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Experiencing the 3D Color Environment : Understanding User Interaction with a Virtual Reality Interface

3차원 가상 색채 환경 상에서 사용자의 감성적 인터랙션에 관한 연구

Danielle Oprean* · So-Yeon Yoon*†
오프리엔, 데니엘* · 윤소연*†

Department of Architectural Studies, University of Missouri*
미주리 주립대학교 건축학과 디지털미디어 디자인 전공*

Abstract

The purpose of this study was to test a large screen and rear-projected virtual reality (VR) interface in color choice for environmental design. The study piloted a single three-dimensional model of a bedroom including furniture in different color combinations. Using a mouse with an 8'x6' rear-projector screen, participants could move 360 degree motion in each room. The study used 34 college students who viewed and interacted with virtual rooms projected on a large screen, then filled out a survey. This study aimed to understand the interaction between the users and the VR interface through measurable dimensions of the interaction: interest and user perceptions of presence and emotion. Specifically, the study focused on spatial presence, topic involvement, and enjoyment. Findings should inform design researchers how empirical evidence involving environmental effects can be obtained using a VR interface and how users experience the interaction with the interface.

Keywords : 3D, Virtual Environment, Presence, Human-Computer Interaction, Emotion, Topic Involvement, Enjoyment

요 약

본 연구에서는 다양한 색채환경에 대한 반응을 파악하기 위해 3차원 가상환경 인터페이스를 개발하고, 개발된 인터페이스에 대해 사용자가 어떻게 감성적으로 인터렉션하는지를 평가하였다. 3차원 가상환경은 후면투사형 대형화면을 통해 제시되었으며, 가구를 포함한 실내 환경요소에 12가지 색채조합을 적용한 후, 피실험자들에게 색채조합에 대한 반응과 아울러 가상환경 인터페이스를 통한 감성적 인터렉션을 함께 평가하도록 하였다. 총 34명의 대학생들이 실험에 참여하였으며, 피실험자들은 대형화면(8'×6')에 제시되는 고화질의 색채환경 속에서 표준 입력장치를 사용하여360도로 시선을 움직일 수 있었다. '공간적 실재감(Spatial Presence)', '주제와 연관성(Topic Involvement)', 및 '유쾌함(Enjoyment)'에 관한 자기보고형 설문지를 통해 가상환경과의 인터랙션을 통한 감성 및 인지적 반응을 파악하였다. 현 연구는 향후 디자인 연구, 특히 환경디자인 연구에 3차원 가상환경 인터페이스를 적용하고자 하는 연구자들이 사용자 인터랙션을 사전에 이해하는데 기여할 것으로 기대된다.

주제어 : 3차원, 가상환경, 실재감, 휴먼-컴퓨터 인터랙션, 감성, 주제와 연관성, 유쾌함

† 교신저자 : 윤소연(미주리 주립대학교 건축과)
E-mail : Yoons@missouri.edu
TEL : 1-573-882-7542
FAX : 1-573-885-6679

1. Introduction

Many Virtual environments (VE) offer another avenue for informing architectural design decisions (Bridges & Charitos, 1997). There are many obvious benefits of using such technology, which address constant issues in architectural design and education. For example, in color choice, painting a real room in different color schemes for decision-making will not be cost effective and, will waste supplies, labor, and time. With a tool such as virtual reality (VR), these issues can be alleviated but the questions, how the VR actually works and how well users adapt, remain. This study aimed to gain a basic understanding of the interaction between the users and an immersive VR interface through measurable dimensions of the interaction: interest and user perceptions of presence and emotion. In this study, we chose the context of color environments in order to elicit the feasibility of a VR environment based on user perceptions. Specifically, the study examined user perceptions of the VR environment focusing on spatial presence, topic involvement, and enjoyment.

2. Background

2.1. Spatial Presence

Spatial presence deals with a sense of physical space. Found within presence research, it is broadly defined as users believing they are actually within a virtual world without acknowledging they are exploring a virtual world. Sacau et al. (2008) define spatial presence as an individual's experience of physically being in a non-realistic space. Unlike immersion, presence is a difficult measure to obtain as it is based on individual perception (Slater & Steed, 2000). Schuemie et al (2001) differentiates between the two by explaining that immersion is a non-subjective account of the system such as resolution. This means that an immersive VR simulation's level of presence can vary from individual to individual. To account for these discrepancies in spatial presence, various questionnaires have been developed and tested (Laarni et al., 2005). This paper will focus on two factors from the MEC-SPQ spatial presence questionnaire for measuring spatial presence: Self Location (SPSL) and Possible Actions (SPPA) (Vorderer et al., 2004). Research suggests several factors influence an individual's state of presence including user attention and enjoyment (Lombard & Ditton, 1997; Witmer & Singer, 1998). For this study, attention will be inferred from the report of topic involvement and enjoyment.

