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A Comparative Study by Age in Evaluating Web-based 3D Model House

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Abstract This study aims to explore age-related differences with the assessment tools in the web-based 3D virtual model house and to propose the 3D model house criteria which everyone can use easily. The participants came from three age groups, ranging from their 20s to their over 40. Presence, Usability and Space perception and cognition in the experiment for navigating and evaluating the web-based 3D model house were measured and compared through one-way ANOVA and two-way ANOVA. The results and conclusions are as follows. (1) The younger the participants were, the more positive they evaluated the experiment on Presence. However, 20s needed higher presence than other two groups. (2) 30s and over 40 groups evaluated that the 3D virtual model house was more efficient than an actual model house on Usability. When the participants were younger, the values of 'expressivity' factor were higher. (3) The younger the participants were, the more positive they perceived the virtual environment (VE) on Space perception and cognition scale. There were no significant differences in the selection of dwelling size and the floor plan type. There were no significant differences of interaction effects between age and online gaming experience on Presence and Usability. The results of the current study demonstrate that there are differences among age groups and older groups have difficulty navigating and assessing in a VE. Although older groups take longer to adapt in the VE, they regard the 3D model house as an effective tool for purchase of house.

Keywords: Web-based 3D Virtual Model House, Presence, Usability, Spatial Perception and Cognition

1. INTRODUCTION

The apartment has become the typical type of urban housing since the first apartment complex was built in 1962 in Korea. The standard floor plan of the apartment unit for the typical Korean households in 1980s helped spur the increase of apartment housing, and eventually becoming over 50% of the entire housing in Korea (NSO, 2010). 'The model house,' which shows the future customers each type of housing unit and information such as construction schedule, costs, and dues, also contribute to the mass production of apartments. However, there has also been criticism of wasted resources and environmental pollution caused by the temporary makeshift buildings. The Ministry of Land, Transport, and Maritime Affairs of Korea prohibited construction companies from building the apartment model house in 2009, recommending the virtual model house for that reason. A virtual model house was introduced into the apartment sales process in 2006 under government sponsorship, and 88% of the total 470,000 customers applied for apartment subscription through the Internet (New City Planning Division, Ministry of Construction & Transportation, 2006). Recently, many companies have been trying to find alternatives to a model house such as a cyber-model house which provides floor plan type, interior concept, 3D modeling and finishing material (see http://www.lh.or.kr, Korea Land & Housing Corporation) and an interactive website named 'My Dream House,' where people can decorate their ideal house for themselves (see www.raemian.com, Samsung T & C Corporation).

The study on usability of the virtual 3D model house has also increased along with the prevailing use of it. The sizes of the displayed images (the computer display and the projected one, Park & Yoon, 2008) and the modeling types (the birds-eye view and walk-through view, Ha & Park, 2011) were compared based on the hypothesis of single user group. The users' fundamental characteristics such as age and gender, however, are effective factors in developing an advanced virtual model house because the digital imaginary technology including a virtual modeling has rapidly progressed and changed during past decades without the proofs that all the users can operate it efficiently.

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The users' age is one of the distinguishing features which affect the adaptation level in the VE. The following literatures indicate that subjects have increasing difficulty assessing VE and operating the system as they age. In the formation and the use of cognitive maps, older participants required more time to form a cognitive map of the environment than younger individuals and required more time and made more errors when subsequently using the cognitive map for orientation (Iaria et al,. 2009). In spatial memory in a VE navigation task, older volunteers took longer to solve each trial, went a longer distance, and made significantly more spatial memory errors compared to younger participants(Moffat et al., 2001). In wayfinding and route learning conditions, there was evidence of age-related differences in the acquisition of configural knowledge (Head, D. & Isom, M., 2010).

The average age of first-time house purchasing is 32.1 years[1] and 63.4% of total lives in apartment (Kim, 2008). When customers purchase apartment, they consider maintenance costs, apartment sales prices, living environment, location, etc. In this sense, the model house is the important tool related to decision making process for purchase of apartment. In particular, 3D model house could give a negative influence on users' decision making due to virtuality, if the users have trouble getting correct information from it. Therefore, it is important to verify how users with different age groups experience and assess in the 3D model house and to find out how to improve customer satisfaction.

This study aims to evaluate the age-related differences using the evaluation tools which include the presence, spatial cognition, and usability in the web-based 3D model house, and suggest the 3D model house criteria which everyone can use easily.

2. METHODS

2.1 Tools

(1) Web-based 3D model house

The web-based 3D model house was built with a size of 85㎡ and type of 3 bay, which were chosen as the most popular dwelling unit of a Korean apartment. It passed through three phases: (1) The floor plan was completed by AutoCAD, professional drawing S/W; (2) The three-dimensional model was built by 3Ds Max using the floor plan imported from Auto CAD, which also represented real finishing materials; (3) Finally, this was transformed into a website for online use and manipulation by the potential customers (the subjects in this research) (Figure 1).

