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DESIGNING A DESKTOP VIRTUAL REALITY-BASED LEARNING ENVIRONMENT WITH EMOTIONAL CONSIDERATION

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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, this study aims to identify 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 30 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.

1. 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 (Burdea & Coiffet, 2003). 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 (Fisher & Unwin, 2002). 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 (Cobb, Neale, Crosier & Wilson, 2002; Roussou, 2004). Most evaluations conducted on VR-based learning environments are on common usability issues such as navigation, degree of presence, cognitive load, and interface design (Kalawsky, Bee & Nee, 1999; Stanney, Mourant & Kennedy, 1998). 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 (Mahoney, 2004; Pekrun, 1992). It is generally agreed by educationists that learning is more likely to occur when learners are in a positive state of emotion. Pekrun (1992) stipulated that emotions have an immediate effect on learning and achievement as mediated by attention, self-regulation and motivation. They direct a person towards or away from learning matters in learning situations, which eventually lead to self-regulated learning. In addition, previous studies (Järvenoja & Järvelä, 2005; Nummenmaa & Nummenmaa, 2008) 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. In this study, the VR-based learning environment is designed and developed based on the learning problem related to the teaching of pedestrian safety skills to young learners. Additionally the term "emotions" is operationally defined as the self-reported state of feelings and psychological responses when engaging in the VR-based learning environments. These feelings are reported in the form of given Kansei words.

2. Background

2.1. *Emotion and learning*

Emotion has often been regarded as a threat to rational thinking. As stated by O'Regan (2003), there has been a constant deep-rooted conviction that emotions are unreliable and untrustworthy and that for sanity to prevail, rationality and intellect must function unfettered by the vagaries of emotion. This belief has formed a major influence in the domain of teaching and learning. Learning theories have largely treated emotion and cognition as occupying separate realms and cognitive processes have been given a primary place in the educational scheme of things at the expense of emotions (Martinez, 2001). According to Sylwester (1994), emotion drives attention, which drives learning, memory and problem solving and almost everything else that a person does. By not exploring the role that emotion plays in learning and memory, educators have fallen decades behind in devising useful instructional procedures that incorporate and enhance emotion. Taylor (2010) supported this view and mentioned that it would be almost impossible to engage the students without considering emotions in the learning process (p. 1110).

Furthermore, several studies (such as Järvenoja & Järvelä, 2005; Nummenmaa & Nummenmaa, 2008) discovered that emotions in computer-supported learning can also affect learners' performance and attainment. In their study, Nummenmaa and Nummenmaa (2008) demonstrated that emotions are important determinants of student behaviour in a web-based learning, and justified the conclusion that interactions on the web can and do have an emotional content. Similarly, Järvenoja and Järvelä (2005) found out that learner's emotional states were pivotal in influencing their judgement and decision making and hence affecting their performance in completing a given task. Hascher (2010) in the author's extensive review indicated how emotion plays an integral part in inquiry-based learning. There is a positive correlation between emotional engagement and more open-ended thinking. Despite the importance of emotion in learning, its position in the field of instructional design is often deserted.

2.2. *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 (Kort, Reilly & Picard, 2001). Though there were efforts by researchers such as Martin and Briggs (1986) to combine both cognitive and affective domains 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 (Martin & Reigeluth, 1999). Emotional development includes understanding own and other's feelings and affective evaluations, learning to manage those feelings, and wanting to do so (Bloom, Mesia & Krathwohl, 1964). 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 studies 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 (Astleitner, 2000; Kort, Reilly & Picard, 2001).

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 bridging 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.

2.3. *Kansei Engineering*

Kansei Engineering is a product development methodology, which translates customers' impressions, emotions, feelings and demands of existing products or concepts to design solutions and concrete design parameters (Nagamachi, 1995; Schütte, 2005). 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 a 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.

