

University of Nevada, Reno

Evaluating User Experience in VR Applications

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science
in Computer Science and Engineering

by

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THE GRADUATE SCHOOL

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Abstract

User studies are an important part of Human-computer interaction (HCI) research that, when designed well enough to answer a research question, can lead to successful outcomes and better use of development resources. Designing user studies can be a challenge, however. Despite going in with best intentions, the data collected may not capture the information needed to answer a research question. It's possible that confounding variables reveal themselves during the process of running a user study. In this thesis, two user studies involving Virtual Reality (VR) are run. Their designs are evaluated and discussed for their strengths and weaknesses toward answering the original research question. Then, a proposal for using a scaffolding approach to design a user study for learning a language in VR is explored. The scaffolding study reveals many insights into potential comfort and social prerequisites that need to be measured and potentially broken into a separate study.

Dedication

I dedicate this thesis to my family and friends who supported me throughout this journey.

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I would like to thank my committee Dr. Frederick C. Harris, Jr., Dr. Sergiu M. Dascalu, and Dr. Xiaoshan Zhu for their invaluable guidance throughout my graduate studies.

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Chapter 1

Introduction

User studies are a tool in Human-computer interaction (HCI) research which allow developers to gain insight into how users' interests are aligned with current forms of software. When designed well, they can answer a research question, lead to successful outcomes and make better use of development resources. Designing user studies for software with a novel purpose can be a challenge.

Collecting data may not always go as expected due to unforeseen patterns of behavior in participants. Variables to measure at the beginning may not effectively capture what needs to be captured to answer the original research question. Observations over several runs of a study may suggest new, previously-unforeseen variables are present. The ability to analyze the resulting data and draw a meaningful conclusion potentially impacts these cases.

Doing a literature review and finding the methods used by other researchers can be a valuable starting point. Using the same types of tests and scales that other researchers have used in the past is beneficial as it allows your measurements to be compared against other researchers' measurements. Experience from running previous studies can assist as well. A researcher can gain experience by running studies, learning from them, redesigning studies, and running them again with subsequent changes.

The remainder of this thesis is structured as follows: Chapter 2 provides background knowledge into Virtual Reality, its applications, and tools for building multi-user VR. Chapter 3 provides the motivation and challenges for the proposed work.

Chapter 4 provides a look at a user study involving ergonomics in VR, along with critique. The documentation for the IRB (UNR IRB/irbnet:1992315-1) is found in Appendix A. Chapter 5 is a user study involving teaching a language using VR and critiques its methods. The documentation for the IRB (UNR IRB/irbnet: 2181433-3) is found in Appendix B. Chapter 6 then continues to look at designing a user study for teaching a language based on lessons learned from the previous study. The study design pivots as an unforeseen issue is encountered. Chapter 7 provides conclusions and discussion of future needed work.

Chapter 2

Background and Related Work

2.1 A Short History of Consumer VR

2.1.1 How it all began

The consumer-grade VR head-mounted displays of today offer stereoscopic imagery produced in real-time. Stereoscopic displays and content have existed for over 100 years. In the mid-1800s, the Stereograph was invented as a tool that could display photographs with depth. Many photographs have been developed and producing them became an entire industry. [27]. Later iterations of the concept have appeared in later years, such as the View Master.

The expectations of consumer Virtual Reality devices have changed over time. In 2025, generally the term refers to a device which can be mounted on one's head. This device produces stereoscopic video in real-time and responds to actions performed by a user. A common expectation is for this display to come with two hand-held controllers that are tracked in the same 3-dimensional space as the user. Alternatively, the users hands are tracked through the head-mounted display's outward-facing cameras. This definition of VR reflects the current market, shaped by past decade's consumer brands: Vive, Meta, Valve, Pico. Only 10 years ago, consumer VR headsets did not have tracked controllers. The original Oculus Rift CV1 released without tracked controllers. Later on, the Oculus Touch controllers were released as an upgrade.

Aside from consumer-grade devices, there are other types of devices that can give an individual an immersive simulated experience. One example is the CAVE system,

in which floor-to-ceiling projectors display the simulated world to the user. The user wears active-shutter glasses to gain a sense of stereo vision. The user's head is tracked so that the viewpoint in the virtual world is constantly updated. Room-scale systems such as the CAVE have their uses in research, but are expensive and inaccessible to everyday VR users. A nice overview of VR can be found in [13]. The rest of this chapter focuses on inexpensive or free options that are affordable to many people.

2.1.2 Modes of VR

Virtual Reality has several different types of experiences, each with their own advantages or uses. A very simple type of VR experience can be created from a photo or video shot with a 360 degree camera. These experiences capture the real world with the same amount of detail that a normal camera would. They also have about the same amount of interactivity that would be expected from a static photo or video. 360 content tends to distort scale, but is still helpful for transporting viewers into a different world or time. As an alternative to a flat 360 video or photo, it's also possible to create a simulated world that a user can experience. This world is rendered using 3D computer graphics and requires the same asset development that would be required of any video game. The environment needs to be created by an artist, characters need to be modeled, and interactions need to be scripted in code. Putting in the effort to simulate a world has its unique properties. At a basic level, the sense of object scale can be properly communicated. Users wearing a headset tracked in 6DoF (Degree of Freedom) space can move around and look at objects with a sense of perspective. It can also help with creating experiences that have expectations of the user. In the context of an educational application, it gives us the ability to present some sort of challenge. Interestingly, it's possible that a different set of biases is created from the use of this approach. The process of 3D modeling and scripting an environment means there are time and budget constraints to creating the 3D experience. Due to resource limitations or limited oversight from experience designers, some objects may be omitted from a scene, or represented in a simplified form. This is in contrast to a

simple 360 video or photo, where the camera simply captures everything it observes. This bias may be something to consider when choosing a VR mode. It's also possible to combine both of these modes for their good points in the same application.

