Exploring the Impacts of the Virtual Reality Shopping on the Customers' Price Prediction

Yujing Ke*
Duke University

Yifeng Liu†
Duke University

ABSTRACT

There are many factors that could affect how much customers are willing to pay for the products in today's online retailing. In contrast to the conventional online retailer, virtual reality comes with many advantages, such as virtual browsing and better product presentation. Therefore, we propose that customers are more willing to accept higher priced items when product presentation is better. In order to validate our assumption, we designed a between-subjects experiment focusing on three shopping categories (toy model, grocery, and furniture). We built a web application and a VR application. Two groups of participants are tested in different environments. The results indicate that the VR group predicted prices are not significantly higher than the desktop group predicted prices in specific category. The contribution of this study could be beneficial to retailers who want to know if customers will expect the same items in the VR environment more expensive than in traditional online desktop shopping environment.

Keywords: E-commerce, Virtual Reality, Online Shopping

1 INTRODUCTION

According to Business Management Ideas[4], there are 6 factors affecting the price determination of product, including product cost, the utility and demand, the extent of competition in the market, government and legal regulations, marketing methods used, and pricing objectives. Among these factors, pricing objectives is an influential factor, and it generally involves objectives such as obtaining market share leadership, surviving in a competitive market, and attaining product quality leadership, and most commonly, profit maximization. We are interested in investigating if a different online product presentation medium could aid online retailers ace in the market under the assumption that a higher price can be accepted by consumers in this product presentation pattern.

In this day and age, we are witnessing that the VR technologies become increasingly crucial to our daily lives. Computer generated interactive experience in VR could provide users immersive and real-life alike experience. While today's electronic commerce industry is much developed already, there are still room for innovations in online shopping for retailers. According to Domia et al, consumer independent judgment considerably influenced consumers' intention to shop in a virtual world in a non-straightforward way. This kind of influence comes from positive effects on perceived control, enjoyment, and ease of use. It is our assumption that if consumers could gain positive enjoyment from a novel form of product presentation, the retailers are more likely to have a better understanding of consumers decision-making processes[3]. It would be more convenient for customers if they could visualize the product in an interactive and immersive way, with increased positive enjoyment. In addition, the decision to shop online depends to a large extent on the shopping experience the consumer is willing to accept, and at the same time online shopping still needs to further consolidate social interactivity[1]. Therefore, it is reasonable to introduce VR in electronic commerce because of its major strength, product visualization. In contrast, traditional online retailing has one major disadvantage: customers could not have an accurate perception of the product. Generally, they could only see a few 2D pictures/video streaming with some size details in the product description section [7]. Bad online shopping experience usually results from the poor product description, including unclear merchandise size labeling, the structure of the product, etc. A good application of VR in shopping could reshape the customers' shopping experience, allowing them to perceive and feel the product better. This notion is similar to what Chin and Swatman had proposed [1] in their paper. They suggested that because consumers can interact with products and have a novel shopping experience, virtual presence might solve the problem of how to fulfill the human needs that are nowadays satisfied by interpersonal shopping activities. Therefore, it is our assumption that customers will enjoy the ease of use and visualization effect from VR application, and they may have a different price expectation on VR shopping.

*e-mail: yujing.ke@duke.edu
†e-mail: yifeng.liu@duke.edu

2 RELATED WORK

The investigation and evaluation of customers' price prediction can be approached from different categories. Specifically, we address three categories, which are grocery, furniture, and toy model. While there are some established work based on the former two categories, at this moment few researchers had studied the last category.

2.1 Grocery

In this work, we investigated whether the virtual environment will have an impact on the grocery. The study *The virtual supermarket: An innovative research tool to study consumer food purchasing behavior* by Waterlander et al [10] investigates the food pricing and labelling strategies in the virtual reality environment. The authors developed a VR application to investigate the effects of retail price interventions, which they named it as Virtual Supermarket. This Virtual Supermarket is a three-dimensional software application in which participants can shop in a way of being in a real supermarket. Time spent on shopping, the number of products purchased, shopping budget, total expenditures and answers on configurable questionnaires are recorded and updated in a real-time manner. The purpose of the application was to assist other researchers to gain insight into food purchasing behavior. Sixty-six Dutch participants conducted the experiment, and Virtual Supermarket accurately collected and stored their behavioral data. Authors concluded that the majority of the customers found the application easy to understand. More importantly, participants believed that using this application is very similar to their daily grocery shopping experience. Therefore, based on this study, we believe that virtual environment could have a positive impact on the grocery shopping.

2.2 Furniture

In this work, we investigated whether the virtual environment will have an impact on the furniture. In *What Virtual Reality Can Offer to the Furniture Industry* Oh et al [8] mentions that using VR in

home furnishing industries and textile industries can help them to be more strategic in terms of consumer preferences, strong marketing, and successful supply chain management. The authors listed the useful features that make customization in furnishing more efficient. For example, real-time 3D interactive views enable customers to see the unlimited number of products from all angles, thus presenting the customers' accurate perception of size and layout. Moreover, the authors concluded that virtual prototyping can improve the furniture product development process because it can lower the lost, respond to the customers' taste quickly. Based on the previous study, we believe that virtual environment can have a vital impact on the furniture.