In product design, Kansei Engineering is widely used to help designers decide the product parameters or features that would result in high satisfaction. It has been applied to vast array of products from cars to mobile phones (Liu, 2003). Schütte and Eklund (2001), for example, studied extensively on the design of trucks by different manufacturers using Kansei Engineering methods. Their results showed various design properties of an ideal truck as perceived by the customers. Similarly, Hu, Zhao and Zhao (2009) employed Kansei Engineering methodology in the study of car design based on several car features such as dashboard and steering design, body build, and colour combinations. They also found out interesting design parameters that are linked with specific emotion of the customers.

Apart from product design, Kansei Engineering methods are applied to website design. Anitawati and Nor Laila (2006) are among the pioneers in introducing Kansei Engineering concepts in website design. Specifically, they employed Kansei Engineering methods in studying the design of various e-commerce websites with the aim of creating a Kansei e-commerce website. Through the use of Kansei Engineering statistical data, they were able to identify the features of a website according to specific Kansei word, which greatly helps website designers. The results from their study were then used to create an expert system called ExpertKanseiWeb (Anitawati, Nor Laila & Nagamachi, 2009). Tharangie, Irfan, Marasinghe and Yamada (2008), on the contrary, applied Kansei Engineering methods on the investigation of colour choice in e-learning web interfaces. The colour preferences of the young learners were identified with the intention of creating an e-learning website that could be attractive to the learners.

Kansei Engineering methodology is also applied in the textile and fashion design. Nazlina, Aoki, Kubo and Terauchi (2002), for instance, investigated on female sensibility in assessing traditional Malay clothes. From the two types of Malay clothing, different types of fabrics and visual appearance were used as to find out which features would be positively accepted by the female participants. The results from the study revealed several Kansei strategies that had played important roles in distinguishing female's physiological sensibility and psychological feelings in desired traditional clothing design.

These studies reveal the flexibility of Kansei Engineering methods to be used in various industries or domains to achieve the intended outcome. Nonetheless, it can be noted from the studies especially by Anitawati, Nor Laila and Nagamachi (2009) and Nazlina et al., (2002) that modification on the generic Kansei Engineering methods are needed if applied to a new domain. Hence, in this study, some modifications were introduced to the generic Kansei Engineering framework in order to obtain optimum results for considering the emotional aspects of virtual-reality-based learning environments.

3. 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:

(1) What are the salient design elements of a VR-based learning environment that could influence learner's emotions?

(2) How can the identified relationships be used to inform future design of VR-based learning environments?

4. 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 (2004), which emphasises the constructivist view of VR-based learning environments. The framework comprises macro-strategy and micro-strategy (refer to Figure 1). The macro-strategy combines the concept of integrative goals proposed by Gagné and Merrill (1990) and the model of designing constructivist learning environment proposed by Jonassen (1999). The micro-strategy, on the other hand, is based on the cognitive theory of multimedia derived by Mayer (2002) which is used to guide the design of the instructional message. The VR learning scenarios were developed fulfilling all the components of the framework. This VR-based learning environment was designed and developed by the researcher in order to ensure it followed the chosen instructional design principles.

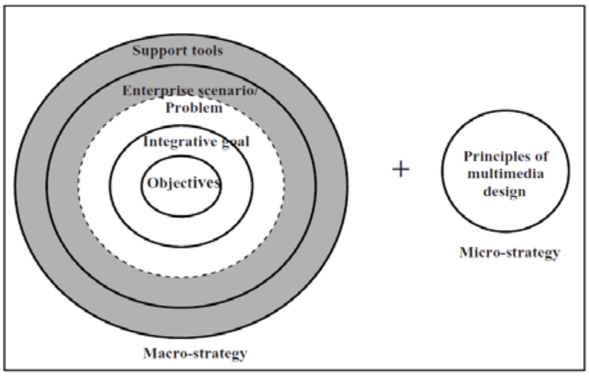

Figure 1. The framework by Chen et al. (2004) which was used in this study in the design of ViSTREET

In the application of Kansei Engineering methods in product design, the design elements are normally selected from the available products in the market. A Kansei evaluation on mobile phone designs, for example, would consider the available designs of mobile phones from numerous brands. However, in the case of instructional design, such selection method may not be possible. Instead, in determining the design elements, careful reference to the components within the chosen instructional design model is crucial (Chuah, Chen & Teh, 2008). A completed scenario according to the theoretical framework was then manipulated in order to generate ten different specimens for Kansei evaluation. 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 2.

