The Effect of Egocentric Interaction Techniques and User-performed Tasks on Problem Solving in Virtual Reality

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ABSTRACT

As we find further applications of Virtual Reality (VR) in the field of education, a need to understand the effects design choices have on a virtual experience becomes vital. Few have studied the impact of interaction techniques on learning objectives. In this paper, we study the effects two egocentric, interaction techniques (virtual hand, raycast pointer) have on solution correctness, recognition, and timing, examples of common learning objectives. Additionally, we observe how these outcomes vary in relationship to the type of user-performed task (selecting, sorting). We describe a study in which participants (N = 107) are presented 30 questions that challenge their ability to alphabetically order English words. Questions are presented as interactive interfaces in a Virtual Environment (VE) and participants answer these questions using the interaction technique they’ve been randomly assigned. Results point to both interaction technique and the type of user-performed task as having statistically significant effects on recognition and timing variables. An understanding of these variables will help us optimize the design of immersive educational learning experiences that attempt to achieve defined learning objectives.

Index Terms: Virtual Reality—Egocentric Interaction—User Interface—;

1 INTRODUCTION

In the last four years, advancements have brought the costs of Virtual Reality (VR) down and with it an renewed interest in its utility. This has also expanded interest in the role VR has in enhancing the educational and learning processes.

VR will be defined as “a computer-generated digital environment that can be experienced and interacted with as if that environment were real.” [7] A Virtual Environment (VE) is another term synonymous with VR. While used in some contexts to mean any digital environment, in this study, we use VR and VE to mean the same thing.

VR has garnered interest because of its ability to expose students to situations that they would otherwise not be able to experience. The ability to immersively situate a student in space, under water, or inside a blood vessel has the potential of providing better context. These situations are difficult to naturally produce in the class so involved in the design of an effective VE, interaction techniques.

Our focus is to study the role VR interaction techniques have on facilitating or hindering some learning objective. We attempt to do this by extending examples of traditional assessment techniques into a VE and measuring variables such as solution correctness, recognition, and time taken.

By extending different types of traditional assessment into a VE, we aim to better understand the role interaction techniques have on a student’s ability to achieve a defined set of learning objectives. Our ability to understand these variables will better inform us about which design decision need to be taken to optimize an immersive learning experience’s benefit.

2 PREVIOUS WORK

In this section, we discuss two major themes. First is an introduction to concepts within the User Interface (UI) and 3D interaction literature. Secondly, we focus on previous work that has studied the role of VR in education.

2.1 User Interfaces and Interaction

“UIs are mediums through which the communication between users and computers takes place.” [4] The command-line interface (CLI) and the graphical user interface (GUI) are examples of UIs that we are more familiar with. This study focuses on 3D interaction techniques; interaction in which tasks are performed directly in a 3D spatial context. [4] All mentions of word interaction refers to 3D interaction.

Interaction techniques are a core component of the VR experience. "An interaction technique is a method allowing a user to accomplish a task via the user interface.” [4] Without a proper interaction technique, we cannot efficiently select or manipulate objects in a virtual environment. There exists a large number of interaction techniques but in this study, we focus on interaction techniques used to interact with 3D user interfaces.

Throughout this section, we utilize the taxonomy of Poupyrev et al. [9] to classify the interaction techniques we use. See figure 1. While there exists other taxonomies that describe different VR interaction techniques, this taxonomy provides a clear distinction of types of interaction techniques used commonly in modern VR applications. The Poupyrev taxonomy defines two main groups: egocentric and exocentric. Egocentric interaction is interaction from the first person view or from within the virtual environment. An egocentric reference frame is defined relative to a certain part of the human body. [4] Exocentric is interaction from a 3rd person or a frame of reference defined relative to something in the virtual environment. [4]

In this study, we focus on egocentric interaction techniques. This is due to the higher immersive nature of egocentric interaction techniques. To further describe egocentric techniques, they are split into hand metaphors and ray metaphors. Here a metaphor refers to a mental model of a technique: an understanding of what the user can do (accordances) and what they cannot do (constraints) with that technique. [4]

Metaphors attempt to facilitate the user’s ability to perform canonical manipulation tasks. [4] These tasks are selection, positioning, rotation. Selection is the task of identifying a particular object from the entire set of objects. Positioning is changing the position of an object in the virtual environment. Rotation is changing the orientation of an object in the virtual environment. [4] Metaphors build on

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the user’s understanding of the real world to allow the user to quickly learn and apply these tasks in the virtual environment providing a faster use the interface.

