Evaluating the Effects of Visual Fidelity and Magnified View on User Experience in Virtual Reality Games

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Abstract

Virtual reality has been becoming more and more affordable in recent years. This led to more content, being specifically developed for this medium. Training with virtual reality is one of the promising areas in terms of the gained benefits. Virtual reality properties may affect usability and user performance, hence are important to understand well. This study aims at exploring effects of visual fidelity (high and low) and view zoom (normal and magnified) on user experience and task performance in virtual reality. Effects of visual fidelity have previously been explored but yielded different results based on the task design. Effects of view zoom on task performance hasn't been explored yet, to our knowledge. A virtual reality inspection task was developed, and a user study was performed with 15 participants. Results indicated that low visual fidelity led to better task performance whereas view zoom did not have an effect on user performance. High visual fidelity increased level of presence and motion sickness whereas view zoom didn't have an effect on these user experience aspects.

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Keywords: virtual reality, visual fidelity, view zoom, video games, serious games, training, usability, user experience.

1 Introduction

Virtual reality (VR) has been becoming more and more prevalent in recent years, with various application areas. VR aims at immersing users so that they feel like they are in a virtual environment other than their physical surroundings. Virtual reality is defined as "a model of reality with which a human can interact, getting information from the model by ordinary human senses such as sight, sound, and touch and/or controlling the model using ordinary human actions such as position" [HS14]. VR is distinguished from other computer technologies mainly by the high level of embodied interaction and immersion it offers.

With the new generation head mounted displays and more content, such as games and training applications, VR now seems more promising than ever for becoming mainstream. Training with VR has been a popular topic since the benefits it promises to offer are invaluable. VR training offers several advantages over real world training such as safety, easy customization, digital gamification, real time alteration of scenarios and environmental elements based on user performance, automated data collection, reduced transportation costs to various training centers, and no severe real-life consequences of mistakes. Several early studies agree on the benefits that virtual reality training provides in various diverse areas, such as medical training [GKB+04, SGR+02], aeronautics and space training [Bro99], and vehicle operation training [BW98].

In virtual reality training applications, decisions that are made on the factors which may affect user performance is important, since they may hinder usability and user performance. In this paper, we focus on two of such properties: visual fidelity and viewing. Effects of visual fidelity on user experience and usability has been explored previously and yielded different results based on the task design. Effects of magnified view, however, hasn't been studied yet, to our knowledge. In this study, we investigate the effects of visual fidelity and view zoom on user experience and user performance at an inspection task in VR. The goal of the participants was to inspect moving boxes on two conveyor belts and to mark the defective ones that had black spots on them. Effects of visual fidelity and view zoom on user experience and usability was investigated in a user study with 15 participants.

Decreased visual fidelity may simplify training and lead to better concentration whereas high visual fidelity may resemble the real world better, increasing the realism and the sense of presence induced by the VR training application. However, high visual fidelity systems are costlier to produce, since they call for more detailed visuals, 3D models, and animations. Hence, if low visual fidelity systems provided similar or better user performance in VR, it would help the developers to avoid unnecessary costs and result in faster production with more variety. Magnified view may result in better concentration, since the users would view a smaller portion of the virtual world at a time in a magnified form. As the view is magnified, the movements and the rotations of the user become amplified as well. Amplified movements and rotations may be advantageous, in requiring less real-world movements and rotations, reducing fatigue. On the other hand, it may induce motion sickness or degrade the level of presence. This study aims at finding out the effects of visual fidelity and view zoom on user experience and usability to provide insight for the design of future VR training systems.

2 Related Work

Some previous studies explored the effects of visual fidelity and field of view on task performance, presence and motion sickness in VR. Visual fidelity can be described as the level of realism of the digital imagery. Higher visual fidelity corresponds to more realistic digital imagery, whereas lower visual fidelity corresponds to simple and non-realistic digital imagery. Ragan et al. studied the effects of visual complexity and field of view on user performance at a visual scanning task in VR [RBK+15]. The goal of the participants was to search for targets around virtual city streets while their point of view was moved automatically. Higher visual complexity in the experiment included more realistic textures, more detailed geometry and additional static props. The field of view was changed by limiting the view with virtual black blinders. Results indicated that higher visual complexity worsened user performance. However, increased visual complexity included both increased visual fidelity and increased clutter in the scene, and the effects of these two elements were not explored separately in the study. In contrast, high field of view led to better user performance in their experiment. Lee investigated the effects of visual realism on searching tasks with a high-fidelity VR display system [LRM+13]. The authors utilized real life images and virtual images of three different visual fidelity levels in a searching task. Results indicated that visual fidelity did not have an effect on user performance. However, the authors linked this result to the difficulty of the designed task for the experiment and concluded that the results may not be applicable to all searching tasks in VR. The results of the study also indicated that level of visual fidelity did not have an effect on level of presence. Zimmons and Panter explored the effects of visual fidelity on task performance and presence in VR [ZP03]. In the study, the level of visual fidelity was changed by changing texture resolution and lighting. The goal of the participants was to drop objects at a virtual target below them. The task took place in a virtual pit room, which created a sense of danger in the participants. Visual fidelity did not affect task performance I the experiment. Presence results were not affected by visual fidelity either. The authors interpreted that the dangerous nature of the task overshadowed the possible differences between the conditions. Slater et al. studied the effects of visual fidelity on the level of presence in VR [SKMY09]. The experiment took place in a virtual pit environment. Visual fidelity was changed by changing the rendering quality through shadows and reflections. The participants were exposed to the virtual environment for three minutes. The results indicated that high visual fidelity led to increased presence and more intense physiological responses related to stress.