2.2. Topic Involvement

Involvement is a construct typically found in consumer research which, focuses on motivation and emotional states and how they are linked to individual relevance (Brennan & Mavondo, 2000). It can be defined as being an individual's state of motivation, interest, or drive towards a stimulus where the motivational state is aroused either by relevance or importance of the stimulus (Rothschild, 1984). This definition of involvement provides a good measure for evaluating the user's perception of meaning and value of the VR interface. Based on the definition, involvement typically consists of two dimensions: importance and interest (McQuarrie & Munson, 1992). These dimensions were studied as a whole to account for user involvement in this study. Mittal (1989) further explained that in order to study involvement, a pre-fix such as 'topic' needs to be added so the source of the involvement can be identified. For this study, topic involvement was used to investigate the experience between users and the VR interface.

Topic involvement, also known as interest, refers to the motivational state in which an individual feels compelled to act on a specific topic based on personal preference (Rothschild, 1984; Zaichkowsky, 1985). In this study the topic, color combinations, is associated with the source of involvement with the VR interface. If the VR interface with a large screen is more interesting to the users, then it is more likely to draw the user's attention. With an increase in user attention, the VR interface should produce higher levels of presence. Also, if the users are motivated to act it is inferred that some level of enjoyment may exist in performing the act.

2.3. Enjoyment

Enjoyment is a highly subjective measure found within human-computer interaction (Monk et al. 2002). It is situated within emotion research as the degree to which using a computer is considered to be subjectively enjoyable to a user regardless of the specific technology involved (Yi & Hwang, 2003). Overbeeke et al. (2003) identified several qualities which elicit enjoyment: challenging, playful, memorable, and rewarding. Enjoyment for this study focuses on the degree to which an individual perceived he or she enjoyed using the VR interface. Research suggests that enjoyment is linked to presence (Witmer & Singer, 1998). Also, ties to involvement suggest that enjoyment can be understood through motivation which can come from challenge and reward (Moon & Kim, 2001).

3. Methods

The purpose of this study was to determine the interest, presence and emotion of student interactions with a rear-projected VR system using QuickTime VR for color perception in computer-mediated architectural renders. The actual color perceptions were measured but not within the scope of this project as our purpose was to focus on the feasibility of using VR environments for environmental design purposes. A 3D bedroom was developed using Autodesk 3D Studio Max 9 and rendered with Vray to ensure photorealistic lighting and shadows. As color combinations were important to the context of the study, color needed to be portrayed correctly in the VR system. To provide correct color, an Xrite color calibrator was used on both the computers and the projector. The use of QuickTime VR added navigability to the 3D bedroom which allowed users to pan the simulated room in a 360 degree motion.

The study sought to broadly answer the question: does the specified level of interaction between users and rear-projected VR system aid in user perceptions of color environments. The findings of actual color perceptions were not within the scope of this project; only how the use of the specific technology used impacted the overall experience with color environments.

3.1. Participants

A total of 34 students, of which 16 were male and 18 female, with ages ranging from 19 to 23 (M=21) and having varying backgrounds in social, economic, ethnic and geographic areas participated. Participants were recruited from a university in the Midwest of the United States. The participants were homogeneous. All participants had normal to corrected-to-normal vision.

3.2. Experiment

Twelve color combinations from a panel of expert designers were chosen and applied to separate copies of the same 3D bedroom model. The color combinations were derived from Kobayashi's list of color combinations matching different adjectives (Kobayashi, 1988). The students sat in a room individually in-front of a single rear-positioned projector and an 8'×6' projection screen