There exists a number of interaction techniques under each metaphor type but a discussion into all of them is beyond the scope of this study. Instead, we focus on describing two main techniques of interest: the classical virtual hand (under hand metaphors) and ray-casting (under ray metaphors).

With the classical virtual hand technique, users can grab and position objects by “touching” and “picking” them with a virtual representation of their real hand. “Classical” virtual hand technique attempts to provide one-to-one mapping between the real and virtual hands. [9]

With the raycast technique, the user selects and manipulates objects by pointing at them. A pointer emanates from the user’s hand and when the the virtual pointer intersects with an object, it can be picked and manipulated. [9]

2.2 Virtual Reality in Education

One of VR’s strengths is it allows for the ability to experience situations that would otherwise be inaccessible. [6] Time, physical and safety constraints can usually be circumvented by building VR experiences that remove those constraints while simultaneously immersing the user. This has allowed students to visit historical periods, observe our solar system up close, and journey into the depths of the earth. Adult training is another core application that allows for applications to train pilots, firefighter, and factory workers for example. [6]

Beyond VR’s ability to immersively place a user in a different location, it’s important to try and evaluate what role VR has on different learning outcomes. A number of studies have attempted to do this.

In [2], the authors studied the role of dimensional symmetry on learning bimanual psychomotor skills. Dimensional symmetry is the correspondence between a virtual interaction metaphor to the real-world equivalent meaning how easy it was for individuals to learn real world tasks by being exposed to these tasks in a VE. The bimanual psychomotor skills were a set of tools the subjects were asked to use after having gone through the intervention. Results included no significant effect of reduced degrees of freedom on learning outcomes; making the task less immersive, in the benefit of simplicity, had no additional effect on learning outcomes. Additionally, 6-DOF (more immersive) interaction provided for more precise learning outcomes for the subjects. At the same time, more participants felt that they could not complete their task when using a 6-DOF interaction technique over a 3-DOF (less immersive) interaction technique. The authors seem to think this is due to the steeper learning curve associated with the 6-DOF technique. [2]

Additionally, a study [5] attempted to assess knowledge retention in an immersive virtual environment in comparison to common safety cards. The authors found that an immersive virtual environment is more effective in the long term on the retention of safety knowledge. Additionally, subjects using the common safety cards suffered from significant knowledge loss between the post-test and retention-test conducted when compared to the group that was administered the VR intervention. The authors attributed this to the larger engagement and emotional arousal that was caused by the VR intervention. [5]

Furthermore, [8] compared a VR experience with that of a desktop setup. This study showed that the VR experience provided better results when testing for learning outcomes such as the student’s ability to analyze, synthesize, and evaluate the knowledge they were learning. The same study also showed that users spent more time exploring their surroundings when in the VE over the desktop setup. Nonetheless, a consistent finding was also an increase in the time needed to finish the tasks assigned to the users. [8]

In summary, the benefits of VR in enhancing learning objectives are many. Nonetheless, there are also challenges when it comes with the higher learning curve associated with more immersive forms of interfaces and interaction. While the first cited paper in this section attempts to observe the role an interaction technique has on learning outcomes, we find questions interested in studying the role interactions techniques have in education is lacking. Most of the studies we have come across study the role VR as a medium has but do not focus as much as the role the type of interaction technique has. We aim to further add to the literature by attempting to understand the role VR interaction techniques have in facilitating learning objectives.