Some previous studies found out that visual fidelity did not have an effect on distance estimation in virtual environments [TWG$^+$04]. On the other hand, some studies reported results indicating that increased visual fidelity affected distance estimation at closer distances, leading to more accurate estimations [KW96]. The previous studies reported different results regarding the effects of visual fidelity on task performance in VR. Bowman and McMahan suggested that for complex tasks that require complex visualizations and that are more difficult to understand, higher visual fidelity may lead to better user performance. However, for simpler tasks that call for simpler visualizations, low visual fidelity may lead to similar results as high visual fidelity [BM07].

Although no previous study to our knowledge has studied the effects of magnified view on user performance in VR, some studies investigated the effects of field of view, which is related to magnified view. Field of view (FOV) is described as the size of the visual field that can be viewed by a user instantaneously [BM07].

Arthur explored the effects of field of view on user performance in a virtual reality searching task [Art00]. The goal of the participants was to find virtual objects outside their FOV by looking around in the virtual environment. The results indicated that higher FOV increased user performance.

Some studies explored the effects of amplified head rotations in VR by changing the virtual viewing direction to a higher degree than the user's real-world head rotations. In their study, Jaekl et al. asked the participants to adjust the level of rotational amplification in a head mounted display while viewing a virtual environment until they felt that the viewing experience was as they would expect in real life [JAH$^+$02]. The results indicated that there was a preference for some amplification, with an average of 1.26x. The participants stated that they felt like the experience was more natural with the amplified head rotations. Kopper et al. investigated the effects of amplified head rotations at a scanning and a counting task in VR [KSB11]. In the scanning task, the participants looked for threatening virtual avatars while driving on a virtual city street. In the counting task, the participants stood still at a virtual intersection and were requested to count the number of avatars around them. The results indicated that an amplification of up to 3x had no effect on the scanning task performance for large and medium FOVs, however increased the performance for low FOV. For the counting task, the amplification decreased the performance, leading to double counting of some virtual avatars. Since there was no selection mechanism in the task the participants had difficulty in distinguishing previously counted avatars. The authors suggested that avoiding large amplifications in tasks that require the users to make large rotations in the virtual environments that lack sufficient visual cues is a good practice. Jay and Hubbold also explored the effects of amplified head rotations and hand movements for narrow FOVs [JH03]. The study included a VR searching task in which the participants searched for and selected some virtual targets. The results indicated that amplified rotations improved user performance and did not make the participants uncomfortable. Most of the participants stated preference for the amplified rotation over one to one rotation. The results also indicated that body movements should also be amplified in proportion to the head rotations, in order to provide a more natural interaction.

These previous studies indicated that amplified head rotations and movements may not be noticeable and can even be favorable by users in some VR applications. Amplified head rotations and movements may decrease the required real head rotations and movements, leading to less fatigue and less risk of getting tangled in cables tethered systems.

There were also some studies that explored the effects of field of view on distance estimation in VR. Kline and Witmer found that field of view had an effect on distance estimation in virtual environments [KW96]. High FOV led to underestimated distances whereas low FOV led to overestimated distances. Some studies focused on the effects of FOV on level of presence and motion sickness. Arthur reported results indicating that FOV in a head mounted display had no effect on either presence or motion sickness [Art00]. Even low FOVs such as 48-degrees did not affect these two metrics.