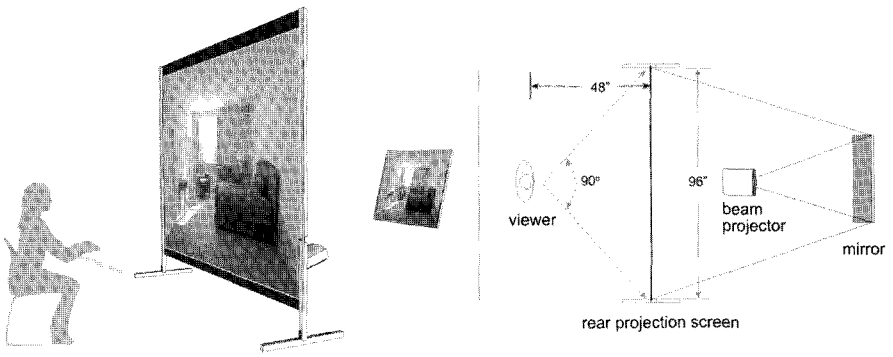

Figure 1. VR System Layout

for approximately 20-30minutes. The students were provided with a mouse and a questionnaire to fill out after twelve 3D rooms were presented. Students were asked to pan around each room using the mouse, and then report their experience. As seen in Figure 1, each scene was rendered with a wide-angle lens to induce a higher level of immersion and spatial awareness with a rear-projected system on an 8'×6' screen (Ni et al., 2006).

To add interaction to the renders, QuickTime VR was implemented. Using Vray settings, the QuickTime VR plug-in for 3D Studio Max was used to generate navigable environments through the use of baked textures (Figure 2). QuickTime VR in this study allowed for limited navigation: 360 degree panning and zooming in and out. To provide correct color through both the development and data collection processes, an Xrite color calibrator was used on both the computers and the projector used for the study.

The experiment was carried out in an isolated room without windows and only one door in order to minimize distractions. A single InFocus IN34 DLP projector (1024×768 dpi - ANSI 2500) was positioned facing a mirror behind an 8'×6' screen (Figure 1). Each student was asked to sit in a secluded chair placed in-front of the projector screen for approximately 20~30minutes. The participants were placed 48" from the screen for optimal viewing. During that time, the lights were off, and the only door was closed leaving just the participant and the researcher in the room during the administration of the study. A small desk lamp and table were provided to help the participant view and fill out the questionnaire (Figure 3).

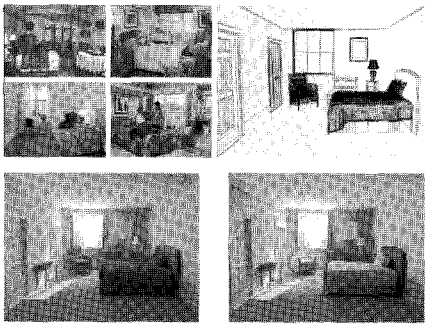

Figure 2. 3D Prototype model development: photos of facility (top left), wireframe (top right), and color model (bottom left and right)

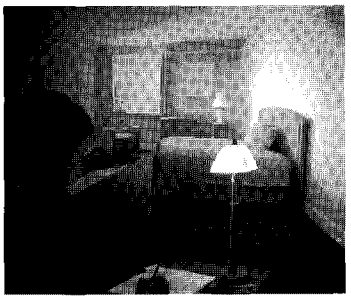

Figure 3. Experimental setting

3.3. Measurements: Selection and Reliability

Data collection consisted of a self-report questionnaire at the end of the color review session. The questionnaire collected demographic information and perception data on two factors of spatial presence, topic involvement, and enjoyment. Each of the scales was presented on a Likert scale with three items for each. The MEC Spatial Presence Questionnaire (MEC-SPQ) consists of nine scales that measure the different concepts of presence. The items related to spatial presence experiences, i.e., Self Location and Possible Actions, were analyzed. Topic involvement items include how interested in color the participants were in general. Enjoyment scales were derived from Davis et al. (1992)'s study on workplace motivation.

All of the scales were tested for internal consistency and Cronbach's alpha values were above desired levels: 0.87 (possible action), 0.91 (self location), 0.89 (presence: possible action and self location combined), 0.81 (topic involvement), and 0.88 (enjoyment). A factor analysis was performed to determine how well the variables are represented individually. Consistent with the original research by Witmer and Singer (1998), two presence factors, i.e. self-location and possible action, were identified. Therefore, the two presence factors were used in the analysis. Unidimensionality of topic involvement and enjoyment scales were also confirmed.

Yoon et al. (2008) demonstrated in their empirical study with a 3D VR integrated furniture review interface that a strong positive association between users' perceived presence on user satisfaction. User satisfaction as comfort and acceptability of use has been probably the most widely used element in assessing interactive systems and predicting their systems not only in HCI but

also in the Information systems fields. In this study, gender, topic involvement and enjoyment variables were investigated focusing on their relationships with presence as a critical indicator of the proposed interface's success.

An exploratory analysis consisting of basic correlations and simple t-tests were performed to determine the relationships among the variables. Initial relationships found were then further explored. As this study was meant to be a precursor for carrying out further research on user experience with VR technology, predefined areas of exploration were kept at the macro level specified in terms of the study conducted by Yoon et al. (2008): gender, topic involvement, enjoyment, and spatial presence.

