Improving empathic evaluations in virtual reality for marketing of housing projects

Athira Azmi[1], Rahinah Ibrahim[2], Maszura Abd Ghafar[3] and Ali Rashidi[4]
[1, 2,3] *University Putra Malaysia, Selangor, Malaysia*
gs48189@student.upm.edu.my[1], rahinah [2], maszu[3]@upm.edu.my
[4] *Monash University, Melbourne, Australia*
ali.rashidi@monash.edu[4]

Abstract: Virtual reality technology has been proven in various research as an effective visualisation tool. This research examines the potentials of virtual reality as a pre-purchase evaluation tool for potential homebuyers to facilitate home purchase decisions. An experiment was conducted to determine whether virtual reality could replace the real environment evaluation of housing design based on emotion and behavioural responses. Results of the experiment suggest that there are no significant differences in the emotions evoked in real and virtual environment. The structural model assessments using PLS-SEM also revealed that atmospherics significantly and positively affect pleasure and arousal emotions. Pleasure was also found to positively influence home purchase intention. This paper highlights practical implications of virtual reality to be strategically applied as a tool for design evaluation especially in the housing industry for better housing design that is more empathic, user- centred and satisfies the emotional and social needs of potential homebuyer.

Keywords: Built environment informatics; virtual reality; empathic design; user-centred design.

1. Introduction

The home buying process is a complex social process that entangles emotions, economy, perceptions of family life and living lifestyle (Levy, Murphy, & Lee, 2008). It is already well established and proven in many researches that price and affordability of the dwelling are the main attributes that influence home purchase (Hasanudin & Chandra Sakaran, 2016; Kam, Lim, Al-Obaidi, & Lim, 2018; Mariadas, Abdullah, & Abdullah, 2019; Olanrewaju & Wong, 2019; Olanrewaju & Woon, 2017; Tan, 2013; Thanaraju, Mentaza Khan, Juhari, Sivanathan, & Md Khair, 2019; Zainon, Mohd Rahim, Sulaiman, Abd Karim, & Hamzah, 2017).

However, this paper found that there are limited studies in the housing industry, where digital visualisation technique such as virtual reality (VR) could be utilized to revolutionize how homebuyers could evaluate the house to purchase for a more satisfactory house purchase decision. The aim of this paper is to investigate whether VR could facilitate understanding regarding how spaces influence emotion and home purchase intention. Henceforth, this study had focused on integrating the concept of understanding emotion or empathy in pre-purchase house evaluation with the application of VR. In this

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paper, the authors present the potentials of VR for emphatic evaluations of housing project under development in view of adding a valuable advantage for residential real estate marketing initiatives.

2. Literature Review

2.1. Stimulus – Organisms – Response (S-O-R Framework)

The theoretical backdrop for this paper is based on the widely applied and extended Stimulus-Organism-Response (S-O-R) framework by Mehrabian and Russell (1974) to explain consumer behaviour in an environment that consists of three key components – stimulus, organism and response. Although the original S-O-R framework was developed more than 45 years ago, this study believes that the S-O-R framework is superior to other theories on consumer behaviours to be used in this study. The S-O-R framework is proven to be the most extensively applied and commonly used theoretical foundation in consumer behaviour studies, especially to explain consumers' purchase intentions (Chan, Cheung and Lee, 2017).

This framework is highly adaptable and has been widely applied to explain behaviours in various fields of studies such as sport service environments (Kim, Byon, Baek, & Williams, 2018), online social network environment (Cao & Sun, 2018) and workplace and organizational behaviours (Attiq, Rasool, & Iqbal, 2017). Since this framework has not been widely examined in the virtual environment and the housing context, this research will contribute to this theory by adapting and extending its applicability to explain potential homebuyers' behaviour in a VR environment. The S-O-R framework also provides a parsimonious and structured theoretical lens (Floh & Madlberger, 2013; Luqman, Cao, Ali, Masood, & Yu, 2017; Tang, Warkentin, & Wu, 2018) to examine and explore the effects of VR features on potential homebuyers' emotional reactions and subsequently, influences their intention to purchase the house. Due to these reasons, this study believes that the S-O-R framework is appropriate to be applied in this study.