All of these previous studies evaluated effects of visual fidelity and FOV on VR tasks that involve large information spaces, such as scanning virtual environments to find objects. Based on the previous studies, we think that task design plays a crucial role in how visual fidelity and FOV effects user experience and performance in VR. Hence, in our study, we examined effects of visual fidelity and view zoom (with amplified rotation and movement) on user experience and performance at a virtual reality inspection task within a limited information space. The user stood still while boxes moved on conveyor belts next to them, hence they did not need to look around as they would in a large information space. To sum up, our study differs from the previous studies in task design and analyzing the effects of view zoom instead of FOV.

3 The Inspection VR Game

A VR inspection task was designed and implemented to evaluate effects of visual fidelity and view zoom on user performance and experience. The goal of the user in this task was to inspect moving boxes on two conveyor belts and mark the defective ones that had black spots on them by reaching out. The defective spots had diameters ranging between 3 and 5 cm. The boxes were on two conveyor belts that were positioned on the left and the right of the user (Figure 1). As the user stood at the center of the tracked area, they could easily reach the virtual boxes by extending their arms to their sides (Figure 2). As the users reached out and touched a virtual box, the box was highlighted in magenta to provide real time feedback. The users could deselect unintentionally selected boxes by reaching out them again. As a box was deselected, its color was returned to original. Physical tables were positioned in the testing area to give the users a sense of physical collision if they moved near the virtual conveyor belts. The main motivation behind including these physical tables was to increase sense of presence. In several previous studies, it was found out that using physical props that matches virtual entities increased the level of presence in users [AJP+16, CHW97, CYD+17, LNWB03].

The defects were placed on the faces of the boxes that were visible to the user at all times, so that they did not need to turn back to check the back faces of the boxes. There were 22 boxes on each conveyor belt, 10 of which were defected. Each conveyor belt had two types of boxes (two brands) that were equal in number and distribution on the belt. The conveyor belts moved with a speed of 0.25 m/sec, which was decided through in-house testing sessions as being a speed with which users could select the moving boxes without getting overwhelmed. The reason behind including two conveyor belts on two sides was to ensure that the users weren't fixated to a viewpoint while performing the task and looked around.

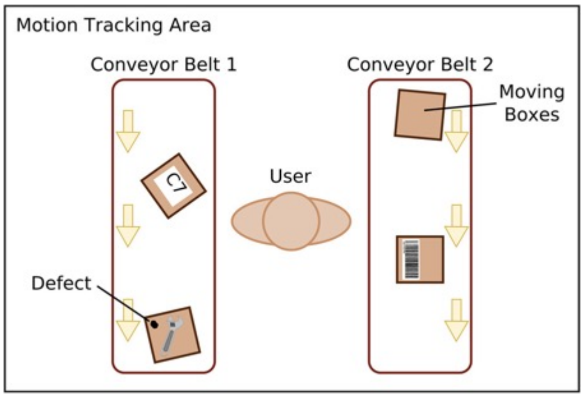

Figure 1: A layout sketch of the virtual reality inspection.

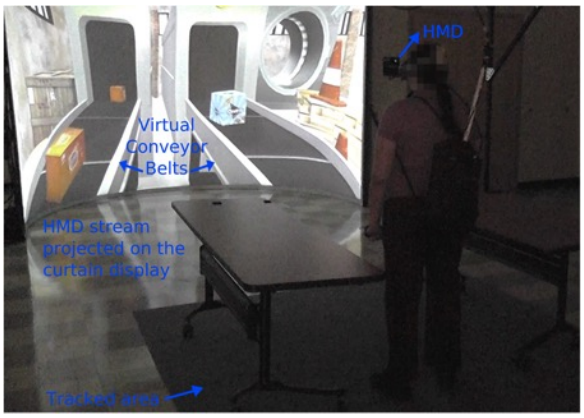

Figure 2: The user is looking at the virtual conveyor belts. View of the user inside the HMD is projected on a curtain display, only for outside viewing purposes. The lights in the room are turned off to prevent any light bleeding inside the headset.

For visual fidelity, there were two conditions: high visual fidelity and low visual fidelity (Figure 3). Visual fidelity was changed for all of the elements in the virtual world. Specifically, four factors were altered: realism of the textures, detail of the geometry, realism of the skybox, and realism of the lighting. For view zoom, there were also two conditions: normal view and magnified view (Figure 3). The virtual view was magnified by 1.25x in the magnified view through altering the field of view property of the virtual game camera in Unity. The defects on the boxes can be seen in Figure 4 for high visual fidelity and low visual fidelity conditions.

