A COGNITIVE INVESTIGATION OF COMPUTERIZED WALK-THROUGH MODELS

by

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ABSTRACT

The growth of the World Wide Web has prompted many businesses to develop electronic commerce (e-commerce) as a domain where consumers can conveniently purchase their products (Chittaro& Ranon, 2002). Marketing and Human – Computer Interaction (HCI) research has focused on the ways interactivity can improve purchasing experience. One particular technique is through the use of computer models of products known as visual object representations (Ozok& Komlodi, 2009).

Research on visual product representations is focused on models of objects typically purchased in a store, such as clothing and electronics, which can usually be manipulated and rotated as desired (Ozok& Komlodi, 2009). There seems to be a gap in the literature regarding computer models for which consumers actually do not have an established mental models. Computerized walk-through models allow users to virtually navigate a space as well as to view a model of a living space from different orientations. An experiment was conducted on 100 participants to investigate computerized walk-through models and the role the type of model and workload plays in the amount of knowledge gained about the layout and consumer preference. Participants navigated a computerized walk-through model or a two dimensional picture set of a hotel room (low complexity) or apartment (high complexity) .Then they completed a series of surveys. Results indicate that two-dimensional models were best for learning the layout of a high complexity model and that three-dimensional models were better for learning the layout of a low complexity model. Results have implications for virtual model use in education and the military.

ACKNOWLEDGEMENTS

There are a number of people who have helped me immensely through this process and without which I would have had a much harder time completing my thesis. First, I would like to thank my faculty advisor, Dr. Valerie Sims, who has offered me so much support with this project. I also thank the other members of my committee, Dr. Mouloua and Dr.Stock, who brought much insight into my thesis. I owe many thanks to my graduate mentor, Matthew Marraffino, as well as Anne Sinatra, Heather Lum and Shane Halse, who helped me at various stages of my project.

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INTRODUCTION

Since 1994, the World Wide Web has experienced extensive growth, and this growth continues to double (Hoffman, Novak & Chatterjee, 1996). The Web has been regarded as a good tool for marketing and what has now become known as electronic commerce (e-commerce). More recently, marketing trends have projected a large shift towards purchasing behavior in online stores. Approximately 40 % of American households have been reported to purchase online, 28% have searched for free offers and coupons, and 22% use comparison shopping engines (Schmidt, 2006). To be more effective, businesses are constantly trying out new technologies for their websites.

Literature Review

Many products sold online (e.g. computers, watches and some types of clothing) may benefit from three-dimensional (3D) representation because 3D representation would allow a consumer to rotate or otherwise manipulate a product before purchase. This level of interactivity is not present in traditional two-dimensional representations currently used on e-commerce websites (Sanna & Montrucchio, 2002). Consumers have indicated a preference for e-commerce websites that have a high level of interactivity and object manipulation (Lightner, Yenisey, Ozok & Slavendy, 2002).

Visual product representations are commonly known as 3D. They do not project from the screen, but are 3D objects projected on a 2D background and can be rotated and manipulated (Sanna & Montrucchio). Past research on visual product representations has examined effects on presence, brand attitude, product knowledge, purchase intention, user satisfaction and preferences. Li, Daugherty, and Biocca (2001) used protocol analysis to examine consumer experiences while interacting with 3D products. They found that experiences were enjoyable, vivid and involving, despite the lack of physical affordances. Li, Daugherty, and Biocca (2002) also compared these 3D products to 2D static products and examined the differences between types of objects used, such as material (objects you might want to touch) or geometric (objects you might want to just examine with your eyes). They found that 3D advertising was more beneficial and resulted in more positive brand attitude for material objects than 2D advertising. They concluded that consumers interacting with 3D advertisements are more likely to experience a higher sense of presence, greater product knowledge and more favorable brand attitude than consumers interacting with static 2D advertisements. Consumers also had a limited haptic experience with visual product representations. Ozok and Komlodi (2009) compared visual product representations with low and high interaction to 2D static representations. They found that visual product representations of any interactive level received higher user preference and satisfaction ratings. They concluded that 3D high and low interaction representations were more meaningful to participants because the capacity for interaction allowed participants to be more aware when they examine product representations.

In addition to 3D virtual models of objects, virtual models of locations have been shown to possess a high degree of realism, presence, immediate control and representational fidelity (Dalgarno, Hedberg, & Harper, 2002). While research has shown that 3D virtual environments may not directly translate to real world settings (e.g. users tend to underestimate distances after navigating through virtual environments) (Richardson, Montello, & Hegarty, 1999), it has been speculated that virtual environments can enhance learning (Dalgarno, Hedberg, & Harper, 2002). Research indicates that virtual models may be beneficial in e- commerce. For example, Chittaro and Ranon (2002) created virtual stores and developed design guidelines for the display of products to improve interface usability. They compared individual displays of a single product presented in isolation, displays of several instances of the same product in a virtual store, and walking products that moved on their own to their corresponding display. They found that walking products were seen as more useful and fun because they aided in navigation towards the matching product the user was looking for in the virtual store. From these findings, they concluded that virtual stores have a great potential to enhance interactivity and product involvement in e-commerce. Yoon, Laffey, and Oh (2008) designed and tested the usability of an interactive 3D graphics system to model a furniture showroom compared to a 2D furniture store website. They found that the 3D system had an advantage in usability, which increased perceived usefulness and sense of presence and recommended a cognitive investigation of such systems. They concluded that 3D virtual environments encouraged more active product examination. The current study proposes a 3D virtual environment as a product in itself.