Using a 360 video camera is one of many way of creating a VR experience from real life. Photogrammetry is another camera-based process. Using photogrammetry it's possible to use many photos to create a 3D model that approximates a real-world scene. The texture data may have more fidelity in some places that artists may not be able to capture. In other places, such as foliage, photogrammetry doesn't work well. Alternative ways of using those photos are emerging and rapidly evolving. In 2023, gaussian splats were a novel way of creating 3D scenes from a set of photos that allow users to move around. The original model proposed a gaussian as a graphics primitive, and was particularly expensive to render. Since the original paper, the gaussian splat-inspired pipeline has evolved, and recently has simplified back to rendering with blended triangles. Gaussian splats and derived methods are good at displaying foliage and reflections.

2.1.3 Currently Available Everyday Consumer VR

As of this writing, in 2025, in the US market for home VR equipment, there are a handful of products that are mainstream. The Meta Quest 3 and Meta Quest 3S are the current most affordable headsets and require no tethered PC to use them. They may be connected to a PC using a numerous amount of options, both wired and wireless, both made by Meta and made by 3rd party companies. The HTC Vive was originally only a PCVR system, but new VIVE systems are both standalone and PCVR. In general, the lower end market has mostly shifted to standalone Android-based VR systems that have an optional PC link component. The Valve Index, released in 2019, and the HTC Vive Pro 2 (2021) remain as some of the few popular PC-only VR systems.

2.2 Game Engines for VR Development

2.2.1 Unity

In Unity Engine, **C#** is the main programming language used. Assets such as 3D models and textures are created in external software, then imported into the project. Unity Engine features a powerful non-destructive asset importer that allows the developer to change settings such as compression and scale of assets. Unity Engine also features a very robust referencing system through corresponding `.meta` files created during asset import. These `.meta` files allow assets to work between vastly different versions of the engine. It also maintains references even when underlying class hierarchy for code is different, as long as the public interfaces stay the same. This allows for easy porting of content between different VR platforms based on Unity Engine. Unitypackage files can be created that allow easy sharing of prefab content between users, and can reference well-known assets as dependencies. A screenshot of the development environment can be seen in Figure 2.1.

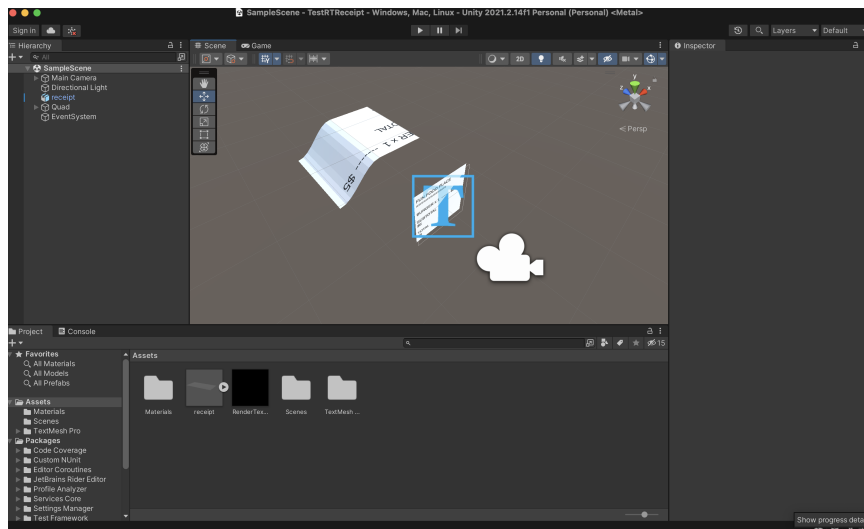


Figure 2.1: Unity game engine

in 2020, Unity began its transition from OpenVR to OpenXR. This transition was incomplete when first released and this created struggles for VR developers during this transition. Once this transition was complete it helped cement Unity as an easy

development platform because Unity assets are very portable. This portability makes it easy to move things around even if you don't know what you're doing. It just works.

Unity uses the **C#** programming language which has certain advantages in ease-of-use. Garbage collection prevents common memory-related errors. Asset store prefabs are portable across a wide range of Unity versions. The peer-to-peer portability of assets in Unity is key to its popularity in Social VR development. Other popular engines, such as Unreal Engine 5 are rarely used for Social VR despite their graphical capabilities due to the lack of asset portability.

There are multiple storefronts where users sell assets made for the Unity engine. The main storefront is the Unity asset store. This store is operated by the Unity Engine developers, and assets are broadly applicable to any new game project. Other popular stores that sell unity assets are itch.io, [gumroad](https://gumroad.com), and booth.pm. Assets sold on these platforms are also applicable to Unity in general, but also can be geared toward integrating toward specific applications. For example, on booth.pm, the 3D clothing category alone contains over 48,000 assets, each a piece of clothing which can be used with your VRChat avatar.

2.2.2 Unreal

Unreal Engine is a game engine created by Epic Games, creator of Fortnite. Unreal Engine supports two languages: **C++** and their own system called **Blueprints**. On a team, engineers are expected to use **C++** to write deep gameplay functionality. That functionality is then exposed to the Blueprints scripting interface used by designers on the team. Unreal Engine has a rich asset creation pipeline from within the editor. Importing assets to Unreal is a destructive process, and sharing assets between projects requires having both projects locally accessible, use same file path structure between both projects, and initiating a "Migrate" procedure from within the editor of the source project. This lack of flexibility creates challenges for moving assets between users in the context of a social VR platform, where each user may have their

own method of organizing projects.

Unreal Engine 5 generally supports most platforms, but as needs become more specialized, compatibility decreases. Usually documentation is incomplete and many features of the engine have delayed support for VR. When developing for mobile VR, even fewer engine features are functional. Unreal Engine has a VR template project that, while demonstrating VR technically working, is not designed to be used as a foundation for a new project. Basic software engineering design pattern concepts are avoided and unusual hard-coded logic is used in order to prevent changing engine settings from their defaults. Other templates such as `GDXR` are available by users in the development community, but such templates require first understanding UE development in order to benefit from.