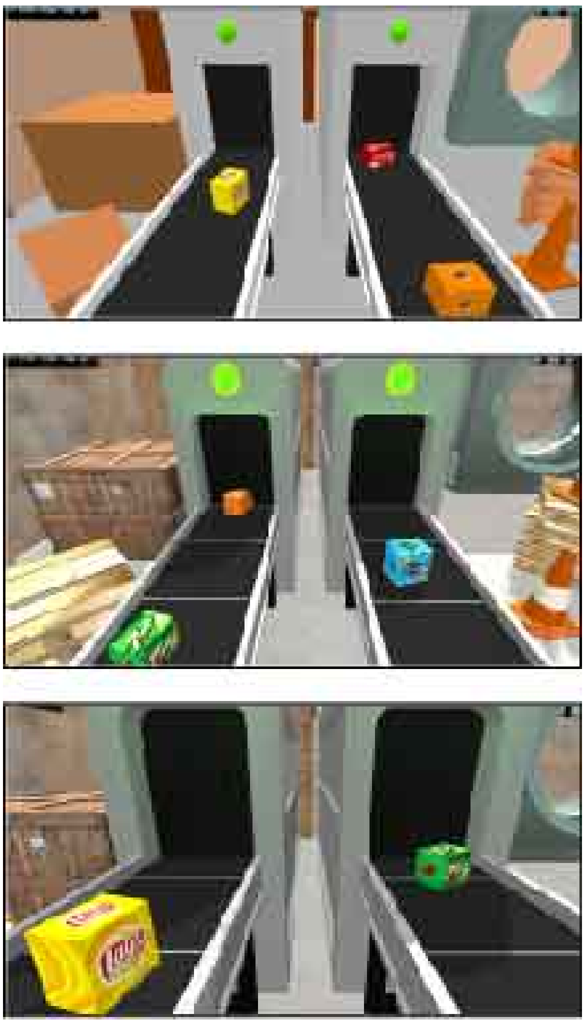

Figure 3: Three conditions of the VR inspection game. Top: low visual fidelity - normal view. Middle: high visual fidelity - normal view. Bottom: high visual fidelity - magnified view.

Figure 4: Defects on the boxes. Left: High visual fidelity condition. Right: Low visual fidelity condition.

3.1 Hardware

Real time motion tracking was performed with 12 Opti Track V100R2 FLEX optical cameras. The size of the tracked area was 8ft by 8ft, but the users did not need to walk in the experiment. A VR2200 head mounted display (HMD) was used for viewing the virtual environment [LLC17]. HMD movement was tracked by the system in real time via reflective markers that were attached on top. This enabled rendering the virtual world accurately, based on the head movements. The application was implemented using the Unity game engine and worked at 60 frames per second, which was the native hardware frequency of the used HMD. Users wore hand bands that were equipped with reflective markers for real time tracking of hand movements.

3.2 Experiment Design

Two by two within subjects experiment was performed with the independent variables of visual fidelity and view zoom. Both of these independent variables had two levels: high visual fidelity and low visual fidelity, and normal view and magnified view. By varying these levels, four conditions were obtained that were changed with-in subjects: high visual fidelity - normal view, high visual fidelity - magnified view, low visual fidelity - normal view, and low visual fidelity - magnified view. Each participant completed a trial with each condition (four trials per participant in total). The order of conditions was assigned randomly with counterbalancing. In each configuration, different box sets were presented to the participants, which were also assigned randomly with counterbalancing. The participants were requested to mark as many defective boxes as they could. One trial took 2 minutes. In each trial, there were 20 defective boxes in total (10 on each conveyor belt) but the participants were not informed on that number. At the beginning, there was a training session for making the users get used to VR interaction and the task. The training session included a single conveyor belt with the aim of teaching the task to the participants without over-whelming them. The condition that was used in the training session was high visual fidelity - normal view, due to its prevalence of use in VR games along with high degree of resemblance to real-life conditions. The training session took one minute.

The score was calculated with a simple algorithm that is commonly used in video games. The scoring algorithm included punishment for missed items, along with a 50% decreased punishment for the corrected items (mistakenly selected and then deactivated) to distinguish fully correct inspections from the ones that included wrong selections that were corrected by the participants afterwards. The scoring algorithm was as follows: Number of hits - number of misses + (0.5)*number of corrections. The defective boxes that were correctly selected by the participants were counted as 'hits' whereas the regular boxes that were incorrectly selected as defective were counted as 'misses'. Deselected missed boxes were counted as 'corrections'.

3.3 Research Questions and Hypothesis

In this study, the following research question was aimed to be answered: *"What are the effects of visual fidelity and view zoom on user performance in a virtual reality inspection task?"* We developed the following two hypotheses: (H1) Low visual fidelity will affect the user performance positively. (H2) Magnified view will affect the user performance positively.