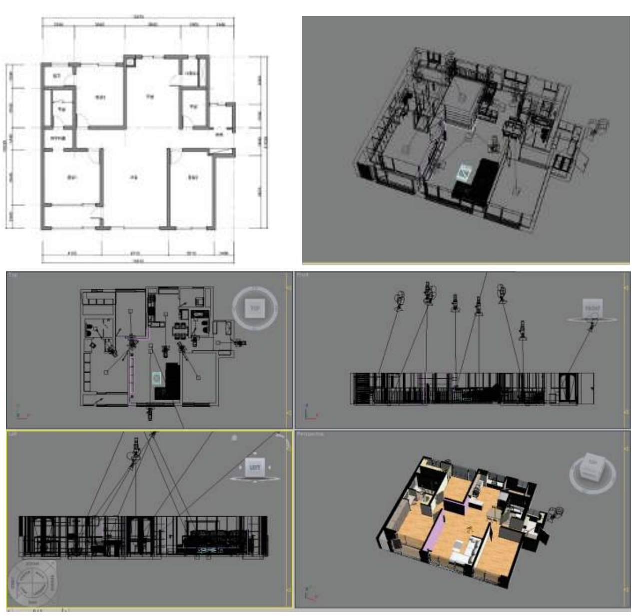

Figure 1. The Floor plan and 3D Modeling process

TurnTool Box was used in this phase, which is the plug-in program of 3Ds Max, and an easy solution for publishing 3D contents online.

The subjects were able to navigate the VE and change finishing materials of the floor (3 types), the walls (4 types), the kitchen (3 types), and the living room furniture (2 types of sofa) using the arrow keys (←, ↑ , ↓ ,→) of keyboard and a mouse (Figure 2).

Subjects can be immersed in the virtual model house named 'walk through view type' by feeling surrounded with the VE.

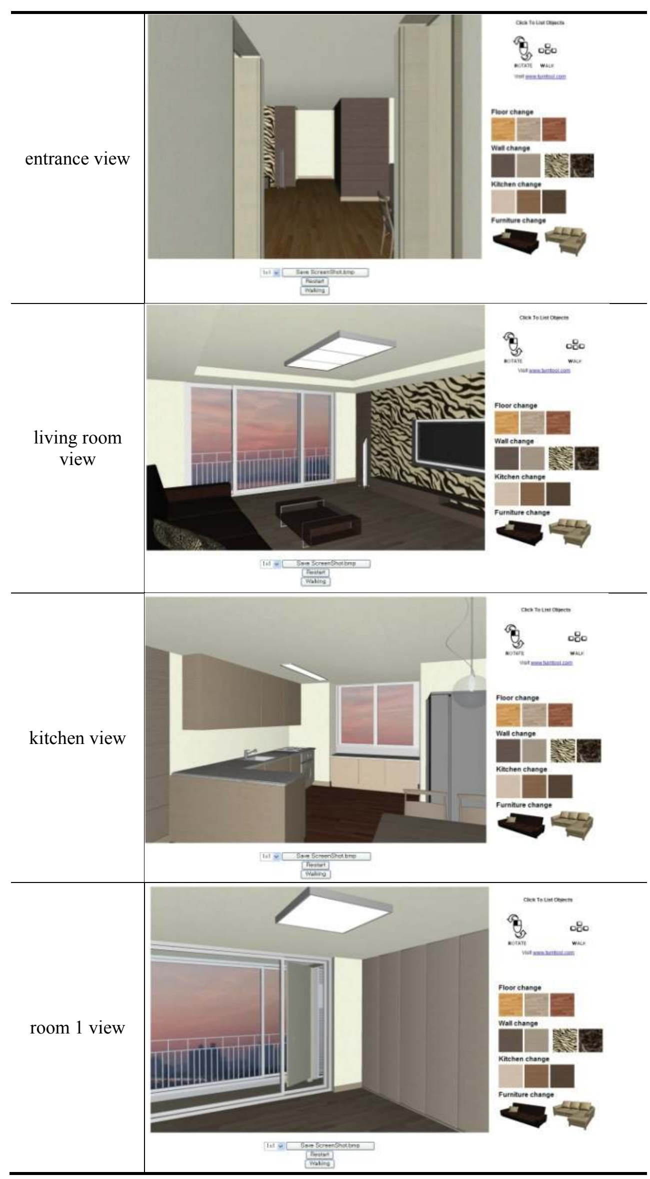

Figure 2. Web-based 3D Model house by TurnTool

[1] 16.1% of 20s, 55.8% of 30s, 71.1% of 40s, and 77.5% of over 50 have experience of home buying.

(2) User assessment tool

The subjects evaluated their engagement through the Presence scale, which was composed of 35 items in reference to ITC-SOPI (Lessiter, J. et al., 2000, 2001) excluding 9 items[2] from total of 44 items. They then evaluated how the model house looked when compared to a real environment through the Spatial perception and cognition scale, which was composed of 10 items in reference to Lee and Kim (2005), and Shin (2005). This included spatial scale, proportion, finish materials, lightings, furniture, and openings. Finally, they evaluated the efficiency and satisfaction of the model house through the Usability scale, which was composed of 15 items in reference to Kim & Kim (2007). Each item consisted of a 5 point Likert scale (1: strongly disagree, 2: disagree, 3: neither, 4: agree, 5: strongly agree).