3 EXPERIMENT

3.1 System Description

To be able to explore what role interaction techniques and user-performed tasks have on learning objectives, we designed and implemented a VR experience that attempts to test these. The experience is dependent on both effective hardware utilization and efficient software implementation.

For our Head-Mounted Display (HMD), we utilize the Oculus Rift CV1, a consumer off-the-shelf VR system. In addition the headset, we also use the Oculus Touch controllers. We utilize a 2 camera setup.

To develop the software that runs on the HMD, we use the Unity3D game engine. Unity allows us to iterate quicker by providing a stable development environment that facilitates prototyping, a great asset pipeline, and continuous support for VR platforms. Additionally, we utilize the Virtual Reality Toolkit (VRTK), a library of extensible C# classes that provide core VR functionality such as implementations of basic interaction techniques.

3.2 Method

3.2.1 Participants

Participants \((N = 107)\) consisted mainly of undergraduate Computer Science students at the University of Georgia with an average age of 20.6 years old. 33.8% of the participants were female. The study was open to anyone who fit our qualifying criteria: the subjects needed to be at least 18 years old and have completed their high-school education. These conditions were defined to insure a baseline for a subject’s educational background. This would help us avoid the need to expose participants to content that they may not be familiar with introducing further bias.

In order to encourage participation, two main forms of incentives were provided. The first was bonus grade points added to participating student from the CSCI 1302 class. The other incentive was a consumable snack. The University of Georgia Institutional Review Board approved this study. IRB ID: MOD00005209.

3.2.2 Study Description

There are two main independent variables that we are interested in: the interaction technique which consists of two factors: the
Raycast Pointer technique and the Virtual Hand technique; and user-performed task that also consists of two factors: selection and sorting. To study how these variables influence other dependent variables in our system, we designed a mixed-factorial study: a between-subjects component for the interaction technique variable and a within-subjects component for the user-performed task variable.

To insure the validity of our randomized-experiment, participants are randomly added to one of the interaction technique groups (Raycast Pointer, Virtual Hand). This is done through the software we’ve written with a constant likelihood of 50/50 for each group throughout our study. This randomization determines which of the between-subjects group the participant will be added to.

The within-subjects portion of the experiment presents to the subjects two main factors: 10 selection tasks and 10 sorting tasks. Participants will be presented with both types of tasks. To insure we control for order effects in our repeated measures, within-participants portion, we counter-balance the selection tasks and the sorting tasks based on the interaction technique group the subject has been assigned to. Subjects in the Raycast Pointer group are subjected to the selection tasks first while subjects in the Virtual Hand group are subjected to the sorting tasks followed by the selection tasks.

Additionally, to further reduce any order effects we randomize task order for both selection tasks and sorting tasks. The last portion of the study presents participants with 10 questions that test their memory of the words that have already appeared in previous sections. Participants are not told that their memory will be tested which gives us less biased information about which previous variables effected their ability to recognize words that have already appeared.

3.2.3 Material
All the tasks mentioned above involve the participant answering a question. Ideally, being able to vary the topic of the questions would allow us to generalize our results. Nonetheless, we anticipated this varying to be a source of further bias in our results. Additionally, there was no efficient way to insure a base level of knowledge across multiple topics. Therefore, we focused to tasks involved in alphabetical order built on the knowledge of basic language and order. The three types of questions are:

- Select the nth word sorted alphabetically? (Select Task)
- Sort the words alphabetically from left to right? (Sort Task)
- Select the word that has previously appeared? (Memory Select Task)

These question items follow a Multiple Choice Question (MCQ) layout. Each item consists of a stem (the question text itself), and 4 words. For both types of questions, there is only one correct answer. The correct answer for the select tasks is one of the possible words (each word functions as possible answers). The correct answer for the sort task is the word set ordered alphabetically from left to right (each permutation of the set is a possible answer).

To further lessen order effects, each question presented in the select or sort tasks was randomized. Additionally, the initial order if the 4 words was randomized. Each question was presented only once.