3 Environment

3.1 Web Environment

We built a web application with Node.js that allows the user to view each item. At each page, one single item will be shown along with the product name and detailed description. The description will help reduce the confusion and increase prediction accuracy, for example, how large is the shown pizza, or what material is the chair made of. There are arrow buttons that allow the user to switch to different product pictures, taken from the Unity environment in different angles. The products that participants view here will be the same set of products shown to VR group participants. At the bottom of the page, there will be a simple form asking the participants to enter the price they predicted for this item.

Figure 1 shows the interface of the web application that we built.

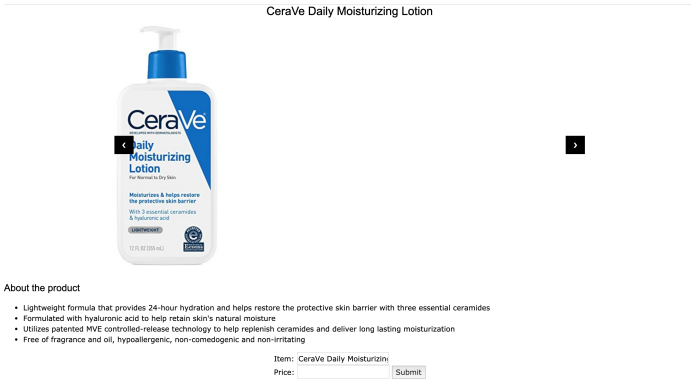

Figure 1: Web Environment

3.2 Virtual Environment

For the VR experiment, we used Unity to build a VR application that allows users to view and interact with each product. Each product is visualized by free 3D model from Unity3D asset store presenting its real-world counterpart. Furthermore, in order to increase immersion, we also implemented physics and set appropriate parameters for each product.

Figure 2 presents the interface of the VR application that we built.

3.2.1 Product Interaction

For the VR application, we utilized the grab interaction technique to manipulate products in the virtual environment. Grab technique is based on the virtual hand technique[9]. The user utilizes a motion controller with a button that triggers the interaction. Since we use HTC Vive for the experiment, the user holds the Vive controller and triggers the interaction with the grip button. Subsequently, the product gets highlighted (yellow) when the virtual hand intersects

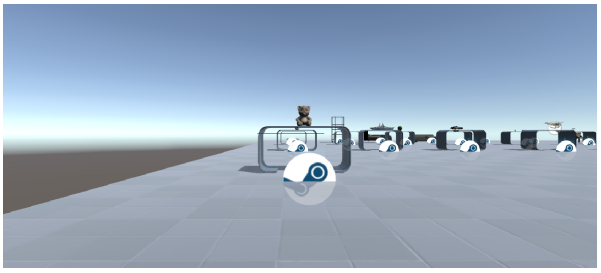

Figure 2: Virtual Environment

with it (see Figure 3). Then, the user is able to press the grip button to grab the highlighted product. The user can manipulate the product while the button is pressed (see Figure 4). When the user grabs the product, the virtual hand disappears. After the user finishes observing the product, he/she can release the product to drop the product, and the virtual hand appears again.

The major advantage of this grab technique is that it is intuitive for the user since he/she utilizes the same technique to grab items in real life. However, the major disadvantage of this grab technique is that he/she has to move to grab the product if it is out of reach.

Figure 3: Highlighted Product

Figure 4: Product Manipulation

3.2.2 Navigation

For the VR application, we utilized the teleport technique to move in the virtual environment. Since we used the HTC Vive, the user holds the Vive controller and triggers the teleport with the multi-function track-pad. The user can press the multi-function track-pad to see teleport points. Afterwards, the teleport point gets highlighted (green) when the virtual hand points to it (see Figure 5). Then, the user is able to teleport to the location when he/she release the track-pad. The major advantage of this teleport technique

is that the users are not required to move when they want to change location.

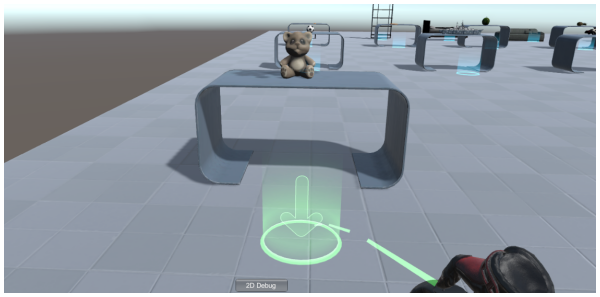

Figure 5: Teleport

4 EXPERIMENT

We conducted a between-subject experiment to investigate the impact of the virtual reality shopping on the customers' price prediction using previously introduced web application and VR application. Our main hypotheses were defined as:

H_0 VR environment will have an impact on how participants expect the price of the products.

H_1 The predicted price for products in furniture category in VR group will be significantly higher than that of web group.

H_2 The predicted price for products in grocery category in VR group will be significantly higher than that of web group.

H_3 The predicted price for products in toy model category in VR group will be significantly higher than that of web group.

4.1 Participants

For the experiment, 24 unpaid graduate students aged between 22 to 26 were recruited from the Duke University's campus. 13 participants (7 males, 6 females) conducted the VR experiment, while 11 participants (5 males, 6 females) conducted the Web experiment.