3.4 Data Collection

Automated data was collected for the following metrics: box sets and distributions on the convey-or belts, number of hits, misses, unintentional touches and corrections with their time logs. After the participants completed a trial with a condition, a questionnaire was filled out by them that had questions about the following user experience aspects: perceived difficulty of the task, level of frustration, ease of finding the boxes, level of dis-traction, intensity of feeling of being restricted, ease of concentration, level of presence, level of motion sickness, estimation of the number of missed defective boxes, and open-ended comments.

3.5 Participants

15 adults participated in the user study, due to the limitation of funding for the participation incentive. The participants were recruited via e-mail announcements and word of mouth. All participants were university students with different majors. Participants were aged between 21 and 33 (μ = 25.80, standard deviation = 3.05). Gender distribution was 5 females and 10 males. 13 participants had no prior VR experience whereas 2 participants had minimal prior VR experience. The user study was conducted under the Institutional Review Board approval (Pro00013008) from the University of South Florida's Human Research Protection Program.

3.6 Procedure

After the participant read and signed the informed consent form and filled out the demographics questionnaire, the research staff briefly explained the VR equipment to the participant along with their objective in the experiment. The participants were informed about the defective boxes and the faces of the boxes the defects might be on. The research staff then helped the participant to wear the VR equipment and the training session began. After the training session, the experiment started. Each participant completed four trials with four conditions, each trial followed by filling out a paper-based questionnaire for the condition they had tried. To fill out the questionnaire, the participant flipped up the head mounted display goggle. Since each trial only took two minutes, and there was a paper-based questionnaire filling breaks be-tween the trials, no additional break time was assigned. After the participant completed all four trials, the experiment ended. The participants were informed that they were free to stop the experiment if they felt uncomfortable for any reason at any time. A flowchart of the experiment procedure can be seen in Figure 5.

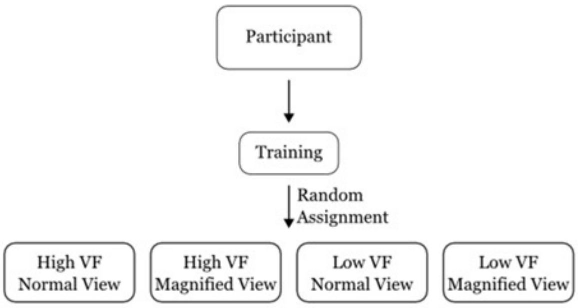

Figure 5: Flowchart of the experiment procedure.

4 Results

All 15 participants completed the experiment. In this section, we present the results of the following user performance and user experience aspects: performance data, questionnaire data, estimation of the missed defective boxes, and qualitative questionnaire results

4.1 Performance Data

Average participant scores for the four conditions are presented in Figure 6. As the data was analyzed to investigate effects of the conditions on the score using two way ANOVA with repeated measures with α = 0.05 and Bonferroni correction, we found out that visual fidelity had a statistically significant effect on score (F(1, 11) = 12.719, p-value = 0.003) whereas view zoom did not have a significant effect (F(1, 11) = 0.002, p-value = 0.967). Paired t-tests results are reported in Table 1 (VF stands for visual fidelity). Effect of visual fidelity was significant for both levels of view (normal and magnified). Plot of the means of the participant scores for the two variables can be seen in Figure 7. High visual fidelity led to lower scores whereas low visual fidelity led to higher scores. Normal or magnified view did not have an effect on the score of the participants.

4.2 Questionaire Data

At the end of the trial of each condition, a questionnaire was filled out by the participants. This questionnaire was designed as modified version of Loewenthal's core elements of the gaming experience questionnaire [Loe01] and consisted of questions assessing different aspects of user experience, such as the perceived difficulty of the task, level of frustration, ease of finding the box-es, level of distraction, feeling of being limited (restricted), ease of concentration, level of presence and motion sickness. The participants were asked to give a score for each variable on a Likert scale of 5 to 1 (5: very much, 1: not at all). The presence questions in the questionnaire were from the Witmer and Singer's presence questionnaire [WS98], and the motion sickness questions in the questionnaire were from the motion sickness questionnaire of Gianaros et al. [GMM+01]. Results of these questionnaire variables can be seen in Figure 8. Error bars on the bar charts represent the standard error of the mean. Two way ANOVA with repeated measures with α = 0.05 and Bonferroni correction resulted in statistical significance only for the following variables: perceived difficulty of the task, visual fidelity (F(1, 11) = 7.549, p-value = 0.016); ease of finding the boxes, visual fidelity (F(1, 11) = 8.654, p-value = 0.011); feeling of being limited/restricted, visual fidelity (F(1, 11) = 6.646, p-value = 0.022); ease of concentration, visual fidelity (F(1, 11) = 6.137, p-value = 0.027); presence, visual fidelity (F(1, 11) = 5.833, p-value = 0.030); motion sickness, visual fidelity (F(1, 11) = 10.000, p-value = 0.007).