We also utilize a “Submit” button that participants can use to allow for some measure of learner control and pacing, an positive variable in learning interfaces.

3.2.4 Measures
Demographics Age, gender, educational level, and previous gaming experience variables are collected.

Outcome Scores These variables are collected for each question and provide information about whether they answered the question correctly or not.

Timing Variables
- Time to Tutorial Completion: Presents us with the amount of time it took the participant to complete the initial tutorial phase which also functions as the demographic collection stage. This variable helps us understand how long it takes a participant to learn how to use the interaction technique they’ve been assigned.
- Time to Question Completion: This variable represents the amount of time the subject spent on each question.
- Time To First Interaction: This variable represents the amount of time it took the subject to first interact with the interface.
Interaction Frequency  This variable keeps count of the amount of times the subject interacted with the interface. This can mean how many time they’ve either selected or attempt to move a sortable object.

Immediate Recognition  This value represents how many correct words a participant has recognized.

3.2.5 Procedure

Participants are exposed to a set of stages that consist of questions that guide their progression through the experiment. The selection and sorting questions are counter-balanced to reduce order effects. Together, the number of questions is equal to 33. These stages consist of the following:

1. The VR Introduction
2. Tutorial + Basic Information Questions
3. Selection Questions (3rd Raycast Pointer, 4th Virtual Hand)
4. Sorting Questions (3rd Virtual Hand, 4th Raycast Pointer)
5. Memory (recognition) Questions

The VR Intro  Two main substages are included in this stage. The first is before the subject puts on the headset. The second, after the subject puts on the headset.

• In Reality: Participants are first asked to fill out the consent form that describes the project, it’s objectives, and the tasks they would be exposed to. Participants are then shown how to hold the controllers and put on the headset.

• In Virtual Reality: This stage provides a simple introduction to the participant’s ability to move in 6 degrees of freedom in addition to a simple introduction to their controllers and the randomized interaction technique.

Tutorial + Basic Information Questions  In this stage, participants answer demographic questions using the interaction techniques introduced to them in the previous stage. This also functions an applied tutorial for the interface and interaction technique. This stage does not conclude until the participant answers a number of questions using their assigned interaction technique.

Main Tasks  As described in the Materials section of this document, this stage is made up of selection task questions and sorting task questions. Participants use what they have learned in the previous two stages to answer the questions they are presented.

Memory Questions  These questions ask the participant to select which words have appeared in the Main Tasks stage. This will be used to measure recognition. Both order of questions and initial order of possible answers are randomized to reduce order effects.

4 Results

4.1 Interaction Technique Results

Varying interaction technique we observe variables such as solution correctness and multiple timing variables and number of interactions.

4.2 User-performed Task Results

Varying the type of user=performed task we observe variables such as solution correctness and multiple timing variables and number of interactions.

<table>
<thead>
<tr>
<th>Tutorial Time (sec)</th>
<th>Time Taken Per Question (sec)</th>
<th>Time to First Interaction (sec)</th>
<th>Number of Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Hand</td>
<td>(M = 57.69, SD = 17.69)</td>
<td>(M = 18.16, SD = 13.08)</td>
<td>(M = 11.37, SD = 9.83)</td>
</tr>
<tr>
<td>Raycast Pointer</td>
<td>(M = 39.19, SD = 12.96)</td>
<td>(M = 14.79, SD = 9.98)</td>
<td>(M = 9.24, SD = 7.67)</td>
</tr>
</tbody>
</table>

\(p < 0.001\) \(p < 0.001\) \(p < 0.001\) \(p < 0.001\)

Figure 4: Percentage of Correct answers based on Question Type and Interaction Technique

4.1.1 Solution Correctness

We find that for the selection and sorting tasks, interaction technique is not an significant factor and also produces similar outcomes. Nonetheless, when it comes to memory, interaction technique significantly affects the participant’s ability to recognize words that have already appeared. See figure 4. Overall, participants using the raycast pointer technique were able to significantly recognize more of the words that appeared. Delving deeper, we find that the virtual hand technique caused significant variation in a participant’s recognition related to words that appeared in both selection and sorting tasks. Raycast pointer provided similar recognition results across words that appeared in both selection and sorting tasks. See figure 5.