2.2.3 Godot

Godot is an open source 2D and 3D game engine that has VR support. It's similar to Unreal and Unity in that it has a built-in asset management and conversion pipeline, level editor, built-in scripting editor. A language called `GScript` can be used to write games in Godot, with other language bindings such as `C#` existing as well.

The open-source nature of Godot makes it appealing to those who want to write software that can be archived and used in the future. As time goes on, ability to work with proprietary platforms like Unity will always be dependent on the actions of the company that owns and develops the software. Godot also takes no royalties from published software. This makes it possible to release an application for free. In contrast, the Unity engine had created an update to the license that charges a fee per app install, and began collecting more telemetry data to enable this fee. This type of license change is a challenge for those who want to release free or small-scale experiences.

Godot has a non-destructive asset importing pipeline that allows assets to be re-imported with different settings. The original assets are stored with the Godot project, similar to Unity. A screenshot of the developer environment for Godot can

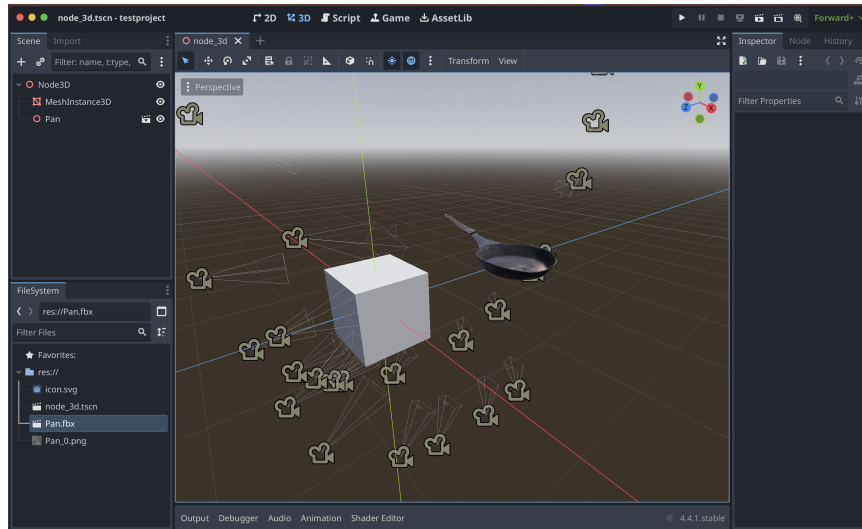


Figure 2.2: Godot game engine features a scene editor and offline documentation.

be seen in Figure 2.2.

2.2.4 LÖVR

LÖVR is a small open source framework for creating VR applications. Using the Lua programming language, a minimal project can be created with just a single `main.lua` file. This framework is useful for sketching out VR concepts in a more code-oriented manner. LÖVR has no scene editor; the user can write their own or create an importing pipeline from another 3D program such as Blender. LÖVR also comes with no lighting; instead shaders need to be written by the developer. LÖVR can be seen as a way to do low-level graphics programming with a high level language.

For the purposes of developing a VR application, LÖVR’s graphical flexibility may be useful when simpler or non-PBR (Physically-based rendering) graphical effects are required. Engines with highly-specialized PBR lighting models such as Unreal can make simpler types of unlit rendering more difficult.

2.3 Multi-user Frameworks and Applications

In 2025 there are many options for creating multi-user VR applications without needing to write avatar and networking code from scratch. This section explores some

notable options that would be useful for research.

2.3.1 VRChat

VRChat is the most popular Social VR platform in 2025, with over 40,000 players online across every time zone. VRChat is an immersive VR chatroom program (Figure 2.3). In this social platform, users can embody an avatar of their choosing, as shown in figure. Users can enter virtual rooms referred to as "worlds," that can be of any type of geometry. Nearly all content, both worlds and avatars, have been created by other users of the platform. VRChat even allows access to GPU shader programming, a highly unusual capability to be exposed to users in such an application, as shown in Figure 2.4, demonstrating programming of games in GPU shaders within VRChat. VRChat has a large number of users and features to meet others with the same interests. VRChat has a lot of potential for prototyping ideas. Due to its worldwide popularity, it's possible to work with people from cultures across the world. One thing to note is that VRChat has particular privacy requirements, so care should be taken if one wants to use it for research. In principle, player data cannot be egressed from the game. This includes but is not limited to usernames and other personal information. Additionally, recruiting from advertisements placed in the game is not allowed, but recruiting from other platforms and using VRChat to execute the study is okay.

VRChat uses a networking middleware called Photon. VRChat exposes a subset of Photon functionality to world creators building upon the VRChat SDK. This creates a development environment with similar challenges as those when developing peer-to-peer applications.

2.3.2 Basis

Basis is an in-development middleware for developing multi-user VR applications in Unity 6. It currently supports creating avatars and worlds which can be packaged into "BEE files." To prevent unauthorized access, these BEE files are encrypted af-



Figure 2.3: First-person point of view screenshot of a VRChat user looking at themselves in a mirror in the default home world. This scene is one of the first things a new VRChat user will see. The user can see themselves wearing the simplistic default robot avatar. An avatar selection UI panel is to the left of the mirror.