2.1.1. Atmosphere as the Stimuli (S) component

Stimulus is the external cues that triggers individual's emotional responses. The atmosphere is the quality of the surrounding space that could be apprehended through human main sensory channels – sight, sound, scent and touch; and are proven to influence consumer behaviours (Choi & Kandampully, 2018; Tantanatewin & Inkarojrit, 2017). This study proposed that the atmospheric properties in the virtual environment is the stimulus component that could stimulate potential homebuyers' emotions. The following hypotheses are proposed for this study:

H_1: There is no significant difference in the atmospheric appraisal of the house between the real environment and virtual environment.

H_{1a}: Atmospheric appraisal have a positive effect on potential homebuyers' pleasure emotion.

H_{1b}: Atmospheric appraisal have a positive effect on potential homebuyers' pleasure emotion.

2.1.2. Pleasure and Arousal Emotions as the Organism (O) component

Mehrabian and Russell (1974) defined organisms as the internal evaluations or primary emotional responses to the stimulus exerted. Pleasure is defined as the degree to which a person feels happy or satisfied within an environment, while arousal refers to an individual's degree of excitement, alert and stimulation triggered by the stimulus. This study hypothesized that:

H_2: There is no significant difference in pleasure emotion between the real environment and virtual environment.

H_3: There is no significant difference in arousal emotion between the real environment and virtual environment.

H_{2a}: Pleasure has a positive effect on purchase intention.

H_{3a}: Arousal has a positive effect on purchase intention.

2.1.3. Purchase Intention as the Response (R) component

In the original S-O-R framework, the response (R) component represents the behavioural outcomes-approach or avoidance behaviour, which is the result of the emotional reactions. This study proposed that pleasure and arousal emotions when viewing the house could influence potential homebuyers' purchase intention. The following hypothesis to be tested is posed:

H_4: There is no significant difference in purchase intention between the real environment and virtual environment.

Overall, Figure 1 summarises the relationships between the stimuli factor – atmospheric appraisal; emotional factors – pleasure and arousal; and their influence on potential homebuyers' purchase intentions.

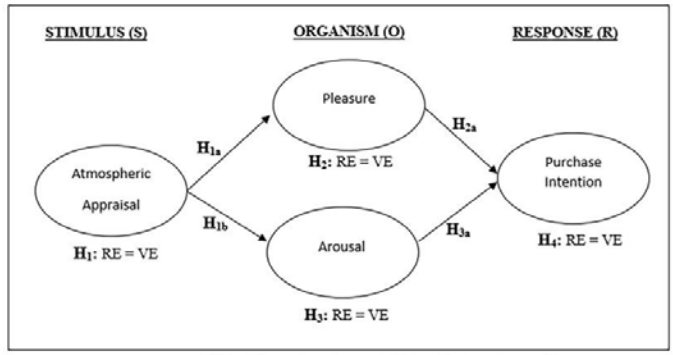


Figure 1: Proposed theoretical framework and hypotheses

3. Research Methodology

3.1. Experimental Design

A randomized crossover study design was used in this study. Each participant visited two different environments – real environment and virtual environment. The order of presentation of two different environments were randomized, and each visit occurred on the same day to minimize the order effect. The study design is illustrated in Figure 2.