Selection  We group all data by user and conduct a Welch Two Sample t-test. We find that there is no significant difference \((t(104) = 0.153, p = 0.88)\) between raycast pointer and virtual hand.

Sorting  We group all data by user and conduct a Welch Two Sample t-test. We find that there is no significant difference \((t(85) = 1.61, p = 0.11)\) between raycast pointer and virtual hand.

Memory (Recognition)  We group all data by user and conduct a Welch Two Sample t-test. We find that there is a significant difference \((t(102) = 2.16, p = 0.03)\) with raycast pointer \((M = 8.02, SD = 1.56)\) performing better than virtual hand \((M = 7.41, SD = 1.35)\).

4.1.2 Timing Variables and Number of Interactions

Across all timing variables, raycast pointer participants required significantly less time in comparison to the virtual hand technique. Additionally, participants interacted significantly more when using the raycast pointer technique. See table 1.

4.2 User-performed Task Results

Varying the type of user=performed task we observe variables such as solution correctness and multiple timing variables and number of interactions.
We find that participants were able to answer more sorting questions than selection questions. Additionally, we find that recognition questions about words that appeared in the selection task were answered correctly at a higher rate than the recognition questions associated with the sorting tasks.

A chi-square test with Yates’ continuity correction was conducted to compare number of correct responses for the sorting task versus the selection task. There was a significant difference (χ²(1) = 67.199, p < 0.001) with sorting questions being answered correctly at a higher rate (M = 101.5, SD = 5.11) than selection questions (M = 89.7, SD = 3.34). See figure 4.

A chi-square test with Yates’ continuity correction was conducted to compare number of correct responses for memory questions associated with the sorting task versus the selection task. There was a significant difference (χ²(1) = 70.41, p < 0.001) with memory questions associated with the selection task being answered correctly at a higher rate (M = 90.4, SD = 17.85) than memory questions associated with the sorting task (M = 74.6, SD = 18.38).

Regarding the timing variables, as expected from previous work [8] [2], we find that more immersive interaction techniques like virtual hand have participants spending more time on their tasks. This could be caused by the lack of exposure most people have with immersive 6-DOF interaction techniques and interfaces.

While not directly contradicting [8] regarding amount of exploration of the VE, we find that the more immersive form of interaction technique, virtual hand, resulted in a significant drop in number of interactions with the interface. This introduces variables such as possible fatigue when using virtual hand over raycast pointer but more research needs to be conducted to better understand why virtual hand resulted in less interaction with the interface.

### 5.2 User-performed Task

From the results, we find that the sorting task which has a higher number of possible answers was answered correctly at a significantly higher rate than the selection task. The correct answer for the sorting task is one of the twenty-four possible orderings of four words. Participants performed worse on the selection task with the correct answer consisting of only 4 options. One possible reason for this outcomes is the sorting tasks conduciveness for cognitive offloading the alphabetical sorting process. “Cognitive Offloading is the use of physical action to alter the information processing requirements of a task so as to reduce cognitive demand.” [10] What this means is that the sorting task that provided more physical interaction and spatial positioning of the sorting order required less cognition and hence mentally an easier task resulting in our higher percentage of correct results.

Additionally, we notice a significant effect on participants being able to recognize words associated with the sorting task. This aligns with early work on cognitive offloading [10] that points to an inverse relationship between cognitive offloading and memory. In this study, the task that allows participants to cognitively offload information into space, the sorting task, resulted in less recognition of the words that were present in that phase. The task that provided less cognitive offloading and the need to order alphabetically without the aid of visual representations in space, the selection task, had a positive effect on the participant’s memory.

