problem Representation	0.05021	0.03147	0.03112
Objectives	0.01933	0.01921	0.02847
Multimedia Design Principles	0.05284	0.04113	0.04921

The highest coefficient values of design elements for each Kansei or emotion are then calculated. The obtained results are illustrated in Figure 3.

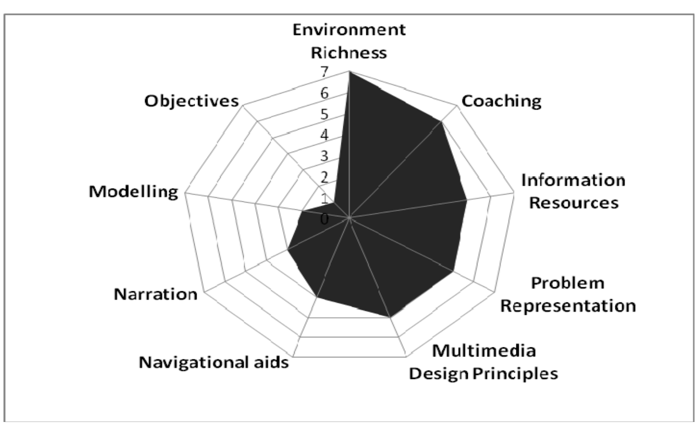

Figure 3: Number of emotions influenced by the design elements

As shown in Figure 3, environment richness of the VR-based learning environment turns out to be a very influential design element. The design element showed strong influence on seven out of the ten emotions. It shows the strongest influence on the emotions of appealing, curious and lively. This is consistent with the findings in previous studies [22, 23] that showed how the attractiveness of the computer-based instructional materials increases learners' positive emotions, which in turn improve their learning performance. The second most influential design element is coaching, which have strong relationships with six emotions especially on confident and motivated. This finding corresponds to the study by Kennewell, Tanner, Jones and Beauchamp [24] who found out that providing relevant guidance and feedback increases learners' confidence in completing a task.

Information resources, multimedia design principles and problem representation are all equally influential on five emotions. These design elements are mainly related to the interface aesthetics, which deal with the presentation of learning content via desktop VR. The design element of navigational aids shows strong influence on four emotions while narration and modelling influenced two and three emotions respectively. The least influential design element is objectives, affecting only one emotion. Interestingly, the presentation of objectives strongly influences the feeling of curiosity. Thus, it can be implied that the environment richness (the inclusion of more life-like 3D virtual objects) could arouse learners' interest and increase their curiosity in wanting to know more about the virtual environment that they are exploring. Craig et al. [25] postulates that a virtual environment which contain objects, content and characters of high realism can activate a person's interest in using the application.

5. Conclusion

Designing a VR-based learning environment to complement other teaching and learning approaches can be a complicated task, which requires careful planning and designing. The identified relationships between emotion and design elements in the present study can be used as a guideline to inform the design of emotionally-sound VR-based learning environment. Due to exploratory nature of the study, it was conducted using solely a VR-based learning environment related to teaching pedestrian safety skills. Thus, the result may not produce globally applicable features. Future research could address such limitation by including more learning environments for a more conclusive comparison. The addition of individual differences as variables in future research is also recommended as it would help to enhance the KE framework further by understanding how each individual reacts to a specific design element emotionally.

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