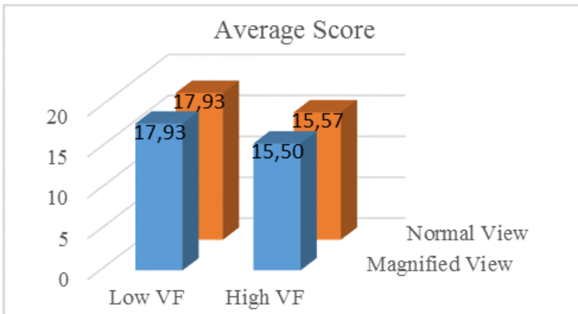

Figure 6: Bar charts of the average participant scores for all four levels of the two conditions.

Table 1: Paired t-test results for the average participant scores.

Condition	N	Degree of Freedom	T-Value	p-value
High VF - Normal View, High VF Magnified View	15	14	0.063	0.951
Low VF - Normal View, Low VF - Magnified View	15	14	0.000	1.000
High VF - Normal View, Low VF - Normal View	**15**	**14**	**-2.748**	**0.016**
High VF - Magnified View, Low VF - Magnified View	**15**	**14**	**-3.200**	**0.006**

4.3 Estimation of the Missed Defective Boxes

The questionnaire also had a question that re-quested the participants to estimate the number of missed boxes in a trial. The results for the real number of missed boxes and the participants' estimations are presented in Figure 9. As two way ANOVA with repeated measures with $\alpha = 0.05$ and Bonferroni correction was applied to the difference of the real number of misses and the estimated number of misses, statistical significance was only found for the visual fidelity variable ($F(1, 11) = 13.407$, p-value = 0.003). High visual fidelity yielded less accurate estimations for the missed boxes whereas low visual fidelity yielded more accurate estimations.

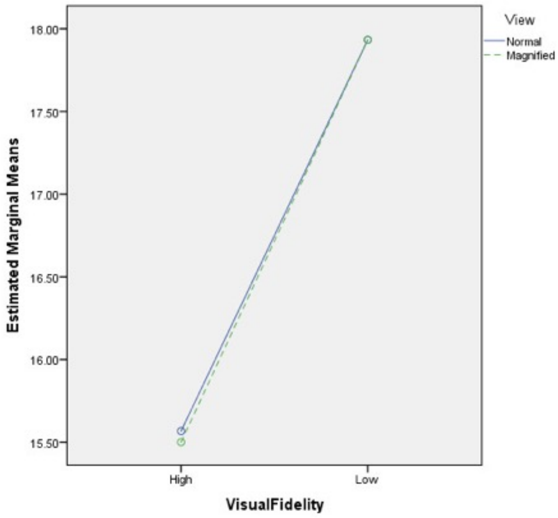

Figure 7: Plot of the means of the participant scores for visual fidelity and view zoom.

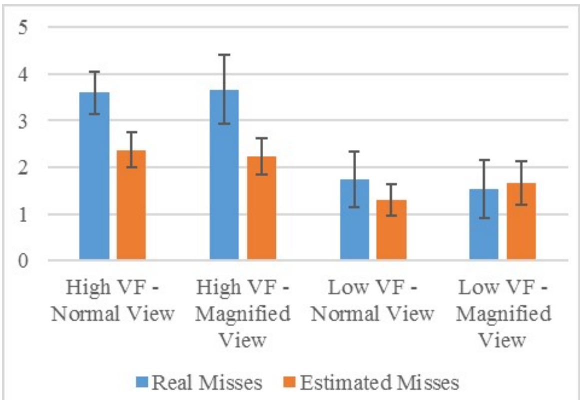

Figure 8: Bar charts of the average number of missed boxes, and the estimations of the number of misses by the participants for different conditions.