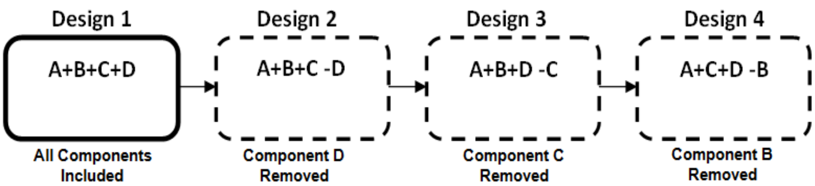

Figure 2. The process of generating design specimens for Kansei evaluation

4.1. *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). This would mean that the participants will try to complete the same task of "going to school safely" but the virtual environment for each of the specimen differs. For example, in specimen A01, no element of coaching was provided, in which specific guidance on how to complete a task was removed. In specimen A04, on the other hand, the richness of the virtual environment was reduced. This is done by reducing the quality of 3D objects and buildings as well as replacing the textures with plain colours. 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 based on the chosen instructional model.

Table 1. Specimen codes and descriptions

Code	Specimen descriptions	Example
A01	Coaching was not given	No feedback messages. There were no pop-up messages guiding the students.
A02	Navigational aids were removed	Location map of scenario was excluded. The navigational map which shows real-time movement of the user was removed.
A03	Modelling was not included	No helpful virtual agents. Several agents in the virtual environment that serve as a model for the learners were removed.
A04	Environment richness was reduced	Reduce the quality of 3D objects. The texturing of the 3D model was removed such as a house was represented by only a box.
A05	Information resources were removed	No guiding fact sheets/help tips. The guide and tips available on the left menu were removed.
A06	Narration was removed	No audio narration. No narration to guide the learner.
A07	No problem representation	Task was given directly as instruction rather than in the form of a story.
A08	Objectives were removed	No presentation of objective was given to the students.
A09	Ignore principles of multimedia design	Font size and font colour were mixed up, creating a cluterred and messy view.
A10	All components included	No manipulation was done with all components included.

Figure 3 shows the sample screenshots of the specimens, which were used in the study.

Figure 3. The screenshot on the left shows the unavailability of the help tools on the left menu while the one of the right is the specimen with all components included

4.2. *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 (Astleitner, 2000; Cornelius, 1996; Kort, Reilly & Picard, 2001) 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. From the initial list of words (around 100 words), it was reduced by using the data gathered from students of the target population in three occasions. In each occasion, the words with lower mean scores were removed since they were not salient to the learners. This was done through factor analysis. The final synthesised Kansei words were then organised in 5-point Semantic Differential scale to form the checklist for data collection. The checklist was piloted on 8 participants (5 females and 3 males) from a secondary school which was not part of the selected schools for the main study. In testing the instrument, the pilot study revealed that some of the participants faced difficulty in understanding a few Kansei words in the checklist. In order to overcome this in the main study, the researcher decided to include an introductory session whereby explanation on the words was first provided.

4.3. *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 as well as English language proficiency (as the content of the VR-based learning environment were essentially in English). To obtain this information, the participants were required to fill in a simple demographic information questionnaire that asked briefly on their personal details (e.g. age and gender) as well as basic computing background. Information regarding their English proficiency levels, on the other hand, was obtained with the help of their teachers. From the filtered students, they were then randomly selected to meet the required number of participants for each school.

4.4. *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 was 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 individual computer screen in the order of V01 to V10. 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 ten minutes to explore each specimen. Then, three 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.