A background survey about participants' prior experience with online shopping and VR was conducted. Participants were asked about the overall online shopping frequency, disregarding the type of goods, rating on scales from 1 (less than 3 times per year) to 5 (almost every day, more than 5 orders per week on average); if they had prior experience with online furniture or grocery shopping; how comfortable are they with buying products online, on a scale from 1 (not at all comfortable) to 5 (extremely comfortable); if they had any prior virtual reality experience, and how they rated their overall VR expertise.

The result (see Figure 6) shows that the majority (83 %) of the participants had online furniture shopping experience before, and 58% of them tried online grocery shopping previously.

In terms of participants' prior VR experience, the result (see Figure 7) showed that 58 % of them have exposure to VR. But more than half of them admitted that their familiarity with VR technology was very limited.

We also learned that the participants are mostly moderate online shopping buyers, and are generally quite comfortable with online shopping from the background survey (see Figure 8).

4.2 Equipment

In this study, we chose HTV VIVE as the VR system. HTC VIVE is composed of a head-mounted display, two controllers, and two base station. The controllers were used for interactions, and the

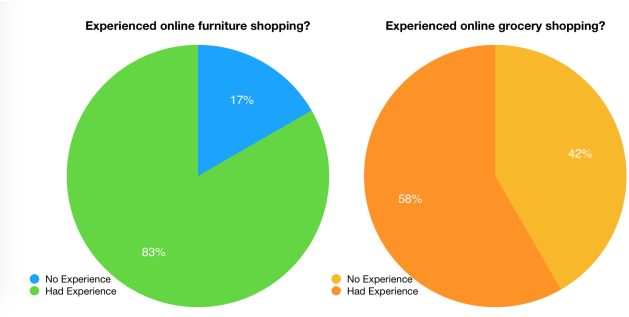

Figure 6: Participant Prior Online Furniture/Grocery Shopping Experience

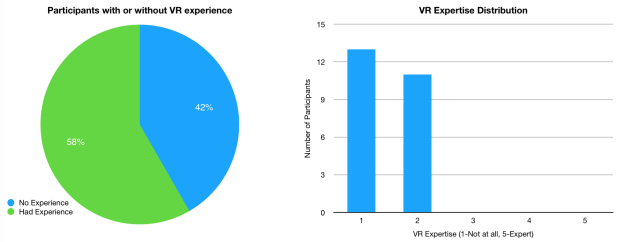

Figure 7: Participants' Prior Experience with VR

base station was installed about 6 feet above the ground, allowing a valid tracking area to be approximately 9 feet by 9 feet. When performing the experiment, the participants were asked to stay within the center part of the tracking area. The resolution of this head-mounted display is 1080 by 1200 for each eye, and 2160 by 1200 pixels combined. A MSI gaming PC with Windows 10 and Unity 3.7 was used with an Intel Core i7-8700K CPU @ 3.7GHz, 16.0 GB RAM, and GeForce graphic card. As for the desktop shopping control group, a MacBook Pro was used for showing participants the desktop application.

4.3 Design

The experiment used a between-subjects design with two independent variables, desktop application versus VR application, and product categories (grocery, furniture, and toy models). In total, 21 products were evenly distributed into these categories, with 7 products in each category. For toy models, we included soccer, battleship, police car, airplane, flower, toy monkey and maid. In the grocery category, we included apple, banana, kiwi, pineapple, watermelon, pizza, and bread. As for furniture, coffee table, bookcase, bed, sofa, dining table, armchair and leather chair are included. In order to guarantee equal conditions for each participant, the experiment is performed in the same place with the same hardware equipment. Predicted price from VR application group and desktop application group are recorded and used as dependent variables.

4.4 Procedures

First, we introduced the experiment to the participants. Participants must sign a consent form that addresses a detailed overview of the study. Then they were required to take a background survey which includes demographic questions (gender) and some general background questions about online shopping and VR, such as their prior experience with VR and their prior experience with online shopping (specifically in furniture and grocery). Background survey is designed to help us to collect characteristics of participants. More

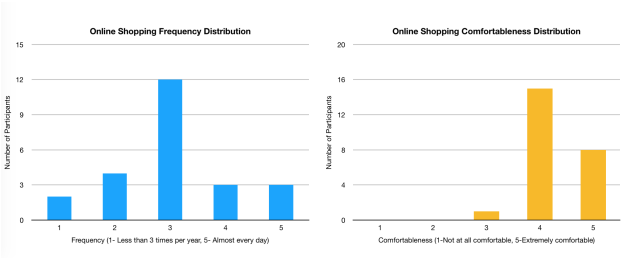

Figure 8: Participants' Online Shopping frequency and comfortableness

Figure 9: Participant with HTC VIVE

Figure 10: Some Products Included in Both VR and Desktop Application

importantly, it assists us to analyze what factors may influence participants' answers in the result.

Second, for the VR experiment, we helped participants to get started with a 2-minute VR equipment demo to become familiar with the headset and the controllers, followed by a 5-minute demo of the virtual environment. In other words, participants familiarized themselves with the grabbing and teleport technique in this phase. In the main part of the experiment, the participant needed to view all 21 products one by one, and predicted the price for each product.

For the Web experiment, participants started with a 2-minute web application demo to get familiar with the website. In the main part of the experiment, the participants viewed the same 21 products in VR experiment in the same order one by one, and predicted the price for each product as well.