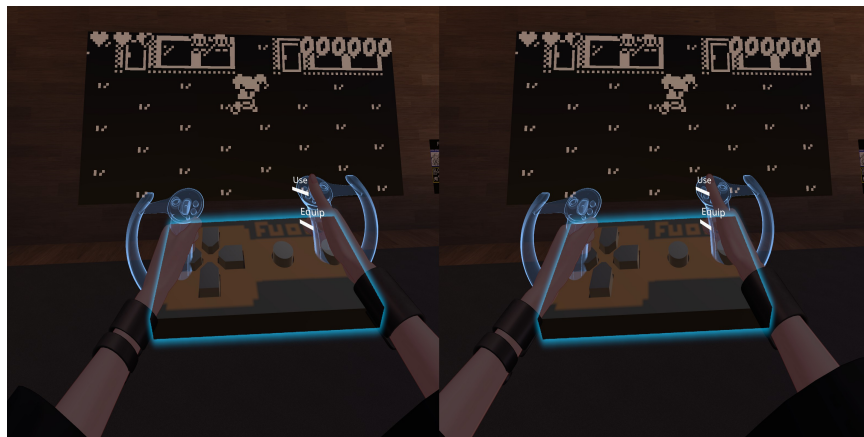


Figure 2.4: As a Social VR platform, VRChat gives users an immersive first-person experience. Using the Unity game engine, users create their own environments with industry standard tools, and even have access to GPU shader programming.

ter compilation, and a decryption key is generated. The application developer can distribute decryption keys in their preferred manner. As an option for building a VR experiment, Basis is an interesting divergence from others due to its middleware nature. It has no social graph, friends list, or any account functionality. This makes it much more appropriate for use in kiosks and more streamlined experiment procedures. Basis uses a client-server networking model (Figure 2.5).

Like VRChat, Basis runs on top of Unity Engine which enables conversion of content from VRChat to Basis, and vice versa. This can help learners as tutorials created in mind for VRChat content largely also work with Basis. It also means that the large marketplace for VRChat content can work with Basis. Basis also happens to be open source.

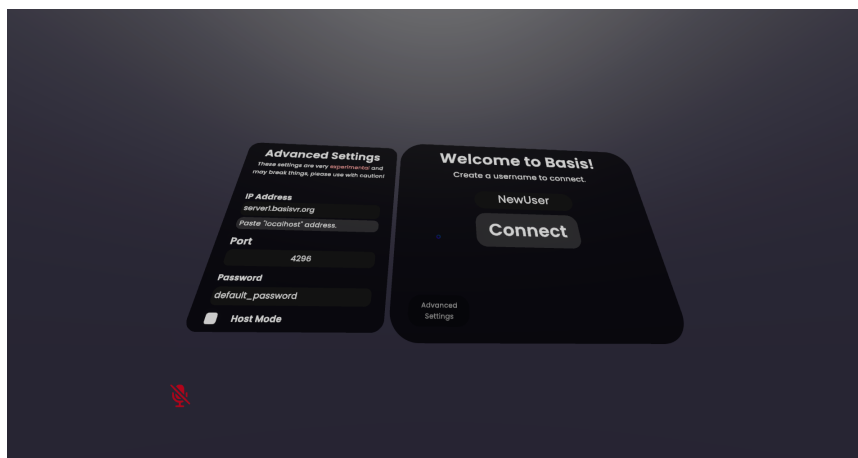


Figure 2.5: Basis client login screen. Basis has no user account system; a separate server must be hosted by the players to join.

2.4 Educational Software

VR has found use in educational software such as museum kiosks, employee training, and self-directed language learning. There are many motivations for employing VR in education. VR is able to capture a sense of scale and perspective that isn't possible with a flat display. The sense of perspective is one of the main reasons for creating the Seven Magic Mountains kiosk as a VR experience. Seven magic mountains allows

the users to view a 3D photogrammetry version of a land art outside the Las Vegas desert. In addition to the photogrammetry scene, there are 360 stereoscopic videos. These videos capture a very human aspect of viewing art in person: appreciating the other people appreciate the art. Recreating that type of appreciating as a VR character wouldn't create the same impact. VR is also good at delivering empathetic experiences. VR can make you play the role of another human from their eyes and ears. This aspect has led to very direct experiences such as *Becoming Homeless*, by the Stanford Virtual Human Interaction Lab [2].

Accessibility considerations need to be made for educational VR software as well. In general, wearing a VR headset can be taxing on the body, especially for new users. Motion sickness concerns are magnified in VR. One common cause of this "VR Sickness" stems from methods of locomotion. Moving your character in the VR world needs to somehow happen without you needing to move yourself in the real world. Depending on the method used for enabling this, the disconnect between the two world's spaces can cause users to feel dizzy or nauseous.

Self-directed language learning can benefit from VR as well. Applications such as *Noun Town* make use of it. A recent AR update to *Noun Town* adds memory palace-like functionality in the ability to place objects around your real-life room.

All of these applications sound exciting to an educator. But is there any empirical way of showing that they are effective? Is it worth the time and money to build a fancy VR experience or would it be better to make a simple video? Does feeling a strong sense of embodiment in VR help with the language learning process or can it lead to more distractions? How does the locomotion method used impact the comfort of the user? One way questions like these can be answered is through the process of running a user study.

2.5 User Studies

User studies are a useful tool for answering questions when humans are involved. User studies are structured as a formal process of carrying out the scientific method.

Before starting a user study, or when deciding what to study, a question needs to be asked.

A motivation to improve or learn something that involves human participants might lead a researcher toward performing a user study. If the researcher has a question they want to answer, but doesn't have a way of finding out through literature review, they'll need to design experiment to answer this question. This question needs to meet a few criteria though. It needs to have some way of being tested. Qualitative and quantitative data can be obtained from running a user study. These data can then be analyzed.

User studies involve human participants. This means an ethical review of the study needs to be performed before running the study. Different countries have different rules on ethics, exist a procedure for getting your study reviewed will exist. In the case of this thesis, at the University of Nevada, Reno, we work with our Institutional Review Board (IRB) to make sure our research respects the rights and welfare of participants (Figure 2.6). The process of filing with the IRB involves documenting every aspect of the study that will be conducted. Before collecting any data, the research question must be well understood. The IRB document must express the motivation for the question, and how humans can help answer it.