Complexity

Research on complexity tends to focus on diagrams and multimedia models of an object used for learning material in a course. Butcher (2003) examined the role of diagram complexity on effectiveness of the diagram by comparing learning outcomes of students learning about the human heart and circulatory system using text only, simple diagrams with text and text with detailed diagrams. Participants also were asked to draw mental models of the human heart and circulatory system before and after learning. Butcher found that students in the diagram conditions were more likely to improve their mental models compared to the students who learned from text alone, but that students were more likely to produce correct mental models in the simple diagram condition. It seems that too much diagram complexity does not aid learning when a simple diagram is efficient, but this seems to be an effect that may be specific to material type (Butcher, 2003).   Butcher concluded that diagrams need to guide learning processes effectively to be beneficial. More recently, Marsh, Griffin and Lowrie (2008) examined the effectiveness of multimedia modules with 3D diagrams and 2D diagrams of the complex process of embryonic development. They found that 3D multimedia modules aided in long-term retention of material compared to only receiving 2D lecture material. They concluded that multimedia modules aided understanding of concepts in medicine in a sense that students felt was not possible from lecture alone.

However, the literature fails to examine the effects of complexity of computerized virtual environments on performance. This is surprising in that technology such as immersive virtual environments and augmented reality has been examined for effects of complexity on performance even though those technologies are not as available as computerized virtual environments (Stanney, Kingdon, & Graeber, 2002; Shelton, 2003). Educational technology is becoming widely used in the form of 3D computer games. Hämäläinen and Oksanen (2012) examined the effects of teaching with 3D computer games for vocational learning in groups and found that the 3D game itself was helpful in problem solving and provided additional guidance to the teacher’s instruction. They concluded that while their study fills a gap in the literature on how teachers help students engage in knowledge construction processes within the gaming environment, aspects of the virtual environment, such as complexity, may need to be examined to gain a sense on how those aspects affect learning.

The present study attempts to expand upon the effects of complexity on computerized virtual environments by examining the effects on learning between two models which differ in complexity. Differences in complexity also may impact whether a consumer would like to purchase a certain product online in that they may find that a more complex product will need closer examination in person.

Computerized Walk-Through Models

Past research also fails to examine 3D models of other types of products such as hotels and apartments, which are more likely to benefit from 3D representation. For instance, consumers looking at purchasing a jacket may already have a mental model of what jackets look like. In this case only a 2D representation of the jacket is needed to see the design features of the jacket. It is not necessary to look at the jacket from all angles to fill in one's mental model about the jacket's style. 3D visual product representations of these objects would not be useful to gain additional information. However, if a consumer is in the market for a more spatially complex product like an apartment or hotel, additional benefits may exist for the information contained in 3D models. Furthermore, consumers are likely to have higher preference for objects such as jackets because they are more easily influenced by brand and other factors such as color in purchases to a greater extent than in purchases of products like apartments or hotels (Hoyer, 1984). It seems likely that consumers are more likely to gain useful information from computerized walk-through models.

The purpose of the present study is to examine 3D virtual environments of hotels (low complexity) and apartments (high complexity) to 2D models of hotels and apartments. These will be examined for differences on the knowledge gained, preference and mental workload.

Workload

Workload is best defined as the load experienced by users in the performance of a task (Rouse, Edwards, & Hammer, 1993; Annett 2002). Subjective measures of mental workload identify an individual’s perceptions of their workload while performing a task or interacting with an interface (Rouse, Edwards, & Hammer, 1993; Annett, 2002). Cognitive Load Theorists propose that subjective mental workload measures are a good way to measure an individual’s mental workload for situations where an individual has to learn from using an interface and can be more accurate than physiological measures (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). The current study involves individuals interacting in a virtual environment with a 3D digital interface. It is proposed that if the interface is difficult to use, it will increase workload ratings, and individuals will show a lack of preference for that particular model.

Hypotheses

H1: Computerized walk-through models with low complexity will receive higher consumer preference ratings than 2D pictures of these models. It is proposed that low complexity 3D models should be easier to understand because they are presented in an interface which provides spatial information.

H2: Participants will have more knowledge of a model when it is presented in walk-through model format regardless of complexity level. Research on virtual environments indicates that virtual environments are suitable for learning and representing models of locations (Dalgarno, Hedberg & Harper, 2002). Virtual environments used for education seem to indicate that virtual environments would beneficial for high and low complexity environments because 3D environments enable the user to navigate through the environment and be more involved with the process than a 2D model would (Dalgarno, Hedberg & Harper, 2002).