Finally, the VR experiment group participants filled out 4 post questionnaires (simulator sickness questionnaire, presence questionnaire, satisfaction questionnaire, and usability questionnaire) at the end of the experiment. The average duration of the whole experiment per participant was about 35 minutes.

For the Web experiment, 2 post questionnaires (satisfaction questionnaire, and usability questionnaire) were filled out by participants at the end of the experiment. The average duration of the whole experiment per participant was about 20 minutes.

4.5 Results

4.5.1 Predicted Price

We have the predicted price from two groups, VR application group and web application group recorded. The average predicted price for each item in both groups is calculated. For products in the furniture category, $M_{CoffeeTableVR} = 31.54$, $M_{CoffeeTableweb} = 36.45$, $M_{BookCaseVR} = 116.15$, $M_{BookCaseweb} = 43.64$, $M_{BedVR} = 236.23$, $M_{Bedweb} = 229.55$, $M_{SofaVR} = 184.62$, $M_{Sofaweb} = 194.55$, $M_{DiningTableVR} = 75.77$, $M_{DiningTableweb} = 51.18$, $M_{ArmChairVR} = 72.31$, $M_{ArmChairweb} = 45.00$, $M_{LeatherChairVR} = 70.38$, $M_{LeatherChairweb} = 108.82$. For products in the grocery category, the averaged answers were $M_{AppleVR} = 0.87$, $M_{Appleweb} = 1.05$, $M_{BananaVR} = 0.57$, $M_{Bananaweb} = 0.58$, $M_{KiwiVR} = 1.13$, $M_{Kiwiweb} = 1.04$, $M_{PineappleVR} = 3.85$, $M_{Pineappleweb} = 4.95$, $M_{WatermelonVR} = 4.92$, $M_{Watermelonweb} = 7.55$, $M_{PizzaVR} = 7.22$, $M_{Pizzaweb} = 9.41$, $M_{BreadVR} = 1.69$, $M_{Breadweb} = 1.91$. For the items belong to toy models group, the averaged answer from both groups are $M_{SoccerVR} = 16.31$, $M_{Soccerweb} = 18.73$, $M_{BattleshipVR} = 116.77$, $M_{Battleshipweb} = 29.18$, $M_{CopCarVR} = 47.69$, $M_{CopCarweb} = 17.45$, $M_{AirplaneVR} = 67.31$, $M_{Airplaneweb} = 20.18$, $M_{FlowerVR} = 13.69$, $M_{Flowerweb} = 8.64$, $M_{MonkeyVR} = 16.15$, $M_{Monkeyweb} = 15.55$, $M_{MaidVR} = 61.54$, $M_{Maidweb} = 34.91$.

The reason of calculating the averages is that we wanted to make sure that if there is a significant difference, it is because the predicted price in VR group is higher when we reject the null hypothesis from ANOVA test for certain products. Figure 11 presents the visualized result of the group mean for each product.

We also calculated the standard deviation for the predicted price for each product, and Figure 12 presents the visualized result. From the graph, we can see that it was obvious that items in grocery cat-

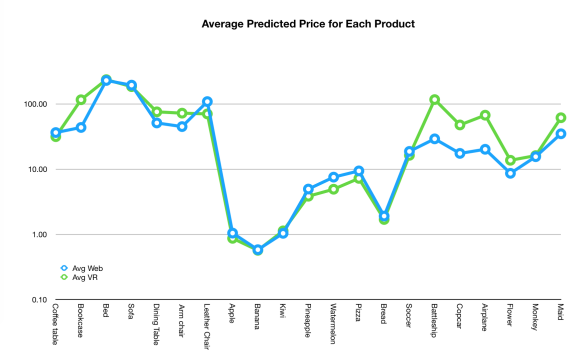

Figure 11: Average Predicted Price from VR and Web Group

egory have lower standard deviation, while the items in furniture category have higher standard deviation.

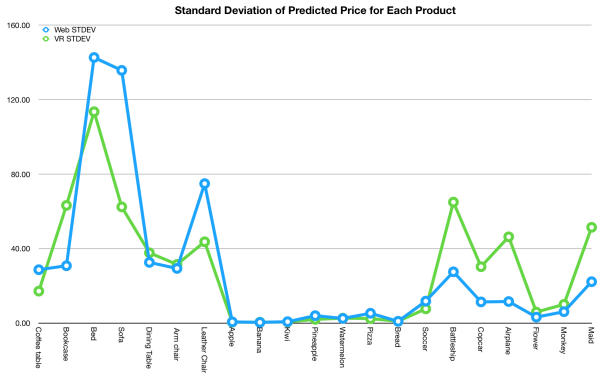

Figure 12: Standard Deviation of Predicted Price from VR and Web Group

In addition to comparing the mean predicted price for each item in both groups, we imported the data and conducted one way ANOVA test to compare if there is a difference in the predicted price for each product.

The null hypothesis is that $\mu_{vr} = \mu_{web}$, where μ_{vr} is the population mean for a product in VR group, while μ_{web} is the population mean for the same item in the web group. We conducted in a total of 21 one way ANOVA test, with 13 data points in VR group and 11 data points in web group for each item, and created a visualized p-value results in each category.

In the furniture category, the p-value of armchair and bookcase is lower than 0.05 ($p - value_{armchair} = 0.0399$, $p - value_{bookcase} = 0.0022$), while the p-value of other furniture products is beyond 0.05. Figure 13 presents the detailed p-value of ANOVA test result for furniture products.