4.5. *Data analysis procedures*

The Kansei evaluation carried out in the main study (as illustrated in Figure 4) elicited three sets of data:

(1) The dependent variables, y, which are the 30 sets of Kansei responses by 90 participants
(2) The sample, which is the ten design specimens of the VR-based learning environment
(3) The independent variables, x, which are the design elements (categories)

From the data gathered in the main study, the average Kansei evaluation value of each design specimen from all 90 participants was first calculated. In this case, an analysis of semantic space of the Kansei words was conducted using Principal Component Analysis (PCA). PCA was performed on the data collected from the evaluation in order to discover the implicit relations between the Kansei words and design specimens. This was done by using the average value between subjects from the evaluation results of each specimen (the ten manipulated virtual environments) and computed with the assistance of Statistical Software for Social Sciences (SPSS) and XLSTAT (an add-in statistical software for Microsoft Excel 2010).

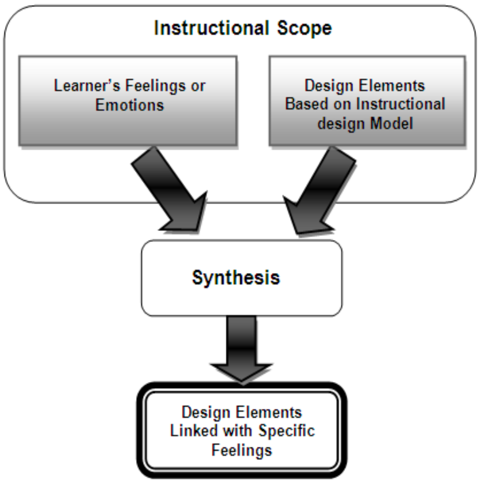

Figure 4. The framework in analysing the relationship between emotions and design elements based on Kansei Engineering methodology

In order to find out the relationships between the feelings and the design elements of the learning environment, the Partial Least Squares (PLS) analysis was performed to reveal the relationships between y (Kansei words or emotion) and x (design elements). It is also used to identify the influence of design elements in each Kansei, the positive and negative value for each design elements, and which specimen induces what kind of Kansei. The coefficient values from PLS analysis for all data sets were obtained. Range value was then calculated to determine the influence of each design category. Range was calculated using maximum and minimum value as shown in the Eq. (4.5.1).

$$Range = \mathrm{PLS}_{\max} - \mathrm{PLS}_{\min} \tag{4.5.1}$$

Mean of *Range* is then calculated as shown in Eq. (4.5.2).

$$\overline{Range} = \frac{1}{n}\sum_{i=1}^{n} Range \tag{4.5.2}$$

Each Kansei word has means of range and if the mean value of a category (design element) is larger than the mean of range, the item is considered to have good influence in design and vice versa.

5. Results and Discussions

The results of the study are essentially based on two main analyses: i) Principal Component Analysis and Partial Least Squares (Nagamachi, 1995). 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 find out the relationship between the emotion and specific design elements of each specimen.

5.1. *Kansei semantic space*

The semantic space is analysed by Principal Component Analysis (Nagamachi, 1995) using the averaged evaluation value for each specimen. This step is pertinent in finding out the salient factors that could uncover the 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, the 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 (PC3) account for a very small proportion of the variability and are considered as unimportant or not significant. Hence, the words in PC3 are excluded from further analysis since they not meaningful to the target participants.

In PC1, Kansei words “confident”, “curious”, “satisfied”, “safe”, and “motivated” obtained the highest positive factor loadings, which may imply a sense of achievement (Factor 1) resulted by various elements that help the learners to complete the given task. These elements include support tools, feedback and modelling. In contrast, Kansei words “interesting”, “lively”, “fun”, “enjoyable” and “appealing” attained the highest positive factor loadings in PC2. These words imply the appeal or attractiveness of the virtual environments (Factor 2).