H3: Participants using computerized walk-through models will experience less workload. It is proposed that computerized walk-through models will be easier to use and to gain information from than 2D sets of pictures because computerized walk-through models provide more spatial information about the layout of the model by allowing the user to virtually move through the model. This will reduce the mental demand of having to mentally construct a map while navigating through the model as a user would have to while looking through 2D sets of pictures.

METHOD

Participants

One-hundred participants were recruited online through SONA systems. The mean age for participants was 19.27 (SD= 3.44). Of these participants, 23 were male and 77 were female. There were four conditions: 3D high complexity, 3D low complexity, 2D high complexity and 2D low complexity. There were 20 females and 5 males in the 3D high complexity condition. There were 20 females and 5 males in the 3D low complexity condition. There were 17 females and 8 males in the 2D high complexity condition. There were 20 females and 5 males in the 2D low complexity condition. Participants received credit for their Psychology courses for their participation.

Materials

The measures used in this study were a preference scale (see Appendix A), knowledge questions (see Appendix B) about the models, the NASA Task Load Index (Hart & Staveland,1988) and a demographics survey (see Appendix C).

NASA-TLX

In order to measure workload, the NASA-TLX was utilized (Hart & Staveland, 1988). The subjective measure uses 6 factors that contribute to overall workload including: Mental Demand, Temporal Demand, Physical Demand, Performance, Effort and Frustration. Each factor is measured on a scale from 1 to 100. Pair-wise comparisons of each of the factors were used to assign relative weights.

Preference

Preference was used to indicate the degree to which participants liked the model they were working with and how much they would learn from that model in comparison to any other representation method they are already familiar with. Preference was used because past research focused on gauging user experience in marketing tends to use preference ratings (Ozok & Komlodi, 2009). The preference measure for this study consisted of a seven point likert scale. The statement used for the scale was “I would rather use a set of (dimension condition) to learn about an (complexity condition)”. Participants were also asked to give reasons for their preference rating.

Knowledge

A three- question survey was used to assess information gained by the participants about the model. Participants answers reflected a specific direction as if they were standing in the entrance of room that they were to give directions from in each question (i.e. The kitchen is to the east of the bathroom or The kitchen is to the left of the bathroom). Participants’ responses were graded based on content. The maximum score participants could obtain was 3 and the minimum score was 0. The score was then divided by 3 and a percentage correct was obtained. For knowledge, the percentage of correct responses was examined.

Demographics

A survey of demographics to record age, race, sex and computer use was administered to participants at the end of the study.

2D and 3D Models

Two –dimensional and three- dimensional models of a hotel room and apartment were created. The computerized walk-through models were created using Sweet Home 3D, a free home modeling application. The 2D models are a series of screenshots of the 3D models. Refer to Appendix D figures 2 and 3 for screen shots of the 2D and 3D interfaces. To make 2D models as representative as 3D models, screen shots of each room were taken from 3 angles. These models have similar layouts. The 2D apartment model had 22 pictures and 2D hotel room model had 19 pictures. The high complexity model was the apartment model and the low complexity model was the hotel room model. The high complexity model had seven rooms and the low complexity model had six. Objects inside the models (e.g. kitchen furniture, living room furniture, beds and bathroom furniture) were identical in all models. The high complexity model was identical to the low complexity model except for one additional room the low complexity model did not have. The additional room was added to manipulate layout complexity. See Appendix D figures 4 through 7 for screen shots of the extra room for 2D and 3D conditions.

Procedure

Participants were given an informed consent form to read upon arrival to the experiment site. Participants were randomly assigned to one of four conditions: 2D low complexity, 2D high complexity, 3D low complexity, and 3D high complexity. Participants had an hour to complete the study but most participants completed the study in thirty minutes. Participants were first introduced to the interface using a practice model in order to become familiar with the controls for navigating. In the 2D interface, participants were told a set of 3 pictures in a row was one room from different angles. Participants in the 2D interface were also told that rooms were ordered so they could assume that rooms were to the left or the right of each other in the actual layout. Participants in 2D and 3D interfaces were told to use the keyboard arrows for navigation. All participants also were shown a slide of the layout of their model for thirty seconds in the main task so they could gain a general sense of the layout. Prior to the main task, participants were told that they would be answering questions about the model. They were told that these questions should be answered by giving a specific direction as if they were standing in a room they were give directions from as a point of reference. Participants in 2D conditions were given an example in the practice session before they practiced navigating. Afterward, each participant navigated a hotel room (low complexity) or apartment (high complexity) model in their assigned condition. After the navigation portion of the study was complete, participants filled out the NASA-TLX and then answered questions about the hotel/apartment they saw and rated their preference for the model. Finally, participants completed a demographics survey and were given a post participation statement.