In the grocery category, the p-value of watermelon and bookcase is lower than 0.05 ($p - value_{watermelon} = 0.0194$), while the p-value of other grocery products is beyond 0.05. Figure 14 presents the detailed p-value of ANOVA test result for furniture products.

In the toy model category, the p-value of battleship, cop car, airplane, and flower is lower than 0.05 ($p - value_{battleship} = 0.0004$, $p - value_{copcar} = 0.0049$, $p - value_{airplane} = 0.0034$, $p - value_{flower} = 0.0183$), while the p-value of other toy model products is beyond 0.05. Figure 15 presents the detailed p-value of ANOVA test result for toy model products.

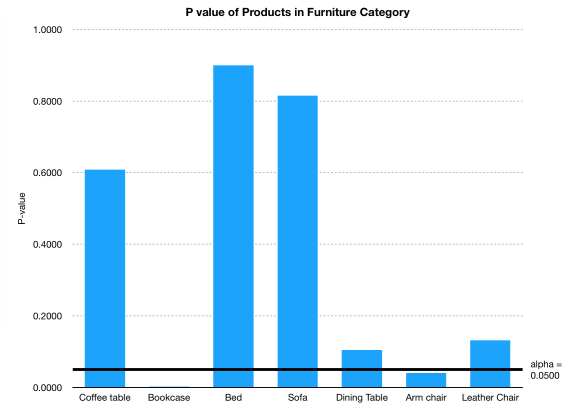

Figure 13: P-value of ANOVA Test Result for Furniture Products

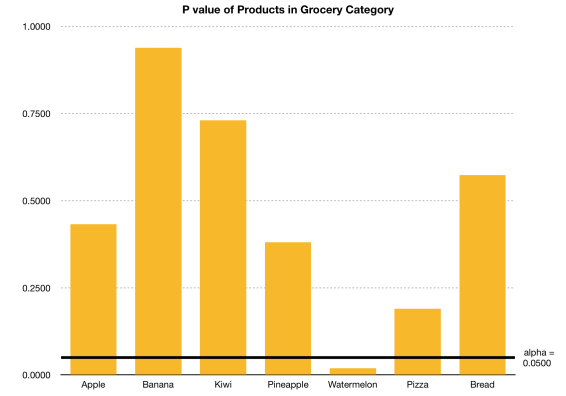

Figure 14: P-value of ANOVA Test Result for Grocery Products

4.5.2 VR Application Motion Sickness

Motion sickness was measured by the simulator sickness questionnaire. Simulator sickness questionnaire includes 17 questions and each question has 4 scales(1 - none, 2 - slight, 3 - moderate, and 4 - severe). In summary, no question's mean score is beyond 2. General discomfort achieved the highest score (M = 1.5385, SD = 0.5189), and Stomach awareness achieved the lowest (M = 1.0, SD = 0). Figure 16 presents the detailed result of simulator sickness questionnaire for better visualization.

4.5.3 VR Application Presence

In the presence questionnaire, we asked the VR application group participants three questions to know the evaluation of the application in terms of creating an immersive environment. First, the participants were asked to rate their sense of being in the virtual environment on a scale of 1 to 5, where 5 represents the normal experience of being in a place. Secondly, they were asked to what extent during the experience when the virtual environment was the reality for them. Lastly, we asked during the time of the experience, if they often think they were actually in the virtual environment. We did statistics on the questionnaire and presented a visualized result as below. In summary, the VR application presence questionnaire showed that the average answer for feeling actually in the virtual environment is 3.692 out of 5. Similarly, they averagely rated 3.769 out of 5 stating that they had a sense of being in a virtual environment. For the last question, the score was 2.615 out of 5. The standard deviation for the three questions is quite low, suggesting that