2.2 Participants

Table 1. Subjects' characteristics

Categories	Detail	N	(%)
Age M=34.4yrs (SD=11.4)	20s	55	(38.2)
	30s	39	(27.1)
	40s	31	(21.5)
	50s	19	(13.2)
	Total	144	(100.0)
Education level	College graduate or higher	72	(50.3)
	In college	51	(35.7)
	High school graduate or under	20	(14.0)
	Total	143	(100.0)
Occupation	Student	62	(44.6)
	Housewife	43	(30.9)
	Professional	16	(11.5)
	Self-employed	12	(8.6)
	White-collared	6	(4.3)
	Total	139	(100.0)
Monthly Income (1,000won)	under 4000	21	(25.6)
	4000~5000	18	(22.0)
	5000~7000	23	(28.0)
	7000 and over	20	(24.4)
	Total	82	(100.0)
No. of Household M=3.6 (SD=1.0)	3 or less	53	(36.8)
	4	72	(50.0)
	5 or more	19	(13.2)
	Total	144	(100.0)
Internet use hours (hour/day)	less than 1 hour	44	(30.6)
	1~3 hours	74	(51.4)
	over 3 hours	26	(18.1)
	Total	144	(100.0)
Online gaming experience	No	86	(59.7)
	Yes	58	(40.3)
	Total	144	(100.0)
Visiting a model house	Yes	120	(83.3)
	No	24	(16.7)
	Total	144	(100.0)
Visiting a virtual model house	Yes	47	(32.6)
	No	97	(67.4)
	Total	144	(100.0)

[2] The items duplicated and measuring sensing (hearing, smell, and touch) and emotion were excluded.

The subjects included women[3] in their 20s, 30s, and over 40[4] who live in Busan. The subjects include 20s as a potential customer in the future.

The sampling size was cautiously used when later compared the age groups. After navigating the web-based 3D model house, subjects evaluated it according to scales under the characteristics of Presence, Space perception and cognition, and Usability, which were developed for a previous study (Ha and Park, 2011).

The total numbers of participants were 144, with the average age being 34.4 (SD=11.4) years old, with women in their 20s (38.2%, N=55), 30s (27.1%, N=39) and over 40 (34.7%, N=50). Regarding Education level, 50.3% (N=72) of the subject graduated college, 35.7% (N=51) were in college, and only 14% (N=20) graduated high school. Their education level was relatively high, with a high ratio of college graduates. In occupation, 43.1% (N=62) of the total was students and 29.9% was housewives. With regard to average income, 74.4% of the subjects earned over 4 million won a month, showing higher earnings than the average urban household income (A Quarter 2011 average urban household monthly income: 4,038,833won, Statistic Korea). Regarding Internet usage, 51.4% (N=74) of total used the internet for 1 to 3 hours, 30.6% (N=44) for less than 1 hour, and 18.1% (N=26) for over 3 hours. In online gaming experience, subjects who enjoyed online games were 40.3% (N=58) and 59.7% of them (N=86) didn't play online games. The result of visiting a model house was that 83.3% (N=120) of the subjects had visited it. While visiting a virtual model house, only 32.6% of total (N=47) visited a virtual model house before.

3. RESULTS

3.1. Presence

(1) Presence by age

To measure Presence, 35 items of ITC-SOPI was utilized, excluding 9 items of the total (44 items) that were not related to this study.

The composition of the Presence scale was released as 'the environmental engagement (11 items),' 'the negative effects (7 items),' 'the positive effects (6 items),' and 'the objects engagement (4 items)' through a factor analysis of 35 items (Table 2). The factor analysis[5] is driven by 'principal components analysis (PCA)' method of extraction and 'VARIMAX' orthogonal method of rotation. The number of factors is determined by the Eigen values (over 1.0) and the factor loadings (about 60%)[6].

[3] This study excludes male subjects because there were no significant differences between genders in the preliminary experiment whose participants were 116, 54 males and 62 females.

[4] The sample included from 20s to 50s. 40s and 50s groups were combined in 'over 40' group because there was no significant difference between these two groups.

[5] Factor analysis is a multivariate statistical method for reducing large numbers of variables to fewer underlying dimensions. It was originally developed to test the relationship between concepts to see if putative relationships or underlying dimensions (Watson & Thompson, 2006).

[6] The item 2, 4, 12, 14, 15, 27, and 28 were excluded because their communality was under 0.5 on the primary analysis. (2. I had a sense that I had returned from a journey, 4. I felt sad that my experience was over, 12. I felt I was visiting the places in the displayed environment, 14. The content seemed believable to me, 15. I felt I wasn't just watching something, 27. I responded emotionally, 28. The content appealed to me)

Table 2. Factors of Presence in 3D Model House

Presence	1	2	3	4
I felt as though I was in the same space as the objects	0.762	-0.061	0.223	0.285
I had a sense of being in the scenes displayed	0.746	0.001	0.291	0.039
I had the sensation that I moved in response to parts of the displayed environment	0.737	0.066	0.155	-0.004
I felt that I could move objects (in the displayed environment)	0.688	-0.010	0.021	0.377
I had the sensation that parts of the displayed environment(e.g. objects)were responding to me	0.686	-0.034	0.065	0.441
I felt surrounded by the displayed environment	0.684	-0.065	0.332	0.005
I felt that the displayed environment was part of the real world	0.589	0.000	0.118	0.345
I felt myself being 'drawn in'	0.572	-0.033	0.542	-0.124
I felt as though I was participating in the displayed environment	0.511	-0.158	0.391	0.340
I felt I could interact with the displayed environment	0.505	-0.213	0.504	0.119
I felt that the objects could almost touch me	0.504	0.187	0.262	0.371
I felt I had a headache	-0.015	0.863	-0.152	-0.033
I felt disorientated	-0.085	0.853	-0.117	0.061
I felt dizzy	0.041	0.824	-0.168	-0.112
My experience was intense	-0.015	0.823	-0.150	0.085
I felt I had eyestrain	0.007	0.807	-0.034	-0.054
I felt tired	0.047	0.711	-0.285	0.087
I felt I couldn't focus my attention	-0.098	0.474	-0.406	0.117
I felt involved (in the displayed environment)	0.451	-0.071	0.708	-0.064
I enjoyed myself	0.070	-0.277	0.692	0.261
I felt I liked the experience	0.114	-0.434	0.661	0.245
I vividly remember some parts of the experience	0.281	-0.146	0.647	-0.212
I felt interested	0.298	-0.268	0.623	0.116
I'd recommend the experience to my friends	0.247	-0.275	0.622	0.159
I had a strong sense that the objects were solid	0.394	-0.012	0.013	0.658
The displayed environment seemed natural	0.125	-0.061	0.523	0.576
It felt like the content was 'live'	0.299	-0.098	0.496	0.535
I felt I could have reached out and touched things (in the displayed environment)	0.091	0.080	-0.037	0.480
Eigen Value	9.4	4.7	1.6	1.3
% of Variance	18.8	17.1	16.2	8.5
Cumulative % of Variance	18.8	35.9	52.1	60.6
KMO	0.891***			
Cronbach's α	0.857			