The protocol documentation is the most detailed part of the IRB document. In the protocol, the researcher will describe a complete step-by-step of what activities and interactions will be performed by a participant. Before any research can begin, participants need to consent. The consent form document includes the motivation for the study, the requirements of participants, and information on potential risks or benefits from participating in the study.

Recruiting participants for a study involves reaching out in several ways, such as email or flyers. All of these materials need to be submitted as part of an IRB application and reviewed. There are different types of reviews that can happen depending on risk factors. The fastest is an exempt review with minimal or no risk to participants. An expedited review takes longer and is necessary depending on the nature of the

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Figure 2.6: IRBNet

research. Full reviews will need to be done if there is risk to the participants.

Chapter 3

Motivation and Challenges

3.1 Motivation

The numerous unexplored opportunities for delivering educational experiences has led to much excitement around Virtual Reality in the past 10 years. @One in the MIKC at the University of Nevada, Reno, has developed several VR kiosks and exhibits teaching about the culture of the people and land around us. One kiosk is the Museum of Native American Basketry, which is located in the Pyramid Lake Paiute Tribe Museum and Visitors Center. This exhibit utilizes the Windows Mixed Reality-based HP Reverb G2 and is built in Unreal Engine 4. Another kiosk is Seven Magic Mountains, currently set up in the Nevada Museum of Art in Reno, Nevada. These kiosks are present in public spaces and built for patrons to experience in a self-serve manner. Building self-serve kiosks is a complicated process, however. Care needs to be taken to ensure the safety and comfort of users unfamiliar with VR by posting clear instructions and ensuring placement is in an open area with minimal obstructions. In terms of software, keeping inputs as simple as possible is also important, as different people have different motor ability. Helping to assemble these kiosks and provide code that manages the software has been an interesting experience in watching software work in unexpected ways. Improving the experience for visitors and making them comfortable to use is an important motivation.

Social Virtual Reality (SVR) is an emerging medium that enables anybody to meet a partner and exchange language at any time, any day. In the United States, it

can be difficult to find a partner to speak with outside of the language classroom. This can impact motivation toward learning languages in general. Social Virtual Reality offers a new opportunity for self-directed language learning. The ability to create multi-user virtual environments means that language learners are able to synthesize custom environments that can help them meet their language acquisition goals. Research into methods that can utilize the unique properties of the SVR medium is a motivation.

User studies can be useful tool for empirically measuring the effectiveness of a language tool or method. It can be difficult to build user studies for many reasons. The multiple domains of knowledge involved in SVR language education research makes literature review important and time-consuming. For example, Virtual Reality as a medium has its own sets of limitations. For decades, it's been recognized that new users to VR have a tendency to experience VR sickness. Research around the causes of VR sickness has led to recommendations and best practices for in-game locomotion methods, distance of text displayed, and other visual factors. In the domain of education and language learning with VR, understanding limitations around a user's sense of presence can help design a good methodology for performing user studies. Designing user studies to research in this area can require many iterations before putting into action.

3.2 Challenges

Running any user study that utilizes Virtual Reality tends to have a basic set of logistical, development, and theoretical problems. Starting with logistical problems, assuming the participant shows up on time, the participant needs to be willing to wear a VR headset. VR studies that include any sort of locomotion need to make sure to offer accessibility settings to avoid the participant becoming VR sick and ending the study early or affecting the results. Complications build further if an educational VR study is to be run. Participants must be willing to learn something. Measuring what is learned can require giving a quiz or other type of assessment. Additionally,

sampling bias due to recruiting participants for a study conducted at a university can easily bias toward other university students as participants.

Developing the software for running a user study is another challenge. VR development doesn't require anything specialized apart from the VR headset, but successful application design requires frequent testing with different ergonomic situations. For example, the developer needs to try sitting or standing when using the application. The developer needs to try using either hand for any action in the world. The developer needs to make sure that, if objects need to be held, that the locomotion method chosen does not affect the ability to perform the task with the held object.

Development becomes more complicated when the software must be multi-user. Network programming is an entire specialized field and as the two generals' problem illustrates, networking is hard. Building on top of an existing multiplayer framework can help alleviate development challenges. Programming aside, other resources are required for building a VR application. Art, level design, sound design, 3D modeling, character animation, and any other type of content required for the study will need to be produced. VR development is essentially game development. The content of the study needs to be developed as well. For example, for a study involving language education in VR, some sort of lesson plan or lecture needs to be created and delivered in a consistent manner for all participants. Additional resources or handouts for the study, such as a dictionary, may need to be prepared. These resources may need to be converted or completely recreated into the VR experience.

Learning the theory and limitations of VR is a challenge in itself. From the HCI researcher's perspective, VR is less of a single piece of technology and more of a medium. Many types of VR research require cross-disciplinary skills and knowledge. Computer Science, Psychology, Physiology, Pedagogy, as examples. To isolate variables for an experiment, much literature review is required across these domains. A helpful approach can be to learn from the methods previously used by researchers in their published work investigating a topic similar to the desired topic of research. The publication will often include useful scales and questionnaires that have been utilized

by numerous other studies. The inclusion of such a scale into a new study helps with contextualizing results across studies.

3.3 Direction

We are going to discuss these challenges in the following chapters by doing two user studies to examine the limitations of VR. In the first user study , physical limitations of VR are explored by asking participants to solve a task using three different input methods in Chapter 4. In the second user study, perceptual limitations of VR are explored by asking participants to watch a lecture and comparing learning outcomes between two different modes of presentation in Chapter 5. We will then tie in a planned user study to bring VR and Language Learning together in Chapter 6.