RESULTS

Data were analyzed through Analysis of Variance. To examine preference, a 2(complexity: high/low) by 2 (dimension: 2D/3D) ANOVA was computed. There were no significant main effects or interactions for this variable. To examine workload, a 2 (complexity: high/low) by 2 (dimension: 2D/3D) ANOVA was computed using overall workload ratings. There were no significant main effects or interactions for this variable. To further examine workload, 2 (complexity: high/low) by 2 (dimension: 2D/3D) ANOVAs were computed for 5 of the 6 factors in the NASA-TLX. Physical demand was excluded from the analysis because there was no physical component involved in the task. There were no significant main effects or interactions for these factors.

To examine knowledge, a 2 (complexity: high/low) by 2 (dimension: 2D/3D) ANOVA was computed. Knowledge scores were the percentage of correct responses. There were no significant main effects for this variable. However, a significant interaction between complexity and dimension was found, F (1, 96) = 53.468 $p<.001$. To further examine the interaction between dimension and complexity, post-hocs were run. Six independent samples t-tests were run to determine where significant differences existed. A Bonferonni correction was used to account for the number of t-tests run, and as a result, $p < .008$ was used to determine significance. There were no significant differences between 3D high complexity (M =.1988, SD =.2148) and 2D low complexity conditions (M =.1336, SD = .2555), t (48) =.977, p = .334.There were no significant differences between 3D low complexity (M =.4932, SD = .2921) and 2D high complexity conditions (M = .6012, SD = .2733), t (48) = -1.350 p =.183. Individuals who viewed the 2D high complexity condition (*M*=.601, *SD*=.052) recalled significantly more than those who viewed 3D high complexity condition (*M*=.199, *SD*=.052), *t* (48) = -5.787, *p* < .001. Individuals who viewed the 3D low complexity condition (*M*=.4932, *SD*=.2921.) recalled significantly more than those who viewed the 2D low complexity condition (*M*=.1336, *SD*=.2555), *t* (48) = 4.633, *p* < .001. Individuals who viewed the 2D high complexity condition (*M*=.6012, *SD*=.2733.) recalled significantly more than those who viewed 2D low complexity condition (*M*=.1336, *SD*=.2555), *t* (48) =6.248, *p* < .001. See tables 1 and 2 in Appendix D for descriptive information of each model broken down by complexity level and dimension. Refer to figure 1 for a graph of the interaction between dimension and complexity.

Interaction Between knowledge and Complexity Level

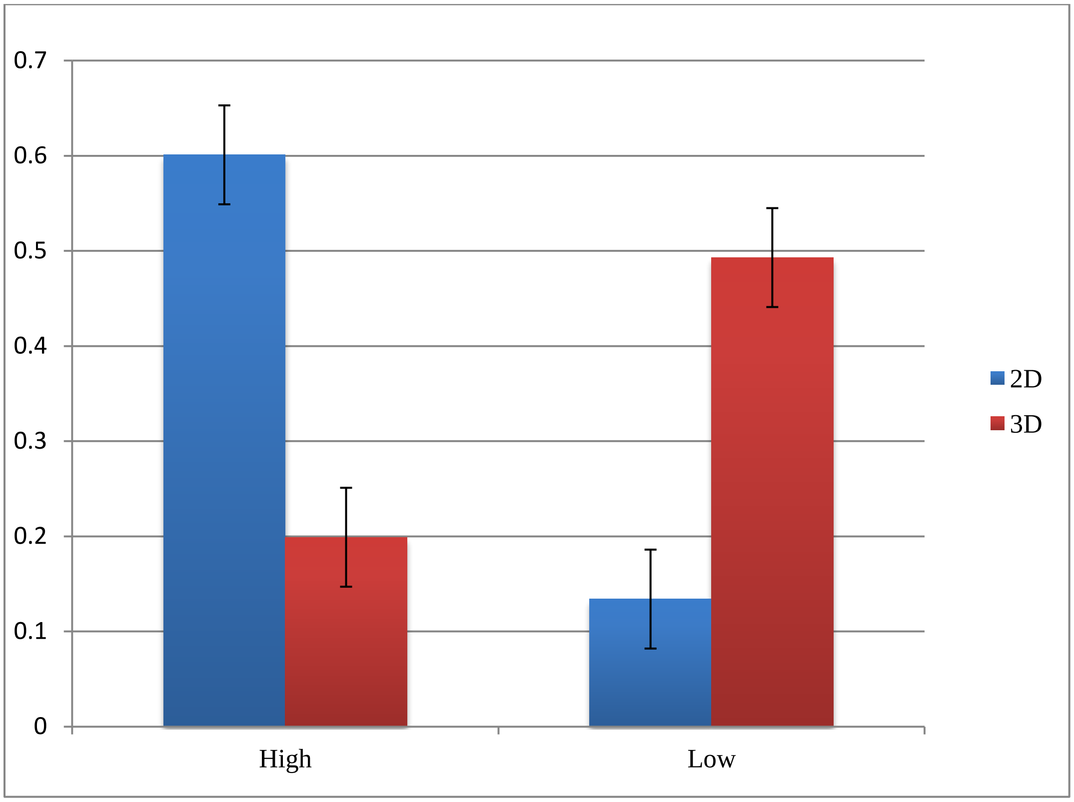

Figure 1.Participants' knowledge scores grouped by dimension and level of complexity

DISCUSSION

The current study examined the role of 2D and 3D models of hotels (low complexity) and apartments (high complexity) on workload, preference and knowledge gained about the model layout. In a low complexity condition participants recalled more correct information on the layout when using 3D computerized walk-through models than when using 2D models. In a high complexity condition, participants recalled more correct information when using 2D models than when using 3D computerized walk-through models.