4. Analyses and Results

The analysis was conducted using SPSS statistical software. The data was tested for the assumptions: normality, homogeneity of variance, independence of observations, and linearity. The data contained one account of missing values which the researchers decided to fill in using the standardized mean.

To begin the analysis a basic correlation of all the variables was performed. This allowed for the identification of relationships between the variables.

Table 1. Correlation Matrix

Measure	1	2	3	4	5
Topic Involvement	--				
Enjoyment	0.43*	--			
Presence	0.05	0.37*	--		
Self Location	-0.06	0.10	0.88**	--	
Possible Action	0.15	0.54**	0.89**	0.57**	--

Note. *$p < 0.05$. **$p < 0.01$.

Table 1 shows the correlation matrix of all the measured variables: presence (self-location and possible-action), enjoyment, and topic involvement. Significant relationships were found specifically between topic involvement and enjoyment as well as enjoyment and presence.

Gender

Before investigating the relationships between the measured variables it was important to look at possible individual differences among the subjects. Since gender is one of the most frequently identified factors of interest in terms of individual differences, gender was compared against each of the variables using independent t-tests. On comparing the means, significant gender effect was found on topic involvement. Females reported their interest in color environments was significantly greater than males, $r(34) = .60$, $p < .001$. Gender did not play a significant role in influencing either presence or enjoyment.

Presence

Since presence was a major concept we were looking to find, we needed to further see if other variables influenced the two dimensions we identified. Only enjoyment significantly correlated to presence. To further see if presence had any more specific relationship to enjoyment, correlations with self-location and possible-action were also conducted. Only possible- action significantly correlated with enjoyment: $r(34) = .54$, $p < .001$. There were no other significant relationships between presence and the other measured variables.

Topic Involvement

Given that only topic involvement significantly correlated to enjoyment ($r(34) = .43$, $p < .05$), the relationship was further explored. Topic involvement was split into low and high involvement using the sample median value (Mdn=6.25) as the data range (4~7) indicated all scores were in the higher end. The two groups, low (M =6.25, $SE = 0.14$) and high ($M = 5.53$, $SE = 0.17$), were then compared with enjoyment.

A t-test was then performed between high to low involvement and enjoyment as according to the relationship found in the original correlations. Participants who indicated high involvement were found to have enjoyed the system more than those with low involvement. The difference between the two groups was found to negatively statistically significant $t(34) = 3.29$, $p < 0.05$. The overall effect of level of involvement on enjoyment was large $r = 0.50$.

Box plots (Figure 4) further indicate the relationship between low-high involvement and the levels of enjoyment.

Although the low involvement group overall was larger than the high involvement group there was a significant difference in the means between the two in terms of enjoyment.

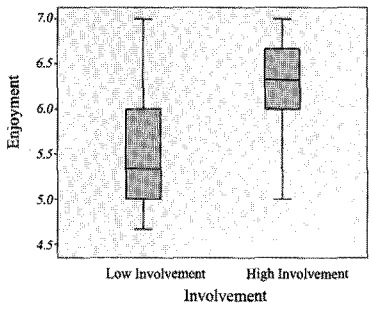

Figure 4. Box Plots: effect between high to low involvement on enjoyment.

Enjoyment

The initial correlations had suggested a significant relationship between presence and enjoyment, $r(34) = .37$, $p < 0.05$. To further explore this relationship, enjoyment was split into two groups (low-high) using the sample median value. The two groups low ($M = 4.28$, $SE = 0.20$) and high ($M = 5.00$, $SE = 0.40$) were then formed to be tested against presence as a whole variable and then as just the one significant dimension, possible-action. Possible-action was chosen for testing next as it was the only dimension of presence which significantly correlated with enjoyment, $r(34) = .54$, $p < .001$.

A t-test was conducted to signify differences between groups who reported high and low levels of enjoyment with presence. The difference between the two groups was not found statistically significant $t(34) = -1.79$, $p > 0.05$. The overall effect was medium $r = 0.30$. The effect can be further seen in Figure 5.

In the box plots, the two groups of enjoyment overlap in terms of presence and the means are very close. This indicates the relationship is not significant between high and low enjoyment in terms of presence.

Despite the findings of presence as a whole concept, the significant relationship between enjoyment and the dimension of possible-action were still explored. Using the split levels of enjoyment, a t-test was performed with possible-action. The findings showed there was a significant difference between low-high enjoyment for possible-action, $t(34) = -2.84$, $p < .05$.