Mean values of each item in four factors were compared among age groups by one way variance analysis.

In the group of participants in their 20s, the mean values of two items in 'the positive effects' factor, 'I vividly remember some parts of the experience (M=3.7, SD=0.6)', 'I felt interested (M=3.7, SD=0.6)' were the highest. In addition, mean values of all items in 'the positive effects' factor were higher than other ages. On the other hand, the mean values of all items in 'the negative effects' factor were lower than other groups. The mean value of 'My experience was intense (M=2.1, SD=0.8)' was the lowest among them. The mean values of six items in 'the environmental engagement' factor were lower than other two groups. 'I felt that I could move objects (in the displayed environment) (M=2.5, SD=0.9)' and 'I felt that the objects could almost touch me (M=2.5, SD=0.9)'

Table 3. Difference of presence mean values by age

Presence	20s	30s	over 40	total	F
I felt as though I was in the same space as the objects	2.8 (0.8)	3.2 (0.7)	3.1 (0.8)	3.0 (0.8)	2.4 (n.s)
I had a sense of being in the scenes displayed	3.1 (0.7)	3.0 (0.7)	3.0 (0.8)	3.0 (0.7)	0.5 (n.s)
I had the sensation that I moved in response to parts of the displayed environment	3.1 (1.0)	3.1 (0.8)	3.1 (0.8)	3.1 (0.9)	0.1 (n.s)
I felt that I could move objects (in the displayed environment)	2.5 (0.9) a	3.1 (0.8) b	3.0 (0.8) b	2.9 (0.9)	6.3 **
I had the sensation that parts of the displayed environment(e.g. objects)were responding to me	2.6 (0.8) a	3.1 (0.7) b	2.8 (0.8) ab	2.8 (0.8)	4.9 **
I felt surrounded by the displayed environment	3.2 (0.8)	2.9 (0.9)	3.0 (0.8)	3.0 (0.8)	1.1 (n.s)
I felt that the displayed environment was part of the real world	2.7 (0.9)	2.9 (0.6)	3.0 (0.8)	2.8 (0.8)	2.8 (n.s)
I felt myself being 'drawn in'	3.2 (1.0)	3.1 (0.7)	2.9 (0.8)	3.1 (0.9)	2.1 (n.s)
I felt as though I was participating in the displayed environment	3.0 (0.8)	3.2 (0.8)	3.1 (0.7)	3.1 (0.8)	1.0 (n.s)
I felt I could interact with the displayed environment	3.2 (0.8)	3.1 (0.7)	3.0 (0.8)	3.1 (0.8)	0.8 (n.s)
I felt that the objects could almost touch me	2.5 (0.9) a	3.0 (0.7) b	2.8 (0.9) ab	2.8 (0.9)	3.9 *
I felt I had a headache	2.2 (1.0) a	2.2 (0.8) ab	2.7 (1.1) b	2.3 (1.0)	4.2 *
I felt disorientated	2.2 (1.0) a	2.6 (0.8) a	2.7 (1.0) a	2.5 (1.0)	3.6 *
I felt dizzy	2.5 (1.1) a	2.7 (1.1) ab	3.0 (1.0) b	2.7 (1.1)	3.5 *
My experience was intense	2.1 (0.8) a	2.6 (1.0) b	2.8 (0.9) b	2.5 (0.9)	7.9 **
I felt I had eyestrain	2.6 (1.1) a	2.6 (0.9) a	3.2 (1.0) b	2.8 (1.0)	5.0 **
I felt tired	2.2 (0.9) a	2.6 (0.9) ab	2.8 (1.0) b	2.5 (1.0)	6.1 **
I felt I couldn't focus my attention	2.3 (0.8) a	2.4 (0.8) ab	2.8 (0.9) b	2.5 (0.9)	3.9 *
I felt involved (in the displayed environment)	3.4 (0.9) b	3.2 (0.7) ab	2.9 (0.8) a	3.2 (0.8)	4.8 **
I enjoyed myself	3.4 (0.6) b	3.3 (0.8) ab	3.0 (0.9) a	3.2 (0.8)	3.8 *
I felt I liked the experience	3.6 (0.7) b	3.5 (0.8) b	3.1 (0.8) a	3.4 (0.8)	5.8 **
I vividly remember some parts of the experience	3.7 (0.5) b	3.6 (0.7) ab	3.3 (0.8) a	3.5 (0.7)	5.6 **
I felt interested	3.7 (0.6) b	3.5 (0.8) ab	3.2 (0.8) a	3.5 (0.7)	6.1 **
I'd recommend the experience to my friends	3.5 (0.8)	3.3 (0.7)	3.2 (1.0)	3.4 (0.8)	1.2 (n.s)
I had a strong sense that the objects were solid	2.3 (0.7) a	2.9 (0.6) b	2.9 (0.8) b	2.7 (0.8)	10.3 ***
The displayed environment seemed natural	3.0 (0.8)	3.0 (0.5)	3.0 (0.8)	3.0 (0.8)	0.1 (n.s)
It felt like the content was 'live'	2.8 (0.9)	3.0 (0.6)	3.0 (0.9)	2.9 (0.8)	1.0 (n.s)
I felt I could have reached out and touched things (in the displayed environment)	2.2 (0.8) a	3.6 (0.9) b	2.7 (0.8) ab	2.7 (0.8)	3.4 *