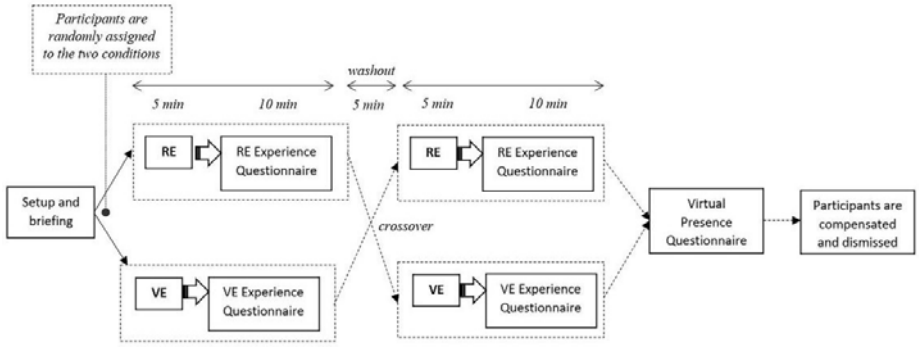
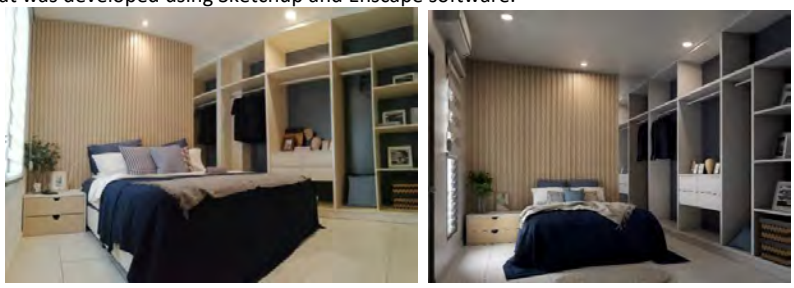


Figure 2: Experiment Procedure

3.2. Model and Apparatus

A real mock-up show unit that was already constructed by a local property developer at a one-to-one scale was used as the model. For the virtual environment, Sketchup Pro 2019 Version 19.3 was used to create an identical model of the apartment unit in 3D with similar dimensions, furniture, interior decorations and lighting conditions. Enscape Version 2.6.1 was employed for real-time VR rendering.

The tools used for the VR system was HTC Vive. HTC Vive system has one head-mounted devide (HMD), two wireless controllers and two base stations which tract both the controller and the HMD positions. The computer used for 3D modelling in Sketchup and rendering of the model in Enscape was a Dell G7 15 7588 laptop with Intel Core i7 processor and NVIDIA GeForce GTX 1050 graphics card. The specifications on this computer satisfies the system requirements for HTC Vive. Figure 3 shows the real show unit and the virtual show unit that was developed using Sketchup and Enscape software.



a) Real environment b) Virtual environment

Figure 3: Example of real and virtual environment of the apartment unit

3.3. Questionnaire Development

A set of self-reported questionnaires were used as the instrument to measure participants' response from both experimental conditions. In this study, atmospheric appraisals were collected in six items with a bipolar 7-point semantic differential scale (e.g., pleasant-unpleasant, inviting-univiting, cozy-not cozy, boring-interesting, monotone-varied, and meaningless-impressive), based on combined evaluative concepts from De Kort et al. (2003), Westerdahl et al. (2006), Franz and Wiener (2008) and Kuliga et al. (2015). Pleasure was measured with a bipolar 7-point semantic differential scale with the following three items: happy-unhappy, bored-entertained and annoyed-pleased (Bigneá, Andreu, & Gnoth, 2005). Similarly, arousal was measured with a bipolar seven-point semantic differential scale with the following three items: calm-enthusiastic, relaxed-stimulated, and indifferent-surprised. Purchase intention is measured by means of even-point Likert scales with three items adapted from past studies (Van Kerrebroeck, Brengman, & Willems, 2017).

3.4. Participants

The target population for this study is potential first-time homebuyers. Respondents were recruited using purposive sampling technique, which allowed the researchers to select participants who were valid, informative and that was deemed appropriate for analysing the effect under study (Sarstedt, Bengart, Shaltoni, & Lehmann, 2018). To ensure statistical power of the experimental results of this study, an *a priori* power analysis using G*Power 3.1 was conducted to determine the minimum sample size required for paired sample t-test analysis.