As such, the Principal Component Analysis results revealed two factors that are important in creating emotionally sound VR-based learning environment: i) sense of achievement and ii) appeal and attractiveness of the virtual environments. For the first factor, it can be implied that the feeling of successfully completing a task could be achieved mainly based on the types of task given and the availability of various guiding tools. In the second factor, it is apparent to note that the appearance of the virtual environment such as high-quality 3D models and attractive user interface is important in eliciting positive emotions.

Figure 5 depicts the participants' average rating (mean score) on the specimens (in the scale of 1 to 5) according to the two factors as identified from the Principal Component Analysis. The ratings pattern seems to reveal that both factors are closely related. This pattern however only indicates the general connection between the two factors. For example, rating for Factor 1 drops when rating for Factor 2 decreases in A04 and A09, and rating for Factor 1 increases in A10 when rating for Factor 2 increases. This is rather expected since the appeal of the virtual environments would somehow influence the way the learners complete the given task.

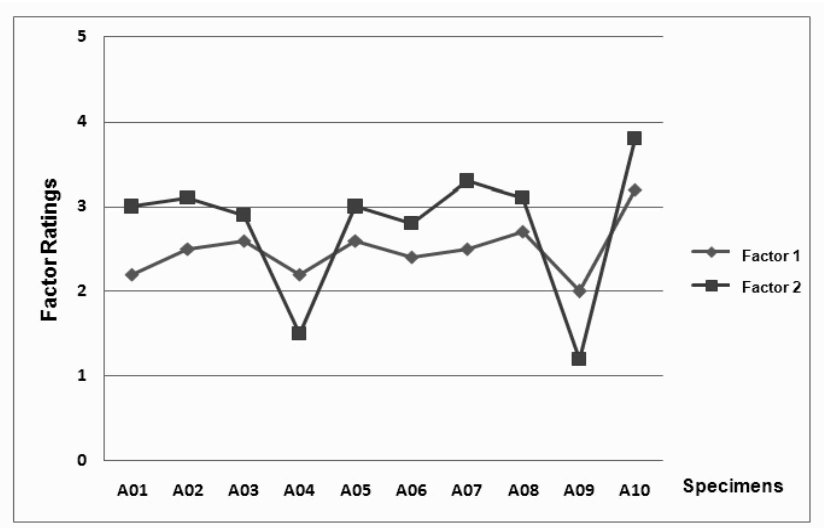

Figure 5. Factor rating of the VR-based learning environment specimens

5.2. *Identifying 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 since the complete table would not be feasible to be presented in this paper.

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. To further illustrate this, a sample tabulated result of the Kansei word “confident” is shown in Table 4.

Table 4: Influences of design elements on the Kansei word “confident”

Confident	
Design elements	Range
Coaching	**0.10271**
Navigational Aids	**0.06481**
Modelling	**0.05946**
Environment Richness	0.02749
Information Resources	**0.04128**
Narration	0.02341
Problem Representation	0.02481
Objectives	0.01547
Multimedia Design Principles	**0.04821**

Mean of range: 0.034

The design elements in bold obtained high PLS range value, indicating their strong relationships with the feeling of confident. This would mean that in order to induce the feeling of confidence on the learners, a designer should pay attention to the five design elements namely coaching, navigational aids, modelling, information resources and multimedia principles. The process of tabulating the result in the example above was repeated on the remaining salient Kansei words (in Factor 1 and Factor 2) and the overall results is presented in Figure 6.

As shown in Figure 6, 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 (Ngo, Teo & Byrne, 2003; Park & Lim, 2007) 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 (2008) who found out that providing relevant guidance and feedback increases learners' confidence in completing a task.