* p<.05, ** p<.01, *** p<.001, Post analysis resulted by Scheffe(α=.05) test

were the lowest among them. Moreover, the mean value of an item in 'the objects engagement' factor, 'I felt I could have reached out and touched things (in the displayed environment) (M=2.2, SD=0.8)' were the lowest.

For participants in their 30s, the mean values of two items, 'I vividly remember some parts of the experience (M=3.6, SD=0.7)' in 'the positive effects' factor, and 'I felt I could have reached out and touched things (in the displayed environment) (M=3.6, SD=0.9)' in 'the object engagement' factor were the highest, whereas 'I felt that I had a headache' in 'the negative effects' factor had the lowest mean value (M=2.2, SD=0.8).

For those over 40, the mean value of 'I vividly remember some parts of the experience (M=3.3, SD=0.7)' in 'the positive effects' factor was the highest, while mean values of two items of 'the negative effects' factor, 'I felt I had a headache (M=2.7, SD=1.1)'and 'I felt disorientated (M=2.7, SD=1.0)'and an item in 'the object engagement' factor, 'I felt I could have reached out and touched things (in the displayed environment)(M=2.7, SD=0.8)' were the lowest.

As a result of comparative analysis, Table 3 shows that there were significant differences in all four factors among all age groups. In 'the environmental engagement' factor, the mean values of the three items in the 20s group, 'I felt that I could move objects (in the displayed environment) (M=2.5, SD=0.9)', 'I had the sensation that parts of the displayed environment (e.g. objects) were responding to me (M=2.6, SD=0.8),' and 'I felt that the objects could almost touch me (M=2.5, SD=0.9)' were lower than in the other two groups. In 'the positive effects' factor and 'the negative effect' factor, all items except one showed significant differences among age groups. Mean values of the group in their 20s were the highest in 'the positive effect' factor, whereas those of over 40 were highest in 'the negative effect' factor. In 'the object engagement' factor, two items, 'I had a strong sense that the objects were solid,' and 'I felt I could have reached out and touched things (in the displayed environment),' also showed significant differences that the mean values were lower for the younger participants.

Those participants in their 20s showed a lower environmental and objective presence for the 3D model house built for the experiment, but they provided positive feedback on it. On the other hand, the 30s and over 40 groups showed a higher environmental and objective presence but they provided negative feedback. As they aged, they felt had a headache, dizzy, tired and couldn't focus on the experiment.

(2) Interaction between Age and Online Gaming Experience on Presence

As the difference among the age groups partly results in their different experiences, the effects of the online gaming experience which also requires familiarity with the virtual world was studied. Two-way ANOVA was used for examining the interaction effects of two factors, age and online gaming experience, on Presence.

Table 4 shows that there were no significant differences of interaction effects between age and online gaming experience in all factors. There were only significant differences by age in 'positive effects' and 'the object engagement'. When the subjects were younger, the value of 'positive effects' was higher, while the value of 'the object engagement' was lower.

Table 4. Interaction between age and online gaming experience on Presence

		20s	30s	over 40	total
environmental engagement					
Online Gaming experience	No	-0.24 (1.2)	0.07 (1.0)	0.06 (1.0)	-0.01 (1.1)
	Yes	-0.07 (1.1)	0.07 (0.7)	0.20 (0.7)	0.02 (0.9)
	Total	-0.13 (1.1)	0.07 (0.9)	0.09 (0.9)	0.00 (1.0)
age		F(p)	1.0 (n.s)		
Online gaming Ex.		F(p)	0.3 (n.s)		
Age*Online gaming Ex.		F(p)	0.1 (n.s)		
negative effects					
		20s	30s	over 40	Total
Online Gaming experience	No	-0.07 (0.9)	0.16 (0.9)	0.31 (1.1)	0.17 (1.0)
	Yes	-0.34 (1.1)	-0.42 (0.5)	0.24 (0.8)	-0.25 (1.0)
	Total	-0.24 (1.0)	-0.04 (0.8)	0.29 (1.0)	0.00 (1.0)
age		F(p)	2.7 (n.s)		
Online gaming Ex.		F(p)	2.8 (n.s)		
Age*Online gaming Ex.		F(p)	0.6 (n.s)		
positive effects					
		20s	30s	over 40	Total
Online Gaming experience	No	0.17 (0.9)	-0.01 (1.1)	-0.49 (1.0)	-0.18 (1.0)
	Yes	0.52 (0.9)	-0.16 (0.8)	0.03 (0.8)	0.27 (0.9)
	Total	0.39 (0.9)	-0.06 (1.0)	-0.38 (1.0)	0.00 (1.0)
age		F(p)	4.4 *		
Online gaming Ex.		F(p)	1.9 (n.s)		
Age*Online gaming Ex.		F(p)	1.2 (n.s)		
object engagement					
		20s	30s	over 40	Total
Online Gaming experience	No	-0.42 (0.9)	0.28 (0.8)	0.36 (0.8)	0.14 (0.9)
	Yes	-0.62 (1.2)	0.57 (0.6)	0.12 (0.7)	-0.21 (1.1)
	Total	-0.54 (1.1)	0.37 (0.8)	0.31 (0.8)	0.00 (1.0)
age		F(p)	13.3 ***		
Online gaming Ex.		F(p)	0.1 (n.s)		
Age*Online gaming Ex.		F(p)	0.9 (n.s)		