The results form G*Power 3.1 indicated that the minimum sample size of 27 was required to achieve a power of 80% with a medium effect size. Furthermore, this study adopts the minimum sample size based on the PLS-SEM rule of thumb which is the "ten times rule" (Hair, Ringle, & Sarstedt, 2011). Therefore, based on the G*Power calculations, the sample size from similar previous experimental studies and consideration of additional provision of respondents anticipated for dropout, a total of 65 participants recruited in this experiment were adequate.

3.5. Experiment Procedure

As illustrated in Figure 2, participants were randomly assigned to experience one of the experimental conditions first, followed by the other experimental conditions (e.g. RE then VE, or VE then RE). This counterbalancing procedure was done to eliminate any order effects, following the procedure conducted by similar experimental studies by Heydarian et al. (2015), Kuliga et al. (2015) and Hong et al. (2019). The five-minute washout or break period in between the environments follows previous similar experiment conducted by Heydarian et al. (2015) and Hong et al. (2019) to reduce the carry-over effect.

Once all participants have experienced the apartment unit in the two experimental conditions and completed the questionnaires, they were given cash as compensation and dismissed. Out of the 65 participants recruited for the experiment, two participants felt dizziness after wearing the HTC Vive HMD and unable to complete the experiment, while three participants did not complete the questionnaire accordingly. Therefore, the analysis for this study is based on the response from 60 participants.

4. Results and Analyses

4.1. Paired samples *t*-test results

For the evaluation of the atmospherics, the *p*-value ($p = 0.000 < 0.05$) indicates that there is a significant difference between the mean values of atmospheric appraisal ratings in the real environment ($M = 6.06$, $SD = 0.75$) and virtual environment (M = 5.51, SD = 1.24); t (59) = 3.80, $p < 0.05$, $d = 0.49$. Therefore, hypothesis H_1 was not supported. For pleasure emotion, the results indicate that there was no significant difference ($p = 0.087 > 0.05$) in the ratings of pleasure emotion in real environment (M = 5.97, SD = 0.89) and ratings of pleasure emotion in virtual environment (M = 5.70, SD = 1.20); t (59) = 1.74, $p > 0.05$, $d = 0.22$. For arousal emotion, the result also indicates that there was no significant difference ($p = 0.503 > 0.05$) in the ratings of arousal emotion in real environment (M = 5.52, SD = 1.20) and arousal in virtual environment (M = 5.66, SD = 1.20); t (59) = -0.67, $p > 0.05$, $d = 0.09$. Thus, these results support H_2 and H_3. However, the results for purchase intention did not support hypothesis H_4. The paired samples *t*-test results indicate that there was a significant difference ($p = 0.006 < 0.05$) in the ratings for the purchase intention in the real environment (M = 5.961, SD = 0.961) and the purchase intention in the virtual environment (M = 5.556, SD = 1.247); t (59) = 2.875, $p < 0.05$, $d = 0.37$. Table 1 summarizes the results for the paired samples *t*-test.

Table 1: Summary of the paired samples *t*-test results

Constructs	Mean		Std. Deviation		Mean difference	*t*-statistics	*p*-value	Effect size, *d*
	RE	VE	RE	VE				
Atmospherics	6.06	5.51	0.746	1.24	0.55	3.80	0.000	0.49
Pleasure	5.97	5.70	0.891	1.20	0.26	1.74	0.087	0.22
Arousal	5.52	5.66	1.203	1.19	0.13	-0.67	0.503	0.09
Purchase Intention	5.96	5.56	0.961	1.25	0.41	2.88	0.006	0.37

4.2. Structural model assessments using PLS-SEM

4.2.1. Measurement model

The result indicates that all the indicator loadings on their corresponding latent variables in both environments and the CR coefficients of all reflective latent variables in the path model were higher than 0.70. These results indicate that the measurement model possessed acceptable reliability. To establish convergent validity, the AVE should be higher than 0.50 (Hair et al., 2017). Results indicates that the AVE values were higher than 0.50 for all constructs. Table 2 indicates that all constructs established discriminant validity where the square root of AVE is greater than the correlations for all reflective constructs.