Chapter 4

User Study 1: Options Matter

Options Matter: Exploring VR Input Fatigue Reduction

This chapter first appeared as a Conference publication in ITNG 2024 [29]. Michael Wilson, Levi Scully, Vinh Le, Frederick Harris Jr., Pengbo Chu and Sergiu Dascalu, Options Matter: Exploring VR Input Fatigue Reduction, Proceedings of the 21st International Conference on Information Technology: New Generations (ITNG 2024) Advances in Intelligent Systems and Computing, Volume 1456 Chapter 37, pp 281-287. April 14-16, 2023 Las Vegas, NV. DOI:10.1007/978-3-031-56599-1_37

Abstract

Virtual and Augmented Reality are technologies that continue to touch the lives of consumers day in and day out. The very promise of immersion is what drives its consistent innovations, even years after the initial peak of interest. And much like the development of the mouse, input methods have to constantly be challenged and studied within all applicable domains to refine that immersion. In this paper, we present a VR User Study that immerses participants in a more non-typical domain for VR, Art Exhibits. While the current VR community tends to lean towards controls that are typical for video gaming, this study showcases a set of alternative VR inputs that 16 participants used to roam and interface with a curated exhibit. By leveraging the newer technologies provided in the Meta Quest Pro, participant metadata was autonomously recorded, processed, and stored without any need for external systems.

Based on the results from this user study, it was found that task completion times were slower for hand-tracked inputs compared to controller or gaze-based inputs. Additionally, there was no significant correlation found regarding the input accuracy between the three input methods.

Keywords: Virtual Reality, Controller, Input-methods, Hand Tracking, Gaze, Museum

4.1 Introduction

The ability to access and utilize technology is a fundamental human right, therefore it is extremely important to design applications with accessibility in mind. The emerging fields of consumer Virtual and Augmented Reality (VR/AR) are no exception to this. Counter to general intuition, these experiences can be incredibly meaningful for people with limited mobility, limb differences, and even low vision or no vision. While a multitude of controller designs exist, they all tend to fall into the same accessibility pitfalls, namely the manipulation of both controllers, buttons that are inaccessible for a users finger dexterity, and depending on the tracking technology used, keeping the controllers in the track-able field [17].

The majority of consumer VR experiences have little need for a highly accurate input method with high task completion time. Merely providing users with additional options for input methods can make the difference in improving their comfort or harming their experience in VR applications. And one such consumer domain that would benefit more from that increase in accessibility than specifically high accuracy VR inputs would be fields that observe Art and artistic expression. The gamification of VR inputs would detract too much from these experiences, whereas considerations made to quality of life and accessibility would yield the same beneficial bonuses it would at their normal medium of museums and exhibits.

In this paper, we present a VR user study designed to immerse participants into a virtual museum exhibit that consists of real curated art assets. The participants will navigate across three exhibits that contain a series of intuitive tasks that blend

into the normal experience of viewing exhibit. Each of these exhibits will be tailored to testing one of three VR inputs designed for this experiment: Gaze and Dwell, point and select with controller, and point and pinch with hand tracking. The participant data gathering methods utilized by this experiment are built directly into the VR application suit and leverages the strength of modern VR technology to autonomously collect data passively as a participant is guided through their tasks.

The paper builds on the numerous studies comparing input methods in VR, the first section will present an overview of the current research in comparing three input methods measured in this paper. The second section will introduce the details of a VR/AR user study focused on selection input methods, the third section lays out results from the user study and the comparative analysis, in the fourth section there is a discussion on the user study and the resulting data, finally section five provides a summary of the paper's findings with a conclusion and statement on planned future work.

4.2 Background & Related Works

4.2.1 Gaze Based Selection

As new technologies are introduced and existing technologies refined, it is imperative to continue research into these input methods. A study in 2017 comparing head-based dwell selection with eye-based dwell selection, which concluded that at the time eye-based selection offered poor performance in terms of error rate, selection time and throughput, however eye-based selection was deemed a less fatiguing and more comfortable experience [21].

Since the introduction of VR headsets capable of three degrees-of-freedom, the primary input method relied on was gaze-based input [15]. The general implementation of gaze-based input usually includes a ray cast originating from the user's head, while dwell, the colloquial term for the prolonged gaze method, involves a user looking at a virtual object for a consistent amount of time in order to invoke an action.

Initial studies found head-based gaze input to be a preferred, if limited, interaction method to others at the time [22, 15]. With the introduction of the dedicated virtual reality controller and headsets capable of 6 degrees-of-freedom, comparative studies at the time showed that while gaze based selection was slower, it was less prone to errors, had the lower target search time and a lower perceived cognitive load [4, 30]. Despite the potential for gaze-based input, in general, users were more likely to rank gaze and dwell as their least preferred input method [20].

With improvements to eye tracking technology there have been new input methods using eye tracking gaze-based input, such as using a combination of eye and hand tracking having the user make a pointing gesture as the selection trigger [25]. Eye tracking technology suffered from calibration errors with sensors drifting causing a high error rate and user frustration. Despite these barriers, eye tracking based gaze and dwell methods continued to show potential with lower cognitive load and the same perceived usability when compared to virtual reality controllers aim and select input [10, 16]. Because of the reoccurring findings of low cognitive load and the overall less fatiguing movement, researchers are motivated to continue research in eye-based gaze selection.

4.2.2 Controller Based Selection

Once consumer-grade headsets were capable of six degrees-of-freedom, the general design of VR systems started to see more of the adaption of traditional video game controller designs into Virtual reality controllers, such as the Meta Quest Pro and its controllers, shown in Fig. 4.1. This development expanded the selection methods with the introduction of the "point and shoot" selection method, described as a ray cast from the controller into the virtual environment where it serves as a medium to select objects that the ray intersects with a button press. Virtual reality controllers suffer from a major pitfall and that is accessibility for users without full motor control of their hands. A comparative study indicated that naturally-mapped virtual reality controllers offered higher speed and accuracy over gaze-based selection, as well as a



Figure 4.1: The Meta Quest Pro controllers are likely the more familiar choice among participants who have some experience with virtual reality.

increase in user presence and engagement [1].