Results show that there was not enough evidence for all three hypotheses. It was expected that there would be a difference in preference ratings and workload between the models, but the results show that this was not the case. This is interesting in that a difference in preference may not be immediately obvious from simple measures. Similarly, participants may not have been aware that they were experiencing workload, which indicates that subjective workload measures such as the NASA-TLX may have not been appropriate because the differences in workload were low. It also was expected that computerized walk-through models would be more helpful in learning about the layouts of the models regardless of the level of complexity but the data shows that much of the research that applies to 2D diagrams may apply to these 3D models. In the research on 2D diagram learning, it has been found that simpler diagrams are more beneficial than complex diagrams (Butcher, 2003). That is, as complexity of the model increases, a 2D representation of the model may be more helpful in learning the layout.

These findings indicate that users may be easily overloaded by complex virtual environments. Users may have experienced overload due to an accumulation of complexity from the model layout and navigation of the virtual environment. These results agree with past research on 2D diagrams. Butcher (2003) found that mental models of the heart did not improve when students learned from detailed diagrams because the level of detail was not essential to learning and made it more difficult for students to select relevant components. With high complexity computerized walk-through models, users may have encountered a similar issue in that they may have had difficulty navigating the complex layout and this difficulty might have made it harder to correctly establish spatial relationships. Another reason participants may have performed better with the 2D high complexity model compared to the 3D high complexity model is that people are more accustomed to learning from pictures. This familiarity with pictures may have improved performance despite the expectation that a high number of pictures may increase workload and diminish performance. Theoretically, this means that individuals are more accustomed to using pictures to learn for higher complexity situations when pictures are not accompanied by text.

This study contributes to the literature for virtual environments for marketing, and education. Although computerized walk-through models do not seem to be particularly useful for marketing based on preference rating, these models may be useful for educational purposes for simple environments. For education, it may be more useful to present educational materials that are complex in two-dimensional format and educational materials that are simple in three-dimensional format. This study has implications for military use in that computer virtual environments may not be beneficial due to the complex nature of military simulations. For military simulations, immersive virtual environments and augmented virtual environments may be more beneficial because of their capacity for close to real-life experience.

Limitations of the current study are the quality of model graphics and the number of questions used to test knowledge gained. The number of questions in the knowledge survey was limited to three out of five questions because the two questions excluded were not parallel in all conditions. It is possible that participants did not do well with the high complexity 3D model because of movement lags and lighting changes within the model that were not realistic. The time spent navigating 2D and 3D conditions was not recorded and should be recorded in future studies to measure how involved participants are in each condition. In addition, a three question survey of model knowledge may have not been sufficient to test knowledge gained for many participants. In spite of these limitations, this study is the first study known to the author that empirically examines the effects of 3D virtual environments for marketing on cognitive variables such as knowledge and workload.

Future studies should include a more extensive set of questions to examine knowledge of model layout and examine the effects among models that differ in types of complexity other than layout complexity. One possibility is examining models that differ in visual complexity (i.e. comparing a model full of furniture with one that has no furniture). Research on the effect of levels of visual complexity of scenes has been conducted for real-life scene images on the perception of visual complexity (Olivia, Mack, Shrestha, & Peeper, 2004). It would be interesting to see if the number of objects and the spatial layout of these objects make a difference in the knowledge that can be gained from virtual environments. Another possibility would be to examine the difference between walk-through models with more decoration. It is possible that consumers would react differently to a virtual environment with more decorations because these decorations could improve the experience by making it closer to the real-life experience of walking through an apartment or hotel room.

The results of this study indicate that users of low complexity virtual environments tend to recall more correct information regarding layout compared to users of low complexity 2D models and that users of high complexity 2D models recall more information than users of high complexity virtual environments. Given that this may be due to some overload in learning how to navigate and the virtual environment itself, future research should also examine if training diminishes this difference.

APPENDIX A: KNOWLEDGE QUESTIONS

Appendix A: Knowledge Questions

Hotel Rooms

1) Where is the first bathroom relative to the first bedroom?

2) Where is the second bathroom relative to the second bedroom?

3) Where is the kitchen relative to the living room in this hotel room?

Apartments

1) Where is the laundry room relative to the living room in this apartment?

2) Where is the kitchen relative to the living room?

3) Where is the first bedroom relative to the first bathroom?

APPENDIX B: PREFERENCE SCALES

Appendix B: Preference Scales

I would rather use a set of pictures to learn about an apartment.