* p<.05, ** p<.01, *** p<.001

3.2 Usability

(1) Usability by age

The composition of the Usability scale was released in factors like 'efficiency (4 items)' factor, 'operability (4 items)' factor, and 'expressivity (3 items)' factor through factor analysis of 15 items (Table 5). The factor analysis is driven by 'principal components analysis (PCA)' method of extraction and 'VARIMAX' orthogonal method of rotation. The number of factors is determined by the Eigen values (over 1.0) and the factor loadings (about 60%) as doing in the Presence scale. On the first analysis, 4 items[7] under 0.5 in the communality were eliminated.

[7] 1. I think the size of screen implemented the Virtual Model House was appropriate, 8. Almost Tools provided in VR were used in The Virtual Model House, 9. It was hard to interpret the information through the Virtual Model House, 10. I could enlarge what I want to see in the Virtual Model House

Mean values of each item in three factors of the Usability scale were compared among age groups by One-way analysis (Table 6).

In the group of participants in their 20s, the mean value of 'I liked that I could change the finishing materials (M=3.9, SD=0.7)' in 'the expressivity' factor was the highest, whereas the mean value of 'To use the Virtual Model House is more efficient than to visit the actual model house (M=2.4, SD=0.9)' was the lowest.

For participants in their 30s and over 40, the mean values of two items, 'I liked that I could change the finishing materials (M=3.6, SD=0.7; M=3.5, SD=0.8)' and 'I liked that I could change the furniture (M=3.6, SD=0.7; M=3.5, SD=0.8)' in 'the expressivity' factor were the highest. All groups evaluated 'the expressivity' factor positively. Participants liked changing the finishing materials and the furniture as they want.

Table 5. Usability factors for experiment tool

Usability	1	2	3
To use the Virtual Model House is more efficient than to visit the actual model house	0.853	-0.019	-0.006
Enough information was given to choose the house	0.791	0.156	0.224
The best environment was provided by the Virtual Model House when users navigated.	0.666	0.203	0.175
I was immediately recognizable the Virtual Model House show what the space was	0.533	0.346	0.208
I could easily identify the location of the buttons	0.093	0.902	0.055
I think the size of the buttons is appropriate	0.038	0.846	0.237
Information offered by buttons is definite	0.337	0.659	0.274
The device to experience the Virtual Model House was easy to operate.	0.493	0.564	-0.090
I liked that I could change the finishing materials	0.072	0.108	0.870
I liked that I could change the furniture	0.119	0.148	0.851
I could see the space what I want in various views.	0.427	0.133	0.517
Eigen Value	4.3	1.5	1.4
% of Variance	24.1	22.9	18.3
Cumulative % of Variance	24.1	47.0	65.3
KMO	0.806***		
Cronbach's α	0.840		

Table 6. Difference of usability mean values by age

M(SD)

	Usability	20s	30s	over 40	Total	F
Efficiency	To use the Virtual Model House is more efficient than to visit the actual model house	2.4 (0.9)	3.1 (0.8)	3.0 (1.0)	2.8 (1.0)	6.5 **
		a	b	b		
	Enough information was given to choose the house	3.1 (0.7)	3.1 (0.7)	3.1 (0.8)	3.1 (0.7)	0.0 (n.s)
	The best environment was provided by the Virtual Model House when users navigated.	2.9 (0.8)	3.3 (0.7)	3.1 (0.8)	3.1 (0.8)	3.4 *
		a	b	ab		
	I was immediately recognizable the Virtual Model House show what the space was	3.5 (0.8)	3.5 (0.6)	3.3 (0.8)	3.4 (0.8)	1.3 (n.s)
Operability	I could easily identify the location of the buttons	3.0 (1.0)	3.2 (0.9)	3.0 (0.8)	3.1 (0.9)	0.7 (n.s)
	I think the size of the buttons is appropriate	3.3 (0.8)	3.2 (0.7)	3.1 (1.0)	3.2 (0.8)	1.0 (n.s)
	Information offered by buttons is definite	3.2 (0.9)	3.3 (0.7)	3.1 (0.9)	3.2 (0.8)	1.0 (n.s)
	The device to experience the Virtual Model House was easy to operate	2.9 (0.9)	3.1 (0.9)	2.8 (0.6)	2.9 (0.8)	1.4 (n.s)
Expressivity	I liked that I could change the finishing materials	3.9 (0.7)	3.6 (0.7)	3.5 (0.8)	3.7 (0.7)	3.3 *
		a	a	a		
	I liked that I could change the furniture	3.7 (0.8)	3.6 (0.7)	3.5 (0.8)	3.6 (0.8)	0.5 (n.s)
	I could see the space what I want in various views.	3.2 (1.0)	3.3 (0.7)	3.3 (0.8)	3.3 (0.9)	0.3 (n.s)