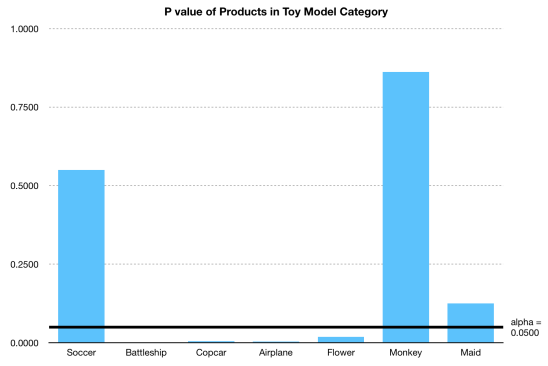

Figure 15: P-value of ANOVA Test Result for Toy Model Products

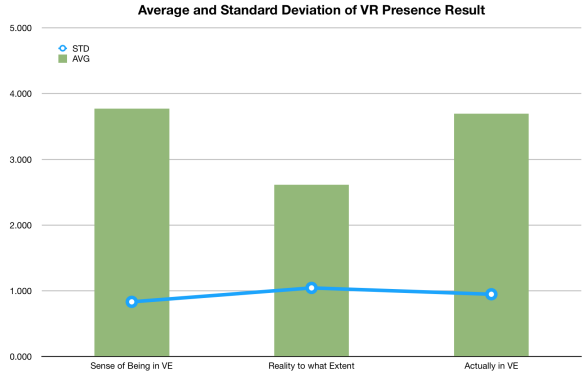

Figure 17: VR Presence Questionnaire Results

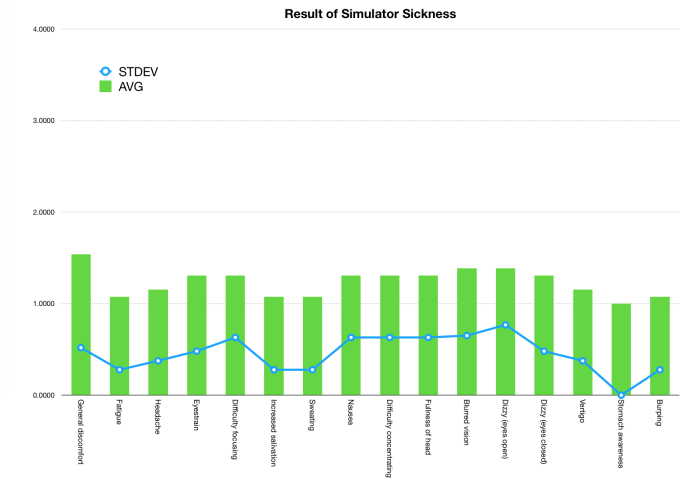

Figure 16: Simulator Sickness Questionnaire Results

the participants did not have distinctively different feelings. Figure 17 presents the visualized result.

4.5.4 Usability

In the usability survey, we asked participants in the VR group and Web group 10 questions about if the system is user-friendly. On a scale from 1 to 5, 1 stands for strongly disagree and 5 stands for strongly agree, participants were asked to rate how did they feel about using the input system. VR group rated they would like to use the input system frequently (M = 3.769, SD = 0.927), while web group rated the question (M = 2.091, SD = 0.944). When asked if the input system was too complex, VR group responded as (M = 1.923, SD = 0.954), and web group's average is (M = 1.455, and SD = 0.522). We also asked if they think the input system was easy to use, VR group response was (M = 4.154, SD = 0.801), while web group response was (M = 4.182, SD = 0.751). Few of them believe they needed support, as VR group responded the question with (M = 2.462, SD = 1.450), and web group responded with (M = 1.182, SD = 0.405). We also asked if they feel they needed support, answer from VR group is (M = 2.462, SD = 1.450), and answer from web group is (M = 1.182, SD = 0.405). When asked about if they think the input system was well integrated, VR group responded with (M = 4.385, SD = 0.870) and web group answered with (M = 4.364, SD = 0.674). VR group tend to think there is not too much inconsistency, with answer (M = 1.462, SD = 0.519), and web group (M = 1.273, and SD = 0.647). When we asked if they feel they could learn how to use the input system very quickly, VR group said (M = 4.769, SD = 0.439) and web group answered (M = 4.727, SD = 0.467). Most of them felt that the system was not very cumbersome to use, with VR group (M = 1.615, SD = 0.650) and web group (M = 1.182, SD = 0.405). In terms of if they think they felt very confident when using their input system, VR group response was (M = 4.385, SD = 0.650) and web group response was (M = 3.636, SD = 0.924). Few of them thought they needed to learn before they could get the input system going, with VR responded (M = 1.692, SD = 0.855), and web group responded (M = 1, SD = 0). Figure 18 represents the organized the information and the visualized result.

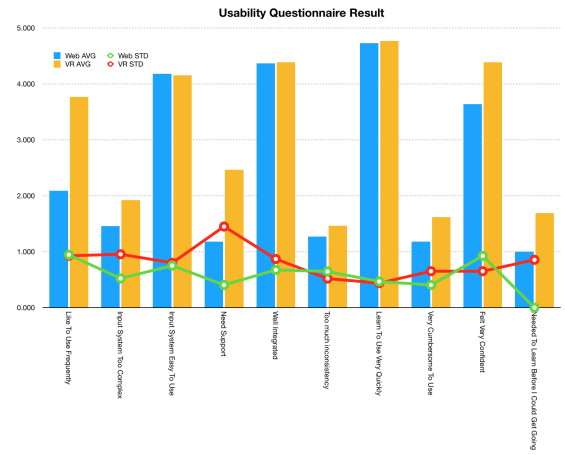

Figure 18: VR Usability Questionnaire Results

4.5.5 Satisfaction

Satisfaction was measured by the satisfaction questionnaire. Satisfaction questionnaire includes 4 questions, and each question has a scale from 1 to 5. 1 stands for "very bad", while 5 stands for "very good". For the VR group, overall experience achieved score (M = 4.385, SD = 0.506). Convenience achieved score (M = 4.077, SD = 0.862). Enjoyment achieved score (M = 4.231, SD = 0.599). Quality assurance achieved score (M = 4.308, SD = 0.63). For the Web group, overall experience achieved score (M = 3.0, SD = 0.775). Convenience achieved score (M = 3.0, SD = 1.095). Enjoyment achieved score (M = 2.364, SD = 1.12). Quality assurance achieved score (M = 2.364, SD = 0.674). Figure 19 presents the detailed result of the satisfaction questionnaire for better visualization.