Regarding timing variables, the selection task resulted in significantly less time spent on each question. This is most likely due to

**5 DISCUSSION**

### 5.1 Interaction Techniques

As we can see from the results, both 3-DOF and 6-DOF types of interaction, raycast pointer and virtual hand, did not affect the participant’s ability to answer selection and sorting questions correctly. This is a positive result which reflects the results found in [2] where an increase in dimensionality did not affect performance results. This lack of significant effect gives us further evidence that participant performance will not be negatively affected as interaction becomes more immersive inside VEs.

On the other hand, there was a significant effect varying interaction technique had on a participant’s ability to recognize words that had appeared previously. From figure 5, we see that participants in the raycast pointer group were able to answer recognition questions from the selection and sorting tasks at an almost identical level of correctness. For virtual hand, we notice that there is a large variance between a participant’s ability to recognize words from the selection task over the sorting task. A possible reason for this is the reduction of load on working memory when conducting the sorting task with the virtual hand interaction technique. This reduction while beneficial to the ability to solve the question, might reduce maintenance and elaboration causing less information to be maintained. This could have negative effects on learning.

Regarding the timing variables, as expected from previous work [8], we find that more immersive interaction techniques like virtual hand have participants spending more time on their tasks. This could be caused by the lack of exposure most people have with immersive 6-DOF interaction techniques and interfaces.

**Figure 5:** Percentage of Correct Memory (recognition) answers associated with selection and sorting tasks and varying interaction technique

**4.2.1 Solution Correctness**

We find that participants were able to answer more sorting questions than selection questions. Additionally, we find that recognition questions about words that appeared in the selection task were answered correctly at a higher rate than the recognition questions associated with the sorting tasks.

A chi-square test with Yates’ continuity correction was conducted to compare number of correct responses for memory questions associated with the sorting task versus the selection task. There was a significant difference (χ²(1) = 70.41, p < 0.001) with memory questions associated with the selection task being answered correctly at a higher rate (M = 90.4, SD = 17.85) than memory questions associated with the sorting task (M = 74.6, SD = 18.38).

**4.2.2 Timing Variables and Number of Interactions**

On average, it took participants less time to answer selections tasks while taking significantly more time for the user to first interact with the interface. Regarding number of interactions, the sorting task resulted in a significantly higher average number of interactions. See table 2.

**4.3 Other Results**

#### 4.3.1 Gender

Gender had a significant role on time needed to finish the tutorial (t(1196.9) = 11.21, p < 0.001) with males completing the tutorial at a faster average time (M = 46.29) than females (M = 55.15). Gender also had a significant role on the number of interactions (t(1660) = 2.09, p = 0.04) with males averaging higher (M = 2.98) than females (M = 2.71).

#### 4.3.2 Previous Gaming Experience

A Kruskal Wallis test revealed a significant effect of Previous Gaming Experience on Tutorial Time (χ²(3) = 163.14, p < 0.001). A post-hoc test using Mann-Whitney tests with Bonferroni correction showed the significant differences in the table 3:

<table>
<thead>
<tr>
<th>Group</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginner</td>
<td>55.15</td>
</tr>
<tr>
<td>Core Gamer</td>
<td>46.29</td>
</tr>
<tr>
<td>Professional</td>
<td>34.58</td>
</tr>
</tbody>
</table>

A Kruskal Wallis test revealed a significant effect of Previous Gaming Experience on Time Taken per question (χ²(3) = 12.253, p = 0.007). A post-hoc test using Mann-Whitney tests with Bonferroni correction showed the significant differences between beginner and core gamer groups (p = 0.02, r = 0.05).
were not significantly affected by previous gaming experience. The tools will not replace traditional learning environments but

variables affected are secondary: tutorial time and time taken per interaction found in the literature. Education is poised to be a core application of VR in the coming years. We hope to add to the vast literature in the hopes of facilitating VR adoption as a core asset to our daily lives in the years to come.

5.4 Limitations
A core limitation to this study was that our sample mainly consisted of younger undergraduate, computer science students. It’s important to consider if our results extend to participants from outside this demographics.