1 2 3 4 5 6 7

Strongly Strongly

Disagree Agree

List some reasons to explain your preference.

I would rather use a set of pictures to learn about a hotel room.

1 2 3 4 5 6 7

Strongly Strongly

Disagree Agree

List some reasons to explain your preference.

I would rather use a 3D walk-through model to learn about a hotel room.

1 2 3 4 5 6 7

Strongly	Strongly
Disagree	Agree

List some reasons to explain your preference.

I would rather use a 3D walk through model to learn about an apartment.

1 2 3 4 5 6 7

Strongly	Strongly
Disagree	Agree

List some reasons to explain your preference.

APPENDIX C: DEMOGRAPHICS

Appendix C: Demographics

Age: ___ years old

Race:

White

Black

Asian/ Pacific Islander

Hispanic/ Latino- American

Native American

Other

Sex:

Male

Female

Number of hours you use the computer per week:

0-10

10-20

20- 40

40+

Number of hours you use the internet per week:

0-10

10-20

20-40

40+

How many times have you shopped online in the past month?

Not at all

At least once

2- 10 times

More than 10 times

How often have you had to decide or help decide which apartment you wanted to live in?

Never

Rarely

Occasionally

Often

Very Often

How often have you had to decide or help decide which hotel you wanted to stay at?

Never

Rarely

Occasionally

Often

Very Often

Have you ever used the internet to rent an apartment?

Yes

No

Have you ever used the internet to book a hotel room?