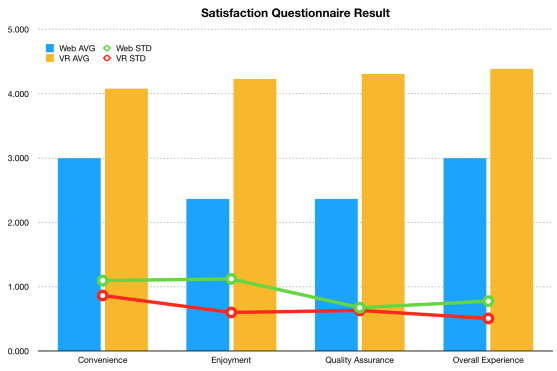

Figure 19: Satisfaction Questionnaire Results

5 DISCUSSION

The study investigated how participants predict prices for 21 products in VR application and web application. In the next few sub sections, we will discuss the results with respect to predicted price in both group, user experience, and limitations.

5.1 Predicted Price

From the data collected and the visualized mean value of predicted price for each product in both group, we can tell that our H_0 for this study, is valid. We put forward H_0 suggesting that VR should have an impact on how participants predict the price, and by the result of average predicted price from VR and web group, we do not reject H_0.

As we can see from the three p-value results graph, it is very difficult to draw a straightforward conclusion for H_1, H_2, and H_3. Some items have a high p-value, while others fall below the $\alpha = 0.05$ line. If the p-value of one product is lower than the 0.05, we can reject the null hypothesis and draw the conclusion that there is a statistically significant difference between the population mean of VR result and that of web result.

5.1.1 Furniture

For the products in the furniture category, only book case and arm chair have a p value from ANOVA test lower than 0.05. If we look further into the average predicted price for book case and arm chair, we can confirm that not only the average of predicted price for book case and arm chair in VR is higher than that in web group, but also this difference is statistically significant.

However, if we look into the bigger picture, other items were not proven significantly higher priced in VR environment. Indeed, 3 out of 7 items has higher predicted price from VR group, it is not enough to prove that we are confident about the validness of $H1$.

5.1.2 Grocery

For the products in the grocery category, only watermelon have a p value from ANOVA test lower than alpha value of 0.05. Nevertheless, this difference is opposite to our expectation: watermelon was actually significantly higher predicted in web group because $M_{vr} = 4.92, M_{web} = 7.55$.

Therefore, for all the products in the grocery section, we have to reject $H2$. The possible reason might be, participants are more familiar with the grocery items in their daily life. Therefore the prediction will be more accurate and closer to real price. As the standard deviation plot shows, there is very little variation in the grocery category. This fact further validated the assumption that the participants tend to have similar answer.

5.1.3 Toy Models

For the products in the the toy models category, 4 out of 7 products meet the requirement of p value lower than 0.05. In addition, almost all products in this category have a higher average predicted price in VR group except for soccer. We conclude that we were able to reject the null hypothesis of ANOVA test for battleship, cop car, airplane, and flower. And although we are not able to reject the null hypothesis that $\mu_{vr} = \mu_{web}$ for monkey and maid, the averaged predict price in VR for these two items are still higher than that in web group.

To sum up, the experiment showed that there was an only significant difference between the predicted price from VR group and web group for some products, including bookcase and armchair from furniture category, watermelon from grocery category, and battleship, cop car, airplane, flower from toy model category. Except for watermelon, all the items listed above we were able to reject the null hypothesis of ANOVA Test that there is no significant difference between the predicted price from VR and web group.

Only certain products correspond to our expectation: bookcase and armchair in the furniture category, battleship, cop car, and airplane in the toy model category. The possible reason is that grocery is more commonly known to most participants. Therefore, when they are predicting the price, the result is more likely to be consistent with the real price in our daily life. However, for other categories, especially toy models, it is obvious that almost all the average predicted price is higher. The possible reason is that the participant could have a clearer view and a better understanding of the toy models type products in the VR environment.

In conclusion, we found out that only certain products accord with our hypothesis, that the predicted price in VR environment will be significantly higher than that in the web environment. In the furniture category, the p values of bookcase and armchair are lower than the $\alpha = 0.05$ value, and it is evident that the predicted price in VR is higher in the average graph. Similarly, in the toy models category, battleship, cop car, and airplane have a p-value lower than 0.05 and their average value is lower in web application. However, for the grocery category, the only watermelon has a p-value lower than 0.05. But when we look closer into the data, we discovered that this difference is not what we expected: the average for watermelon in the VR group is lower than that in the web group.

5.2 User Experience

The crucial features of VR are interactivity, immersion, and presence[5]. For the VR group, we evaluate the user experience through the simulator sickness, usability, satisfaction, and presence questionnaire. For the Web group, user experience is measured by the usability, and satisfaction questionnaire. The main purpose of the usability questionnaire is to evaluate how easy the application is to use for the participants. From figure 18 we could see that both VR group and Web group highly agree that both the VR and Web application are simple to use, well integrated, and easy to learn quickly. Therefore, we believe that both the VR application and Web application are able to reach our experiment goals. The main goal of the satisfaction questionnaire is to evaluate how satisfied the participants are with different aspects of the application. Figure 19 shows that the VR group achieved an excellent rating for convenience, enjoyment, quality assurance, and overall experience. However, since the implementation of the web application was only focused on functionality, the Web group achieved a relatively low rating for enjoyment and quality assurance. Moreover, from figure 16, the VR group achieved surprisingly low ratings on all motion sickness questions. The standard deviation for the questions is quite low as well, suggesting that the participants did not have distinctively different feelings. Lastly, because most of the participants do not have any prior interactive VR experiment, the VR group achieved high ratings on presence questions.