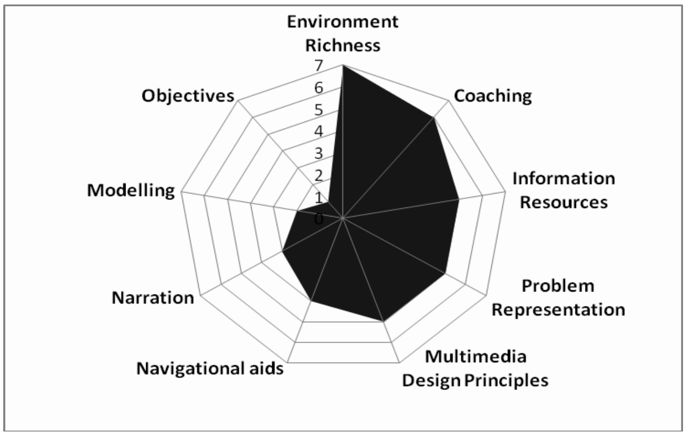

Figure 6: The number of emotions as influenced by the design elements

Information resources, multimedia design principles and problem representation are all equally influential in 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, Sherman and Jeffrey (2009) postulates that a virtual environment which contain objects, content and characters of high realism can activate a person's interest in using the application.

On the whole, the findings revealed the importance of appeal factor (Craig, Sherman & Jeffrey, 2009; Jacobson, 1993) and guiding elements (Kirschner, Sweller & Clark, 2006; Savery & Duffy, 2001) in influencing learners' emotion. The richness of the 3D environment and the quality of interface design as well as the support tools to guide the learners are highly related to the positive emotions such as "fun", "motivated" and "lively".

Nonetheless, it should be made known that the number of Kansei words does not merely indicate the level of importance of each design element. It serves to identify the relationships between the emotion and its corresponding design element. For example, though the design element "objectives" only influence one emotion (i.e. curiosity), it does not mean that it is not important. In fact, it reveals the importance of "objectives" in stimulating the emotion "curious". Hence, such information can be used by the designer to find such relationship and optimise necessary design element to induce a particular intended emotion. This study has shown that it is possible to discover the emotional aspects of VR-based learning environment using the proposed Kansei Engineering methodology. The identified relationships between emotion and design elements can be used as a guideline to inform the design of emotionally-sound VR-based learning environment.

6. Conclusion

Designing a VR-based learning environment to complement other teaching and learning approaches can be a complicated task, which requires careful planning and design. 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. The findings of the study also provide insights in addressing the lack of attention to emotional dimension by instructional designers particularly in the case of VR-based learning environment. Many studies related to the design of VR-based learning environment emphasised heavily on the cognitive aspects (Bailenso & Beall, 2006), neglecting the roles of emotions in promoting learning (Martinez, 2001).

This study has managed to utilise the synthesised Kansei Engineering framework to identify the relationships between emotion and design elements of VR-based learning environment. Important design elements that influence a specific emotion is revealed, with an aim of helping designers of VR-based learning environment to decide what should and should not be emphasised. The influential design elements on each Kansei presented in the earlier section has shown some key patterns in terms of the relationship between them. However, due to the 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.

7. Future Work

The attempt of this study to examine the underlying relationships between learners' emotion and design elements of VR-based learning environment using the Kansei Engineering approach creates the opportunities to use these concepts in future research. Many research directions can be envisioned as a follow-up to the present study. Firstly, future research could include a comparison of more than one VR-based learning environment since this study only uses ViSTREET as a case. A comparison of more VR-based learning environments could provide a richer data for the Kansei Engineering analysis and hence allow better representation or mapping of the relationships between learners' emotion and design elements. Furthermore, VISTREET simulates a real-world scenario and it would be beneficial for future research to investigate the effect of VR-based learning environment, which are unreal or non-existent in reality (such as exploring the biological cell or travel into an alien planet). Such non-existent environments could perhaps provide different effects on learners' emotional states.

In addition, the inclusion of individual differences as variables in future research is also recommended. Variables such as gender, learning styles and attention span would help enhance the Kansei Engineering framework further by understanding how each individual reacts to a specific design element emotionally. In view of this, further research could also integrate the use of qualitative methods in obtaining data covering the variables mentioned.

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