* p<.05, ** p<.01, Post analysis resulted by Scheffe (α=. 05) test

Three items, 'To use the Virtual Model House is more efficient than to visit the actual model house', 'The best environment was provided by the Virtual Model House when users navigated', and 'I liked that I could change the finishing materials' showed significant differences. In expressivity factors like changing finishing materials, the younger, the more positive subjects assessed. However, in the efficiency factor, those in their 30s and those over 40 evaluated the VE more positively than those in their 20s.

(2) Interaction between Age and Online Gaming Experience on Usability

Differences were also expected on Usability depending on online gaming experience as well as age. A two-way ANOVA was also used, as in the Presence study, for examining interaction effects between age and online gaming experience.

As a result, there are significant differences of each factor only in regards to 'the efficiency' factor (Table 7). The group who enjoy online games showed higher values than those who don't play them. In other words, people who have online gaming experience tend to consider the efficiency of the virtual model house more positively. However, 50% of them usually play 2D games, more results will expectedly be produced if the future research is conducted according to a 3D online gaming experience.

Table 7. Interaction between age and online gaming experience

		20s	30s	over 40	total
efficiency					
Online Gaming experience	No	-0.62 (0.9)	0.15 (0.9)	0.03 (1.0)	-0.09 (1.0)
	Yes	-0.12 (1.0)	0.38 (1.1)	0.64 (0.7)	0.14 (1.0)
	Total	-0.31 (1.0)	0.23 (1.0)	0.17 (1.0)	0.00 (1.0)
age	F(p)	7.3 **			
Online gaming Ex.	F(p)	6.3 *			
Age*Online gaming	F(p)	0.4 (n.s)			
operability					
Online Gaming experience	No	-0.19 (1.3)	0.17 (1.0)	-0.09 (0.8)	-0.04 (1.0)
	Yes	0.19 (1.0)	-0.07 (0.9)	-0.23 (1.0)	0.05 (1.0)
	Total	0.05 (1.1)	0.09 (1.0)	-0.12 (0.9)	0.00 (1.0)
age	F(p)	0.4 (n.s)			
Online gaming Ex.	F(p)	0.0 (n.s)			
Age*Online gaming	F(p)	1.2 (n.s)			
expressivity					
Online Gaming experience	No	0.02 (0.9)	0.00 (0.9)	-0.17 (1.1)	-0.07 (1.0)
	Yes	0.40 (0.9)	-0.34 (0.9)	-0.25 (1.0)	0.11 (1.0)
	Total	0.25 (0.9)	-0.12 (0.9)	-0.19 (1.1)	0.00 (1.0)
age	F(p)	2.4 (n.s)			
Online gaming Ex.	F(p)	0.0 (n.s)			
Age*Online gaming	F(p)	1.4 (n.s)			

* p<.05, ** p<.01

3.3 Spatial Perception and Cognition

Mean values of spatial perception and cognition scale were compared among the age groups (Table 8).

For the group in their 20s, the mean value of 'I think that the arrangement of furniture is appropriate (M=3.7, SD=0.7)' and 'I think the size and location of doors in VR were similar to the actual size and location of door (M=3.7, SD=0.6)' were the highest, while the mean value of 'I feel that the Virtual Model House was similar to the real model house (M=3.1, SD=0.8)' was the lowest. For those in their 30s, the mean value of 'I feel that the Virtual Model House was similar to the real model house' was the highest (M=3.5, SD=0.6), but it was the lowest (M=3.0, SD=0.9) for those over 40.

Four items out of ten, 'I think the size of each room in VR was similar to the actual size of rooms,' 'I feel that the Virtual Model House was similar to the real model house', 'I think that the arrangement of furniture is appropriate' and 'I think the size and location of doors in VR were similar to the actual size and location of door' showed significant differences. Mean value of 'I think that the arrangement of furniture is appropriate' and 'I think the size and location of doors in VR were similar to the actual size and location of door' were highest in 20s, while lowest in over 40. The mean values for those in their 20s for three items and mean value of 30s for one item are the highest than in the other two groups.

Table 8. Difference of spatial perception and cognition values by age

M(SD)