Table 2: Discriminant validity using Fornell and Larcker Criterion

	ATM	PLE	ARO	PUR
ATM	0.897*			
PLE	0.874	0.916*		
ARO	0.840	0.888	0.891*	
PUR	0.633	0.576	0.444	0.948*

Note: The diagonal elements (in bold) represent the square root of the AVE, while the off diagonals represent the correlations among constructs. * indicates that discriminant validity has been established

4.2.2. Structural model assessments

Based on the assessment of the path coefficient as shown in Table 5, three relationships are found to have *t*-value > 1.645, thus significant at 0.05 level of significance, except for the relationship between arousal and purchase intention. Atmospherics has a significant positive effect on Pleasure (β= 0.875, t = 20.25, p < 0.05), which explains 76.6% of variance in Pleasure. Thus, H_{1a} is supported. Atmospherics also has a significant positive effect on Arousal (β= 0.841, *t* = 13.08, *p* < 0.05) which explains 70.7% of variance in Arousal; hence supporting H_{1b}. Pleasure has a significant positive effect on Purchase Intentions (β= 0.857, t = 4.07, p < 0.05); supporting H_{2a}. However, the result indicates that Arousal has a small insignificant negative effect on Purchase Intention (β= -0.318, *t* = 1.250, *p* > 0.05); therefore, H_{3a} is not supported. Both Pleasure and Arousal explains 35.2% of variance in Purchase Intention. All coefficient determination values (R^2) are above the 0.26 value as suggested by Cohen (1988), which indicates substantial model.

In addition, the effect sizes (f^2) are also assessed in SmartPLS 3.2.8 as both the substantive significance (effect size) and statistical significance (*p*-values) are essential results to be reported (Sullivan & Feinn, 2012). To measure the effect size, this study follows the guideline by Cohen (1988), whereby the values of 0.02 represent a small effect size, 0.15 represent a medium effect size, and 0.35 represent large effect size.

Table 3: Hypothesis testing results

Relationships		Std beta (β)	Std dev	*t* - value	*p* - value	Supported	R^2	Effect size (f^2)
H_{1a}	Atmospherics → Pleasure	0.875	0.043	20.247	0.000	Yes	0.766	3.270
H_{1b}	Atmospherics → Arousal	0.841	0.064	13.084	0.000	Yes	0.707	2.415
H_{2a}	Pleasure → Purchase Intention	0.857	0.211	4.072	0.000	Yes	0.352	0.240
H_{3a}	Arousal → Purchase Intention	-0.318	0.254	1.250	0.106	No		0.033

From Table 3, it can be observed that Atmospherics has a substantial effect in producing the R^2 for Pleasure (f^2 = 3.270) and Arousal (f^2 = 2.415). Moreover, the result indicates that Pleasure has a medium effect size in producing the R^2 for Purchase Intention (f^2 = 0.240). Furthermore, Arousal has a

near to small effect in producing the R^2 for Purchase Intention ($f^2 = 0.033$). Figure 5 illustrates the results of the structural model assessment using PLS-SEM.