4.4 Qualitative Questionnaire Results

The questionnaires included open ended questions about what the participants liked the most and the least about the trial, and if they had any additional comments or suggestions. There were many positive comments about the experiment in general: Participant 1: *"I liked how realistic it seemed. It seemed like the boxes were actually moving past me."* Participant 2: *"I liked that it was a little challenging."* Participant 3: *"Easy to understand."* Participant 5: *"It gave me a feeling that I was working in that warehouse."* Participant 6: *"It is intuitive."* Participant 9: *"It is easy to touch the defective box. I can see the spot clearly and the distance of the belt is very well."* Participant 10: *"Animation was good."* Participant 11: *"I enjoyed having to keep track of two belts moving; it was more challenging and more representative of the real world. Maybe you can have the belts even move faster. I liked being able to bend down to get a better look at the boxes like you would in real life."* Participant 12: *"Freedom of movement like in a real world."* Participant 13: *"Not much moving; it was more observing. It felt like a video game. Easy to perform. I liked everything."* Participant 15: *"I liked that it made you hurry, but not rush."* Participant 17: *"Real world simulation and easy interaction."* Participant 18: *"I enjoyed the difficulty of the task (having two conveyor belts). I liked that it was challenging and interactive."* Participant 20: *"The task felt realistic and doable; I imagine it would be good for training employees."*

There were also some negative comments about the experiment in general: Participant 3: *"The defect on the boxes was small."* Participant 5: *"It will be better if there are haptic feedbacks when touch the boxes."* Participant 6: *"When you hit a red colored box, its not easy to see the highlight."* Participant 8: *"Spotting the defects is difficult on darker boxes."* Participant 12: *"It would help to know if I touched the box or not without looking at it. Maybe vibration feedback or something would be helping."* Participant 13: *"It was slow but I like a challenge. For rehabilitation it may be excellent."* Participant 15: *"I didn't think this session was as fun as the one for selecting boxes on shelves. This one was more drab."* Participant 20: *"Some of the colors made it difficult to spot defective boxes. Also, sometimes the boxes seemed to move too fast. Both of these would be realistic problems though."*

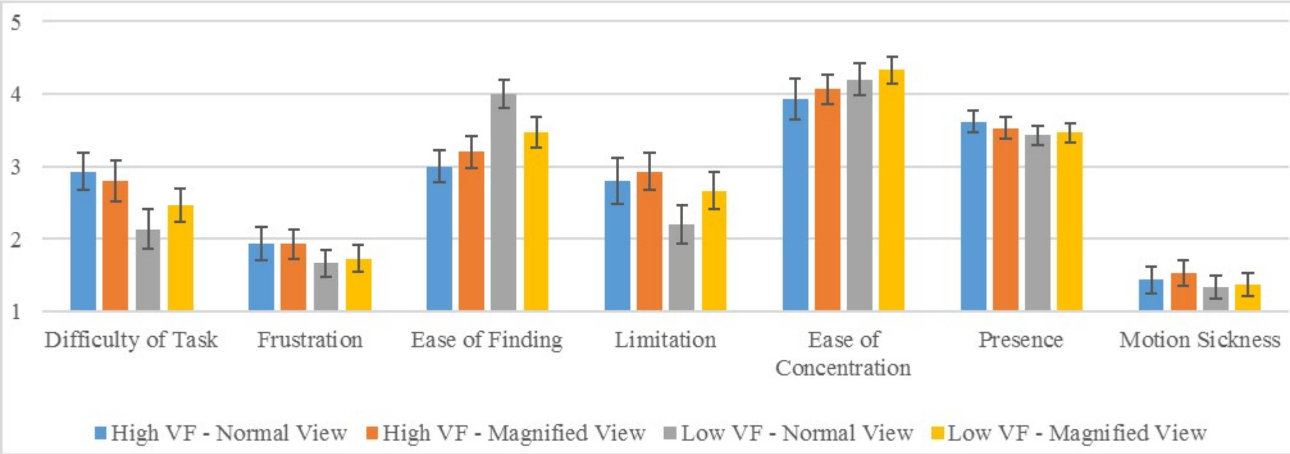

Figure 9: Bar charts of the average scores for the questionnaire variables for different conditions.

Many participants made comments stating that high visual fidelity made the VR experience seem more real whereas making the task seem more difficult: Participant 2: *"Challenging.* Participant 4: *"Felt more realistic."* Participant 5: *"The pat-tern on the boxes are more complex and colorful makes it more difficult to spot the defect."* Participant 6: *"The belt was faster than before."* Participant 11: *"Felt like the belt moved faster or more products went through than before [Simple High FOV - Simple Low FOV]. So it was more challenging and more realistic."* Participant 9: *"Sometimes I could not find the spot because the boxs colour was too fresh."* Participant 15: *"I noticed the green lights at the top of the conveyors which were cool."* Participant 20: *"I appreciated that the warehouse had more details and felt more real [than low visual fidelity]. However, some of it was a little more distracting [than low visual fidelity]."*

Many participants stated that low visual fidelity made the task seem easier but degraded the level of realism: Participant 4: *"Simplicity made it easier to see defectives but made it feel less real. Didn't like how 'smooth' everything was."* Participant 5: *"There is no reflected lights on the boxes surface which makes it easier to spot the defects."* Participant 6: *"Seems slower than before [normal view]."* Participant 9: *"I think it is clearer [low visual fidelity] and I can see the spot quickly."*