Further research indicated that there was no significant difference in training outcomes when utilizing virtual reality controllers or hand tracking, and although participants preferred the controller, they reported hand tracking to feel more natural [5, 9]. While users tend to prefer controllers for most tasks in Virtual Reality, the actual performance difference between methods is small and some tasks in virtual reality are more suited to other interaction methods [7].

4.2.3 Hand-Tracking Based Selection

Before the introduction of machine learning models, hand-tracking was regarded as a more natural input method but ultimately unreliable [6]. Consumer headsets now ship with hand-tracking utilizing external cameras for reliable hand-tracking, thus enabling the utilization of hand-tracking into the VR research workflow. An example of this consumer headset style of hand-tracking is presented in Fig. 4.2 In a study comparing controller and hand-tracking interaction while performing two tasks, object



Figure 4.2: The Meta Quest Pro head-mounted display allows for the usage of hand-gesture recognition through auxiliary cameras.

manipulation and typing numbers found using hand-tracking for typing tasks had a statistically significant improvement over the virtual reality controller [28]. When comparing task completion with controller or hand-tracking, another study concluded that participants tended to use both hands when performing tasks via hand-tracking while primarily using their dominant hand with controllers, stating this was a direct outcome of hand-tracking feeling more natural [8].

Regarding a eye-based tracking system, a comparative study observed selection triggers between pinching index and thumb together, a button press on a virtual reality controller, and dwell. Ultimately, it was determined that pinch was slower and more error prone than controller input, but significantly faster than the dwell input, despite the findings suggesting that none of these differences were significant [18]. This highlights the potential in re-examining the effects of mixed and alternative interaction methods in VR applications and research.

4.3 VR User Study

4.3.1 Design

The basis of this user study revolved around two research questions. The first research question was that given the circumstance of the domain that this VR application covered, would an input method influence the time it would take for a participant to complete a task? The second research question followed a similar suit of asking whether an input method would be capable of influencing the number of misclicks when completing a task.

Regarding the overarching design of this VR User Study, it was constructed with the focus on input selection methods and was based around an within-subjects design. The independent variable for this experiment was the input method, with factors: gaze-based selection, controller-based selection, and finger-tracked selection. The dependent variables of this study include the objective task completion times and the number of misclicks per task for each input method. The task completion time was calculated internally inside the application using the delta between task start and task end. Unlike the task-completion time, the misclick counter was calculated differently depending on the input method.

For controller-based input, a click resulting in no action was considered a misclick. Similarly, any hand-tracked input pinches with no target counted as a misclick. Finally, the most difficult type of misclick interpretation to perform related to the gaze-based input. Due to the temporal nature of gaze-based selection and imprecise reticle, it's possible to have a false positive occur. For example, a brief graze over an arbitrary target while the user is moving toward the desired target might be a false positive. Despite this, for the purposes of this study, all types of grazes were included, and no heuristic was applied to disqualify such events from counting as misclick. This may need to be revisited in a future revision of the study.

The controlled variable of this study was the headset type and for this study, it was conducted using the Meta Quest Pro headset. No other headsets, even the

software-compatible Quest 2, were used. Fixing the headset type was important for this experiment because the physical design of the Quest Pro allows the user to see the world around them and VR at the same time. The presence of this design's openness may significantly affect the ease-of-use for the implemented hand-tracked input.

Qualitative data was collected during this experiment during the pre and post experiment questionnaires for basic demographic data and for the participants' current perception of VR comfort. Processing this data after the experiment was accomplished by writing an external Lua program that analyzed pairs of events and correlated them to meaningful data points. Task completion times as well as number of misclicks per task could be determined through collected data. After performing file conversion, the result was two types of CSV files for each user: a file containing the times for each task's completion, and a file containing the number of misclicks for each of the 9 tasks.

4.3.2 Software & Assets

The software for the experiment was built using the Unity game engine and the C# coding language. This was chosen due to the compatibility with the Meta Quest Pro, a stand alone headset capable of running the user study locally, requiring no rendering assistance from desktop hardware. New assets used to display any instructions for the participate in VR, were developed in-house and 3D models of controllers and hands were provided by Meta's Movement SDK for input on the Quest line of VR headsets.

The 360 degree video and real photo assets were used with permission as part of a modified version of a collaboration between the Nevada Museum of Art and the @One team of University Libraries, University of Nevada, Reno. The original exhibit was a virtual reality version of the "Seven Magic Mountains" land art by Ugo Rondinone. The modified version of the virtual reality exhibit was created to test three different input methods. Navigation through the exhibit was modified to utilize a selection method for each input tested. Each of these methods had users select and load into 360 video recordings, with three selections required for each input method,

while collecting data on the user events and pairing them with a timestamp.

4.3.3 Participants

Recruitment for participants in the experiment was done by email, explaining the basic motivation for the experiment and what was required of a participant. Additionally, participants volunteered to participate through word-of-mouth and given a formal briefing and flyer of the study. The participants were chosen primarily from a pool of University Nevada, Reno students and faculty. Sixteen adults over between the ages of 20 and 43 participated in the user study. The target demographic for the study were any adult over the age of eighteen who would be willing to put on a VR head-mounted display. The participants were not compensated for their involvement in the study. While initially described as taking as much as 25 minutes, in practice, most participants completed the study in around 15 minutes.

4.3.4 Procedure

The study was performed in-person using the same equipment for all iterations of the study. Each session with a participant was taken consistently to the same testing location, which was a laboratory on the fourth floor of the William N. Pennington Engineering Building, located at the University of Nevada, Reno. Before each session, every participant received the instructions regarding the study either verbally or through email. Additional information was provided on the study consent form when the participant physically attended the appointment to perform the study. Participants needed no additional items of their own prior to arriving. After signing the consent form, participants filled out a pre-experiment survey containing questions for basic demographic data and for the participant's current perception of VR comfort.