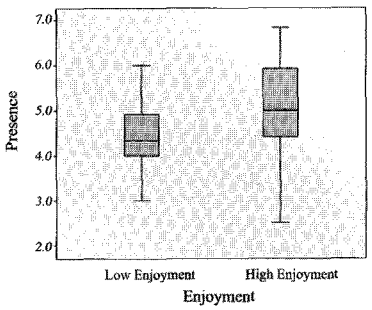

Figure 5. Box Plots: effect between high to low enjoyment on presence.

5. Conclusion

This study sought to investigate a specified model of user-computer interaction with a rear-projected VR interface on the user's gender, sense of presence, enjoyment, and topic involvement in studying color environments. The findings would help to inform the use of VR environments for architectural design issues through a basic understanding of user perceptions. In order to focus this area of research, an interactive close-to-real scale color review system prototype was developed and, user responses on their experience were gathered for analysis using simple statistical methods.

Initial findings suggested that the topic of color review in interiors played a major role in how a user enjoyed using the system. In addition, the topic of color review was also highly related to gender differences. Female subjects reported that viewing interior colors using the interactive VR system was more interesting to them as they felt more interested in the review topic itself compared to the male subjects. These findings support previous research which indicates females as being more interested in color (Mos & Colman, 2001). However, how strongly viewers are interested in the topic was not a contributing factor towards a feeling of being more involved in the interaction with the interface, otherwise known as presence. Also, despite the relationship between gender and the topic of color and that of topic and enjoyment, gender was not an indicator of enjoyment. This suggests that users who preferred the topic of color were more likely to enjoy using the system regardless of gender. This follows with the research that motivated actions induce a sense of

enjoyment (Moon & Kim, 2001).

Further exploration of the relationship between topic and enjoyment showed that participants who were highly involved were more likely to enjoy the experience. Breaking down the sample of participants into groups of high and low involvement, the highly interested participants overall enjoyed the experience to a greater degree.

Presence did not correlate with gender but did relate strongly to enjoyment. This indicates that users who enjoyed using the rear-projected VR interface with a large screen will be more likely to experience a higher level of presence regardless if they are male or female. This also follows findings of previous research where individuals who enjoy an experience are more likely to have a higher degree of presence (Witmer & Singer, 1998).

More specifically, presence was not highly influenced by gender in this study most likely because presence is dependent on many factors (Witmer & Singer, 1998; Schuemie et al., 2001). It is therefore important to consider the specific aspects of the study which may have had an influence on the results found.

Gender did influence topic involvement which had some affect on enjoyment. Since these influences exist, it can be inferred that some indirect relationship to presence may also exist. This is due to presence being influenced by attention, interest, and immersion (Schuemie et al., 2001; Wirth et al., 2007). Previous studies have suggested both presence and enjoyment being critical determinants of user satisfaction and technology acceptance for interactive systems (Yoon et al., 2008; Davis et al., 1992). This study found that users' interest in the design review content has direct effects on enjoyment and females reported significantly greater interest in the topic than males.

In addition, it was also discovered that how enjoyable users felt while interacting with the design review system was significantly correlated with their perceived sense of presence. Therefore, findings of this study imply that the proposed VR system for color aesthetic review tasks will be more effectively used and accepted by female users or users who are interested in the topic with more satisfying interaction experience with the system.

The questionnaire contained one final question which asked overall how well users liked the system and would be willing to participate in another similar type of study. The results: ($M = 5.88$, $SD = .91$) $t(34) = 12.0$ $p = .00$, indicated that users liked the system overall and would be willing to participate in similar studies. This indication from the study's sample can be generalized to a larger population for future study with different user groups.

The main objectives of this study were very simple and meant to explore the basic concepts of user experience with a basic VR system; the findings suggest that further study with more robust measures and analysis could provide interesting and useful results.

While this study contained many limitations, the initial findings are promising for future endeavors. Such limitations which could be incorporated in future studies would include more robust measures of each of the variables, including more objective rather than just subjective measures. Also, looking at the variables from both a simpler system for comparison would provide clues as to the level and quality of the system necessary to achieve the optimum results.

As such, with a better understanding of how users interact with design review systems such as the rear-projected VR system proposed in this study, designers and design researchers would be able to obtain design feedback more effectively. Furthermore, contributions of this study include useful insights for different populations such as elderly population, into not only the perceptions of color for environments but also the use of technology for its representation. Further study, in this area could lead to studies in other areas of individual differences, such as age, and the affect on the perception of color using a rear-projected VR system.

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