Magnified view received mostly negative re-views from the participants: Some participants stated that they liked it Participant 12: *"Boxes seemed larger and easier to touch."* whereas many participants stated that they didn't like it Participant 1: *"I felt like I was too close, it was hard to see both conveyors at the same time. Zooming out would be better."* Participant 2: *"Hard to see both boxes at once."* Participant 4: *"It was challenging."* Participant 5: *"I think the view is too narrow compared to the real eye view. This makes it difficult when the boxes come out fast."* Participant 6: *"The belt seems higher than before. I dont like high platform."* Participant 13: *"I felt I was close to the conveyor and needed to move my head too much to see the boxes. It felt I was closer to the exit and sometimes it was difficult to see the boxes."*

As we interviewed the participants at the end of the experiment, the majority stated an overall preference for low visual fidelity and normal view.

5 Discussion

The results revealed that high visual fidelity affected task performance negatively and low visual fidelity improved the task performance, supporting H1. The results for the favored visual fidelity level align with [RBK+15] and contradict [LRM+13, ZP03]. The reason behind this could be the difference in task design in these studies. High visual fidelity led to perceiving the same task as more difficult, finding the defective spots easier, more feeling of being limited, more difficulty in concentration, increased sense of presence and increased motion sickness. We interpret that low visual fidelity leads to better user performance in inspection tasks in VR, making it easier to focus and perform the task, and induce less motion sickness. However, it may degrade the level of presence, increase motion sickness, and make the virtual environment seem less detailed and interesting. When interviewed, the participants stated an overall preference for low visual fidelity with the reasoning of it making the task easier for them. However, they also stated that low visual fidelity made the virtual environment seem “drab” and “less real”.

Level of view zoom did not have an effect on user performance, rejecting H2. View zoom did not have an effect on any other variable as well, indicating that changing the view zoom may not have an overall effect on user performance and user experience. One of the most anticipated side effects of the magnified view was increased motion sickness, which was not encountered in the experiment results. Although no significant effect of the view zoom was observed on user performance or experience, when the participants were interviewed, they stated an overall preference for the normal view stating that they were able to see more space at once. In applications that aim to restrict the user’s view, magnified view may be re-sorted, since we didn’t encounter any negative effects on user performance or experience.

High visual fidelity yielded less accurate estimations of the missed boxes than low visual fidelity. The participants tended to underestimate the missed boxes with the high visual fidelity condition. We believe that since the environment was visually more detailed in this condition, the participants were less aware of the missed boxes, which aligns with the outcome of perceiving the same task as more difficult with the high visual fidelity condition.

Some participants stated that the conveyor belts were closer to them when switched from high visual fidelity to low visual fidelity, although the objects did not move between the two conditions. Low visual fidelity also made the environment seem more spacious. Some participants stated that the conveyor belts moved faster in the high visual fidelity trials as compared to the trials with low visual fidelity. Hence, in applications that desire to train users in a fast-paced virtual environment, we recommend using high visual fidelity. On the contrary, in applications that aim to create serene virtual environments, low visual fidelity may be a better choice.

In light of these results and the participants’ comments, we suggest that low visual fidelity improves task performance and does not degrade user experience and can be used for VR training tasks with limited information spaces that are similar to inspection. In our study, magnified view did not degrade user performance or experience, but was not preferred by the participants. Hence, we recommend not resorting to magnified view, unless necessary.

5.1 Limitations

The task in this study included inspecting boxes in VR while standing still, and did not involve moving around, which could have a direct effect on the presented results. These results may or may not be applicable for other tasks in VR that have larger information spaces or that involve locomotion. The task design in this study focused on training, which is expected to have a direct effect on the study results. Hence, the results of the study may or may not be applicable for entertainment-based games or other application designs in VR. Age range of the participants (μ = 25.80) may be another limitation. The results of the study may not be transferable to special population groups, such as children or elderly.

6 Conclusion and Future Work

This study aimed to investigate effects of visual fidelity and view zoom on user performance and experience at a VR inspection task. A two by two user study was performed with 15 participants. The results indicated that low visual fidelity led to better user performance whereas view zoom did not have an effect on the user performance. High visual fidelity increased level of presence and motion sickness whereas view zoom didn’t have an effect on these user experience aspects. Future work may include investigating grained levels of visual fidelity on task performance and user experience and evaluating these properties for other game and application genres in VR. User studies with increased sample sizes are of future interest also, as they would yield stronger conclusions.

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