Yes

No

APPENDIX D: TABLES AND FIGURES

Appendix D: Tables and Figures

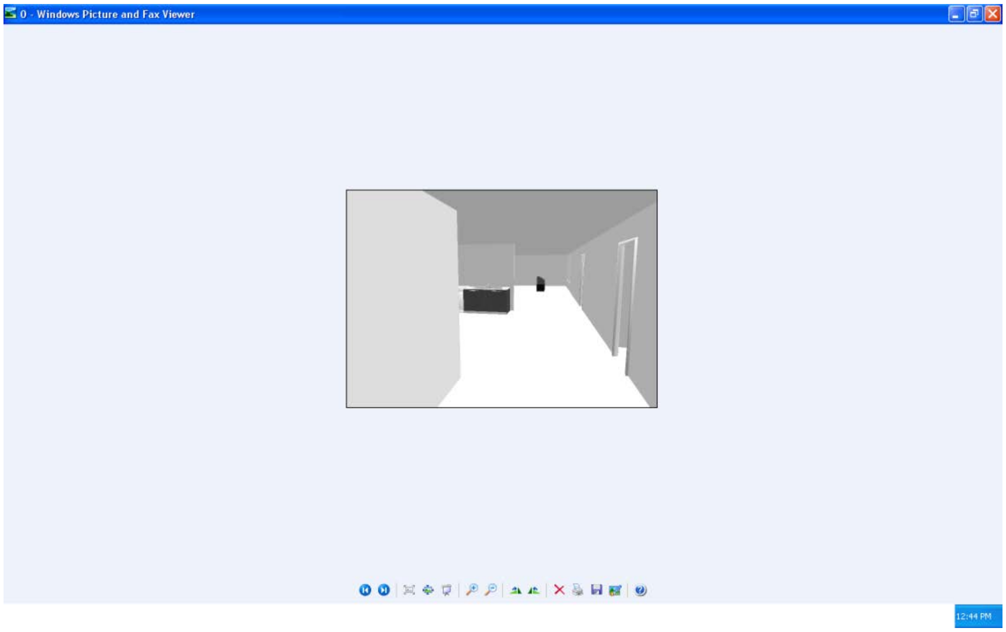

Figure 2. 2D model interface

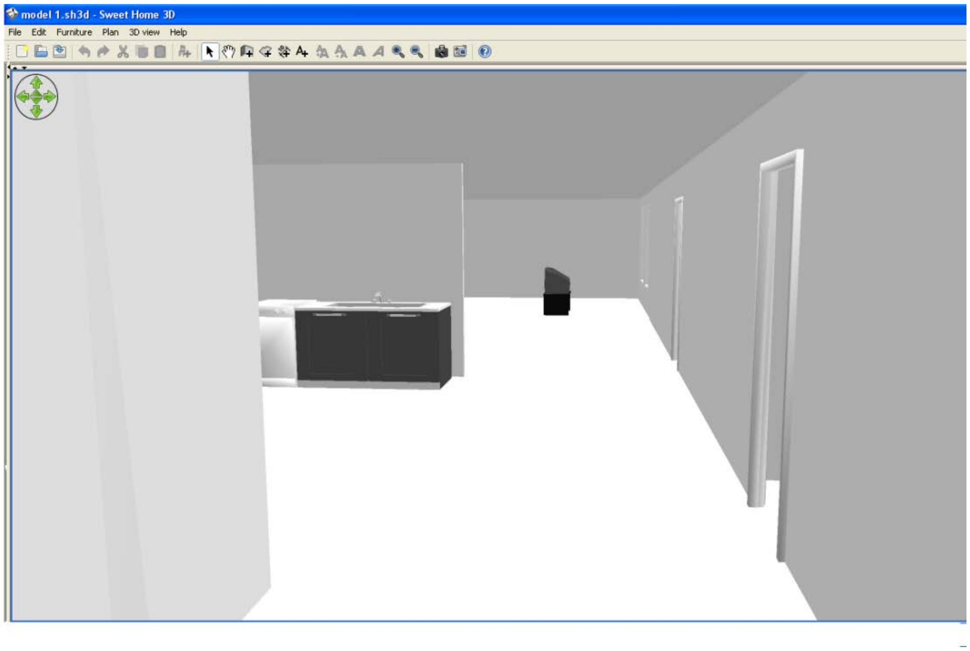

Figure 3. 3D model interface

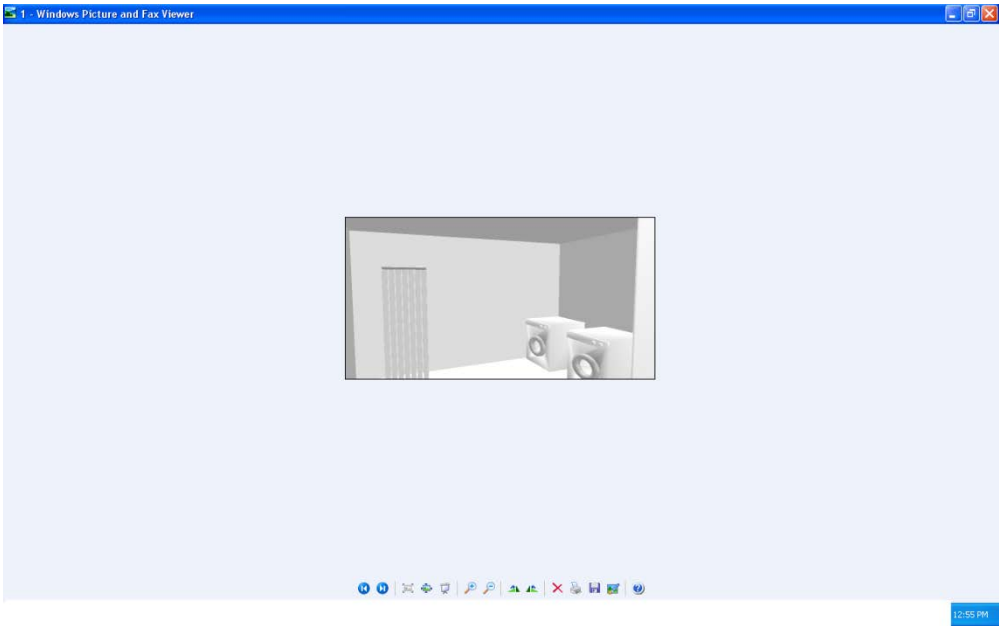

Figure 4. Additional room in high complexity 2D model first angle

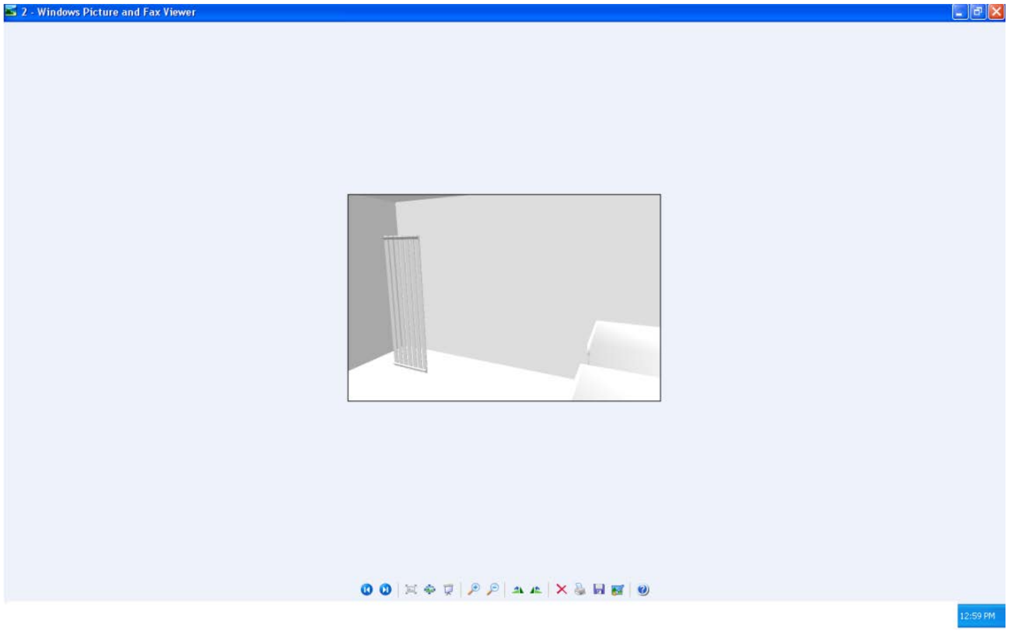

Figure 5. Additional room in high complexity 2D model second angle