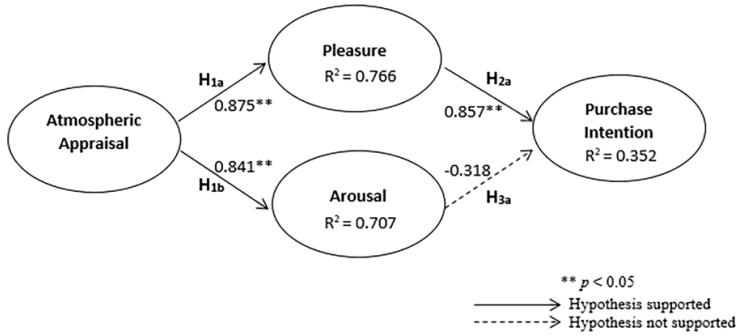


Figure 4: Results of the structural model assessment

4.3. Analyses

The purpose of this study was to examine whether VR could be an effective approach as a pre-purchase evaluation tool for potential homebuyers to emotionally experience a house before making purchase decisions. An experiment was conducted to evaluate the potential homebuyers' response in terms of atmospheric appraisal, pleasure and arousal emotions, as well as their purchase intention through a set of questionnaires and compared participants' response on a set of identical questionnaires in a real and virtual environment with the same design.

The analysis using paired samples *t*-test and PLS SEM resulted in several important findings. Firstly, this study found that there was a statistically significant difference ($p = 0.000 < 0.05$) in how potential homebuyers rate the atmospheric qualities of a house between a real and virtual environment ($M_{RE} = 6.06$, $SD_{RE} = 0.75$; $M_{VE} = 5.51$, $SD_{VE} = 1.24$); t (59) = 3.80, $p < 0.05$, $d = 0.49$. Secondly, the study found that there was a statistically significant difference ($p = 0.006 < 0.05$) in the purchase intention between real environment and virtual environment ($M_{RE} = 5.961$, $SD_{RE} = 0.961$; $M_{VE} = 5.556$, $SD_{VE} = 1.247$); t (59) = 2.875, $p < 0.05$, $d = 0.37$. However, there is no significant difference in the pleasure ($p = 0.087 > 0.05$) and arousal emotions ($p = 0.503 > 0.05$) evoked in these two different environments. The structural model assessment in PLS-SEM reveal that atmospherics has a significant positive effect on pleasure emotion (β= 0.875, t = 20.25, p < 0.05), and arousal emotion (β= 0.841, $t = 13.08$, $p < 0.05$. Pleasure also has a significant positive effect on purchase intention (β= 0.857, t = 4.07, p < 0.05).

This finding corresponds to the findings of study by Kuliga et al. (2015). The difference in evaluation of the atmospherics between the two environments could be explained by the lower level of experiential realism in the virtual environment which is lower than that of real environment (de Kort et al., 2003). Due to the significant difference in atmospherics evaluations between real and virtual environment, this study proposed that for VR to be used for pre-purchase evaluations, the quality and vividness of the virtual environment should be enhanced. Furthermore, it is suggested for housing

developers to invest in sound and haptics systems, position tracking sensors and wireless HMD for users to walk naturally and have more intuitive interaction within the virtual environment that would notably improve the comparability of experience in VR. Secondly, another important finding from this study is regarding the capacity of the virtual environment to evoke similar emotions of pleasure and arousal as in the real environment. The results found in testing the path coefficients using PLS-SEM revealed that pleasure emotion has a significantly positive effect on purchase intention, which coincide the results found in previous research.

5. Conclusion

The findings in this study has successfully extended the current knowledge in residential real estate literature. The findings in this study revealed that potential homebuyers could induce the same emotion when viewing a house in the virtual environment as they would when visiting a real show unit or mock-up model of the house. Therefore, for VR to successfully be used as the pre-purchase emphatic evaluation tool to influence purchase intention, it is important for the designers present the living environment with an aim to provide potential homebuyers with the utmost pleasure while experiencing the house in VR.

This study contributes in extending the applicability of the S-O-R framework to a new and important research field focusing on VR and its applications in the housing industry. The theoretical framework proposed is expected to provide a new paradigm for researchers, residential real estate developers as well as building designers to tackle new strategy for influencing home purchase using VR. Furthermore, it is important to note that the experimental realism of this study is maximized by conducting the experiment in a naturalistic setting where actual consumption or homebuying experience takes place, to observe and measure responses (Morales, Amir, & Lee, 2017). This study had also recruited real potential homebuyers instead of recruiting students as the participants in the experiment thereby, extending the generalizability of the findings with larger realistic impact.

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