5.3 Limitations

There are 3 main limitations of the experiment. To begin with, free 3D models from the Unity3D asset store are the first limitation. Even though the Unity3D asset store has many high-quality 3D models, free 3D models are usually limited in some categories. For example, the Unity3D asset store does not have free high-quality 3D models in fashion. Moreover, free 3D models typically have poor quality, which means that the texture and shape are not good enough to be indistinguishable. Therefore, if we had used the high-quantity 3D models, results concluded from the experiment would have been more credible.

Next, poor Web application UI is the second limitation. Since the implementation is only focused on functionality, the design of the website is not addressed. However, layout, color scheme, and all other design details determine how well the participant perceive the products. Therefore, the bad design might cause for skewed data results for the experiment.

Lastly, participants in the experiment are the third limitation. Based on the background survey, even though 58% of the participants claimed that they have prior VR experiment, the average of VR expertise is rather low. More importantly, most of the participants only had limited real VR experience, such as 360 Videos. For the majority of the participants in the VR experiment, the VR experiment is their first interactive VR experience.

6 Conclusion and Outlook

Current online shopping stores generally only incorporate 2D images and text description as the product presentation medium. And while most participants in our study agreed that they are very satisfied with the online shopping service today, we thought there should still be room for online retailers to improve their user experience, and hopefully, attracting more customers and win their heart. According to Childers et al[2], attitude towards the new interactive media will be more positive as the usefulness of the media increases. We wonder if an immersive, interactive, and novel product presentation method in the virtual environment should be adopted by online retailers.

In order to find an answer to this question, we designed a between-subjects experiment for products in three categories. Grab and teleport techniques are applied in our VR application, while 2D images and short description are included in our web application. We recruited 24 participants to test our hypotheses, and our result showed that we accept H0 but are not confident to accept H1, H2, and H3. In addition, according to the user questionnaire, we received positive feedback in terms of usability, especially in VR application.

At this point, we can not be fully confident that VR application will have a significant impact on affecting consumer's price prediction with every product from different categories. However, we believe for some products with certain traits, it could be more beneficial to online retailers if they consider developing tools and VR shop for these products. For example, customers are more likely to be interested in grabbing and interacting with toy models than with grocery items in the virtual environment. This notion is supported by the finding in our study: toy models items in VR had a significantly higher predicted price than toy models items in web 2D environment, but the same thing did not happen to grocery products.

In future work, we are interested in integrating more products, adopting 3D models with better quality, and building a more user-friendly UI.

To sum up, we believe that VR has the potential to reform the future online shopping industry as it becomes increasingly widespread. More attention should be drawn to this field as the current research has not been widely supported to the beneficiaries, the online retailers.

7 Acknowledgements

The authors would like to thank Professor Regis Kopper, Zekun Cao, and Jeronimo Grandi for their help and advice, and the participants who gave their time for our experiment.

References

[1] Carolyn Chin, Paula Swatman, Paula Swatman. The Virtual Shopping Experience: Using Virtual Presence To Motivate Online Shopping. Australasian Journal of Information Systems, [S.l.], v. 13, n. 1, nov. 2005. ISSN 1449-8618.

[2] Terry L. Childersa, Christopher L. Carrb, Joann Peckc, Stephen Carson. Hedonic and Utilitarian Motivations for Online Retail Shopping Behavior. Journal of Retailing 77 (2001) 511535. Received 31 August 2000, accepted 19 July 2001.

[3] Tanya Domina, Seung-Eun Lee, Maureen MacGillivray. Understanding Factors Affecting Consumer Intention To Shop In A Virtual World. Journal of Retailing and Consumer Services 19 (2012) 613620. Available online 8 September 2012.

[4] Kalpana R. Price Determination: 6 Factors Affecting Price Determination of Product. Business Management Ideas.

[5] Kun Chang Lee and Namho Chung. 2008. Empirical analysis of consumer reaction to the virtual reality shopping mall. Computers in Human Behavior 24, 1 (2008), 88 104.

[6] Marco Speicher, Philip Hell, Florian Daiber, Adalberto Simeone, Antonio Krger. A Virtual Reality Shopping Experience using the Apartment Metaphor. May 29 June 1, 2018.

[7] Marco Speicher, Sebastian Cucerca, Antonio Krger. 2017. VR Shop: A Mobile Interactive Virtual Reality Shopping Environment Combining the Benefits of On and Offline Shopping. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 1, 3, Article 102 (Sept. 2017), 31 pages.

[8] Hyunjoo Oh, So-Yeon Yoon, Jana Hawley. What Virtual Reality Can Offer to the Furniture Industry. Journal of Textile and Apparel, Technology and Management. Vol 4, Issue 1. 2004.

[9] Ivan Poupyrev, T Ichikawa, S Weghorst, and M Billinghurst. 1998. Egocentric object manipulation in virtual environments: empirical evaluation of interaction techniques. In Computer graphics forum, Vol. 17. Wiley Online Library, 4152.

[10] Wilma E Waterlander, Michael Scarpa, Daisy Lentz and Ingrid HM Steenhuis. The Virtual Supermarket: An Innovative Research Tool To Study Consumer Food Purchasing Behaviour. Waterlander et al. BMC Public Health 2011, 11:589.