Additionally, the questions we asked focused on the task of ordering English words in alphabetical order. Extending this study to consider if our results extend to participants from outside this demographics augmenting traditional learning.

What we attempted to do in this study was to study what role interaction techniques and user-performed tasks have on problem solving. We believe these are important questions to ask as we attempt to optimize VR as a learning tool. We have found significant effects of both interaction technique and user-performed task.

We hope that these results better inform researchers, developers, and designers when attempting to build VR educational experiences. We hope to add to the vast literature in the hopes of facilitating VR adoption as a core asset to our daily lives in the years to come.

REFERENCES

Table 2: User-performed task effect on timing variables and number of interactions

<table>
<thead>
<tr>
<th>Time Taken Per Question (sec)</th>
<th>Time to First Interaction (sec)</th>
<th>Number of Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select</td>
<td>M = 19.62, SD = 12.49</td>
<td>M = 16.67, SD = 10.89</td>
</tr>
<tr>
<td>Sort</td>
<td>M = 22.09, SD = 10.35</td>
<td>M = 8.14, SD = 5.34</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

Table 3: Results of Mann-Whitney tests with Bonferroni correction between Previous Gaming Experience Groups and Tutorial Time

<table>
<thead>
<tr>
<th>Beginner</th>
<th>Casual Gamer</th>
<th>Core Gamer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Gamer</td>
<td>p &lt; 0.001, r = 0.14</td>
<td>p &lt; 0.001, r = 0.19</td>
</tr>
<tr>
<td>Core Gamer</td>
<td>p = 0.03, r = 0.5</td>
<td>p &lt; 0.001, r = 0.11</td>
</tr>
<tr>
<td>Casual Gamer</td>
<td>p &lt; 0.001, r = 0.14</td>
<td>-</td>
</tr>
</tbody>
</table>

the way participants interacted with the selection questions where after considering possible answers, participants would select and move on. It took participants significantly less time to begin interacting with the interface and correctly answer questions. While in our case the experiment did not result in any perceived difference in gender performance, it’s important to note that designing VEs that do not privilege one gender over the other is core to scaling effective VR learning experiences.

Additionally, the lack of significant effect of previous gaming experience on our main variables is a positive. We notice that the variables affected are secondary: tutorial time and time taken per question. Solution correctness, recognition, number of interactions were not significantly affected by previous gaming experience. The main difference was between the beginner and core gamer groups affecting the time taken per question.

5.3 Other Variables
Gender mainly affected time taken to complete the tutorial and number of interactions. The variables that were effected are of secondary importance and do not provide us with an indication that gender was a factor in participants being able to interact with the interface and correctly answer questions. While in our case the experiment did not result in any perceived difference in gender performance, it’s important to note that designing VEs that do not privilege one gender over the other is core to scaling effective VR learning experiences.

Additionally, the lack of significant effect of previous gaming experience on our main variables is a positive. We notice that the variables affected are secondary: tutorial time and time taken per question. Solution correctness, recognition, number of interactions were not significantly affected by previous gaming experience. The main difference was between the beginner and core gamer groups affecting the time taken per question.

5.4 Limitations
A core limitation to this study was that our sample mainly consisted of younger undergraduate, computer science students. It’s important to consider if our results extend to participants from outside this demographics.

Additionally, the questions we asked focused on the task of ordering English words in alphabetical order. Extending this study to other types of tasks is goal. While recognition was a core focus, delving into the role interaction technique and user-performed task have on inducing higher forms of learning such as the ones defined in Bloom’s Taxonomy is an obvious way forward.

Finally, our focus on two main egocentric VR interaction techniques is in no way comprehensive of the large number of interaction techniques in the literature. Possible future work could extend our experiment to many of other egocentric and exocentric methods of interaction found in the literature.

6 Conclusion
Education is poised to be a core application of VR in the coming years. With adoption of VR technologies growing, we expect to see more and more classrooms with access to head-mounted displays. These tools will not replace traditional learning environments but will attempt to enhance them by providing immersive, educational experiences augmenting traditional learning.