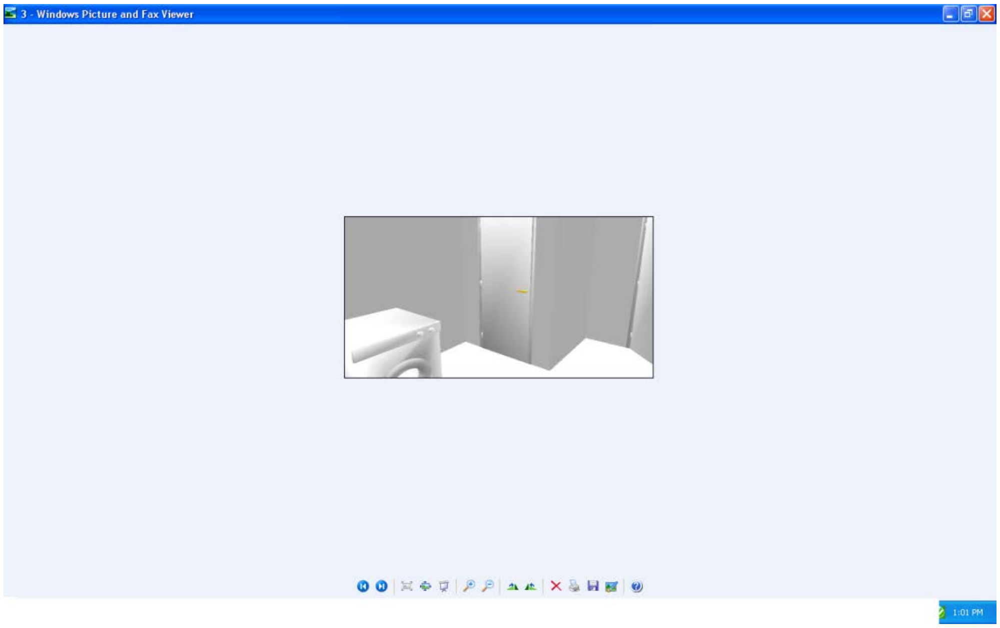

Figure 6. Additional room in high complexity 2D model third angle

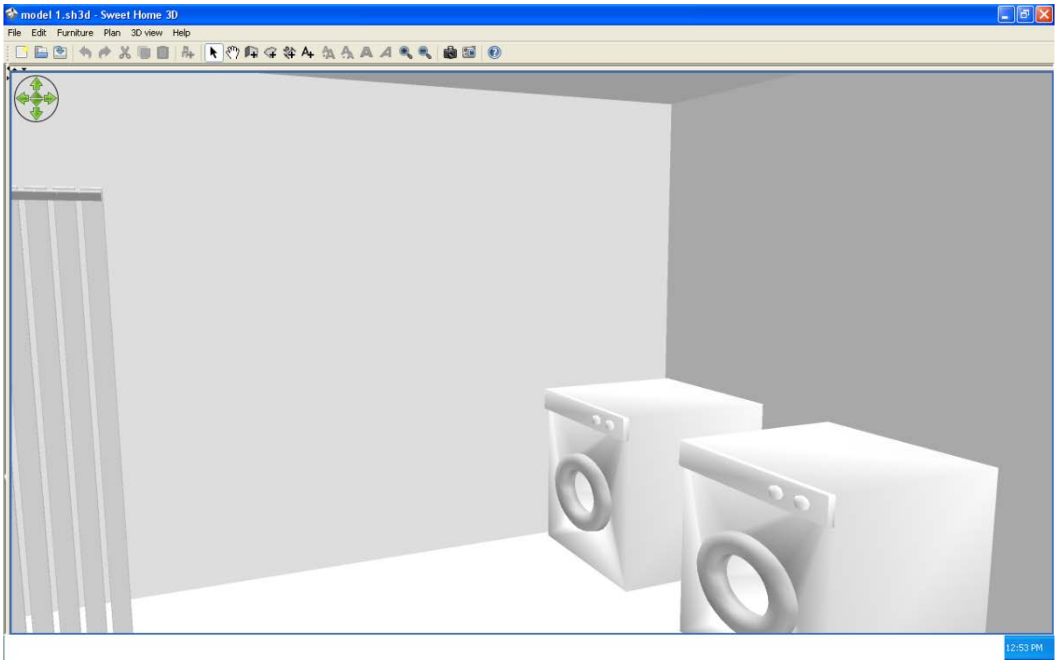

Figure 7. Additional room in high complexity 3D model

Table 1.Descriptives for 2DConditions

Complexity	Mean	SD
Low	0.134	0.052
High	0.601*	0.052

Note.
*p<.001

Table 2.Descriptives for 3D Conditions

Complexity	Mean	SD
Low	0.493*	0.052
High	0.199	0.052

Note.
*p<.001

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