Spatial perception and cognition	20s	30s	over 40	Total	F
I think the size of each room in VR was similar to the actual size of rooms	3.5 (0.7)	3.3 (0.6)	3.1 (0.8)	3.3 (0.7)	4.6 *
	b	ab	a		
I feel that the Virtual Model House was similar to the real model house	3.1 (0.8)	3.5 (0.6)	3.0 (0.9)	3.2 (0.8)	3.6 *
	ab	b	a		
I think the floor-finishing materials in VR were expressed similarly to real floor-finishing materials	3.4 (0.8)	3.4 (0.6)	3.1 (0.8)	3.3 (0.8)	1.5 (n.s)
I think the wall-finishing materials in VR were expressed similarly to real wall-finishing materials	3.2 (0.8)	3.4 (0.6)	3.1 (0.7)	3.2 (0.7)	2.5 (n.s)
I think the size of furniture in VR was similar to the actual size of furniture	3.5 (0.7)	3.3 (0.6)	3.2 (0.7)	3.3 (0.7)	2.8 (n.s)
I think that the arrangement of furniture is appropriate	3.7 (0.7)	3.5 (0.6)	3.3 (0.7)	3.5 (0.7)	4.8 **
	b	ab	a		
I think the furniture-finishing materials in VR were expressed similarly to real furniture-finishing materials	3.2 (0.8)	3.2 (0.6)	3.1 (0.7)	3.2 (0.7)	0.1 (n.s)
I think the size ratio of space and furniture in VR is appropriate	3.6 (0.7)	3.4 (0.6)	3.4 (0.7)	3.5 (0.6)	1.3 (n.s)
I think the size and location of doors in VR were similar to the actual size and location of door	3.7 (0.6)	3.4 (0.6)	3.3 (0.7)	3.5 (0.7)	5.7 **
	b	ab	a		
I think the brightness of the space is adequate	3.4 (0.9)	3.5 (0.7)	3.3 (0.8)	3.4 (0.8)	0.9 (n.s)

* p<.05, ** p<.01, Post analysis resulted by Scheffe (α=. 05) test

The subjects were also asked to identify the right size and the floor plan types which they had experienced. They chose one each from four different sizes and six different types of floor plans. The results (Table 9, 10) show that there are no significant differences among age groups.

In the selection of dwelling size (right answer is no.2. 85㎡), 82.1% of those in their 30s were correct, while 74.0% of those over 40 was correct. In the selection of the floor plan type (the answer is type 4), 87.2% of those in their 30s got the correct answer, but only 70.9% of those in their 20s were correct. The results are interesting because those in their 30s recognized the scale and space of the virtual model house in the experiment better than the group in their 20s who are familiar with the VE.

Table 9. The selection of dwelling size by age group

N(%)

		20s	30s	over 40	Total	X2
1.	60㎡	3 (5.5)	1 (2.6)	1 (2.0)	5 (3.5)	4.923 (n.s) df=6
2.	85㎡	42 (76.4)	32 (82.1)	37 (74.0)	111 (77.1)	
3.	132㎡	8 (14.5)	5 (12.8)	12 (24.0)	25 (17.4)	
4.	165㎡	2 (3.6)	1 (2.6)	0 (0.0)	3 (2.1)	
Total		55 (100.0)	39 (100.0)	50 (100.0)	144 (100.0)	

Figure 3. The types of floor plan

Table 10. The selection of the floor plan type by age

N(%)

	20s	30s	over 40	Total	X2
Plan 1	4 (7.3)	1 (2.6)	3 (6.0)	8 (5.6)	8.192 (n.s) df=10
Plan 2	5 (9.1)	1 (2.6)	6 (12.0)	12 (8.3)	
Plan 3	4 (7.3)	1 (2.6)	1 (2.0)	6 (4.2)	
Plan 4	39 (70.9)	34 (87.2)	37 (74.0)	110 (76.4)	
Plan 5	1 (1.8)	0 (0.0)	0 (0.0)	1 (0.7)	
Plan 6	2 (3.6)	2 (5.1)	3 (6.0)	7 (4.9)	
Total	55 (100.0)	39 (100.0)	50 (100.0)	144 (100.0)	

4. CONCLUSION

The purpose of this study is to explore age-related differences with the assessment tools in the web-based 3D virtual model house and to propose the 3D model house criteria which everyone can use easily. The participants came from three age groups, ranging from their 20s to over 40. In the experiment for navigating and evaluating the web-based 3D model house, Presence, Usability and Space perception and cognition were measured and compared through one-way ANOVA and two-way ANOVA. The results and conclusions are as follows:

First, in the results of Presence scale assessment, the younger the participants were, that led to lower mean values showing in 'the negative effects' factor and the higher mean values in 'the positive effects' factor. Those in their 20s who often use the computer and are familiar with VE were interested in the experiment, whereas those over 40 felt dizzy and tired. However, those in their 20s needed a higher presence than other groups. There are no significant differences of interaction effects between age and online gaming experience on Presence.

Second, in the results of usability scale assessment, those in their 30s and over 40 groups evaluated that the 3D virtual model house is more efficient than an actual model house. Customers who have purchasing power think that a virtual model house could be a good method to provide information on an apartment. No significant differences showed in 'operability' factor among age groups because they were immersed in the VE. They had difficulty operating and finding buttons. The younger they were, the higher the 'expressivity' factor. Those in their 20s were more interested in changing the finishing materials and furniture as they wanted. There were also no significant differences of interaction effects between age and online gaming experience on Usability. Those who enjoy online games felt that the 3D virtual model house is more efficient.

Lastly, the younger the participant, the more positive they perceived the virtual space on Space perception and cognition scale. Such a result corresponded to that of 'the positive effects' factors in the Presence scale. There were no significant differences in the selection of dwelling size and the floor plan type.

The results of the current study demonstrate that there are differences among age groups with older groups having difficulty navigating and assessing in a VE. In conclusion, 20s had fun with a 3D virtual model house while 30s and 40s regarded it as an effective tool for purchase of home even if they experienced negative effects such as eyestrain and dizziness. The entertaining and guiding elements such as sounds and images will help the negative effects of the older users reconcile and make them have pleasant experience. More specific methods to reduce motion sickness in VE and establish an easy-to-use 3D model house need to be discussed in future research.

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