After filling out the pre-experiment survey, participants were given the Meta Quest Pro headset and were assisted by the study facilitator to comfortably and safely put it on. After the Quest Pro felt comfortable, the participant was handed the corresponding controllers. The participants were told that the experiment is self-



Figure 4.3: Menu screens to greet and guide participants through the experiment and into each subsequent set of tasks.

guiding and provides in-application instructions, but the facilitator remained nearby if something seems unclear. The experiment software guided the participant through each part of the exhibit and collected data at relevant times.

As a form of minor training and allowing for comfort, the participant was asked to navigate using a particular input method, where they were taken to a simple scene with an explanation and a button on which to practice, as seen in Fig. 4.3. After successfully completing the practice button, the data collection began, and the participant was placed into the exhibit to formally start. The software provides three objective tasks for the participant and allowed them to complete it any order they felt comfortable with. The tasks involved navigating the exhibit for a form of VR artifact that would contrast with the current assets, as shown in Fig. 4.4. This action would place them in a more focused part of the exhibit and thus completing the task. At their pace and upon completing the third task, the next set of input methods would activate, refreshing the objectives, and providing a means of training for the participants before continuing the study.

After the participant completed the ninth task, in the order preset by the facili-



Figure 4.4: The hub in which the data collection occurs and participants interact with the circular artifacts to complete a task.

tator to serve as a form of counter-balancing, the data collection officially concluded. The participant was shown a final scene thanking them for their time and the facilitator assisted in the removal of the headset. Finally, the participant was given a post-experiment survey. This survey again asked the participant about their general impression of VR comfort through a series of ordinal questions. From this information and the passively captured data in the headset, the entirety of the three input methods could be analyzed.

4.4 Results & Analysis

4.4.1 Task Completion Time Analysis

One of the research questions was whether the input method would influence the time it takes to complete a task. For this analysis, the null hypothesis is as follows: all input methods have the same or similar task completion times. The data gathered by the VR application and plugged into ANOVA was broken into three main factors, one for each input method. There was a fixed number of tasks run for each test. After running the test across 19 participants, 17 sets of data were usable. This is due to two records of individuals having logistical issues that were caused during the scheduling portion of the experiment. Running the ANOVA analysis for the task completion time among the three inputs produced a P-value of $0.0009 < 0.05$. Thus, one of the

ANOVA treatments is significantly different. Looking at Tukey HSD results, in the treatment pair between controller-based input and hand-tracked input, the P-value was 0.0010053. The other pairs were insignificant: gaze-based vs controller-based had a P-value of 0.1153367, and gaze-based vs hand-tracked had a P-value of 0.1619902. This means for the case of controller-based vs hand-tracked, we can reject the null hypothesis.

4.4.2 Button Click Accuracy Analysis

For this analysis, the null hypothesis is as follows: all input methods have same input error rate. Like with the first investigation, the data was broken into three factors consisting of the input methods. The number of misclicks per user were input again into ANOVA for analysis. Unlike before, the resulting P-value was $0.2576 > 0.05$ for the second hypothesis, which indicates a that there is no statistical significance. Interestingly enough, the implication of this result can suggest that the input methods are all relative enough to be justified as accessibility options of similar importance.

4.4.3 Qualitative Results

The participants were given a 1-5 Likert scale rating choice for how much they enjoyed each individual input method. The mean rating for the gaze-based input method was 3.5, with the hand-tracked and controller-based methods averaging at 3.6 and 4.5, respectively. This means the controller-based input method was the most preferred, and gaze-based was the least preferred.

Eight written responses brought to light that the hand tracking was inaccurate and that issues occurred with both aiming and actuating the click. Coincidentally, five written responses indicated that the participants did not enjoy gaze-based tracking due to the advent of involuntary head movement which would disturb the activation. The time to activate the click was considered too long and caused participants a degree of impatience. While there is more criticism regarding gaze-based tracking, two written responses praised the accuracy of gaze-based tracking over that of the

hand tracking method.

In regards to feedback on the user study itself, a change to procedure was suggested by participants. To elaborate on this, when starting the hand tracking section, participants thought it would be helpful to add additional instructions to put the controllers completely away. The transition away from controllers was found to be too awkward. Furthermore, participants suggested increasing the size of the selection circles because the circle sizes were deemed too small and thus hard to click for the controller-based system.

4.5 Conclusion and Future Work

To summarize, this paper presented a VR User Study investigating the usage of input methods inside a consumer VR application. In this study, there were no significant differences found in performance, in terms of the number of misclicks, when comparing between gaze-based, controller-based, and hand-tracked input methods. In terms of time-to-complete tasks, hand-tracked falls significantly behind controller-based inputs. These results suggest that it would be beneficial to allow all input methods for work of similar precision. However, special consideration should be made regarding the time needed to be given to the users when applying a hand-tracked input method in a VR experience.

In regards to future work, the research and feedback from this user study will provide valuable insights in developing VR applications that exist outside of the common domain. One such domain would be in the field of education. Work is already underway for the development of a similar immersive environment but tailored towards mining education at a collegiate level. In regards to immediate research, repeating this study with other headsets may give more insight into how natural hand-tracked input truly performs. Finally, the upcoming Apple Vision Pro uses Pupillometry to enhance the precision of hand-track pinch inputs and the comparison between these headsets on the same experiment could yield an interesting result on the viability of the discussed input methods.

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Chapter 5

User Study 2: Actions Teach

This chapter will form the basis for a publication which is in the process of being submitted.

Abstract

Monolingual speakers often have issues learning a second language. Some reasons may be financial, others due to lack of confidence. One potential way to make a potential learner regain confidence is to use the safe environment offered by Virtual Reality to put them into a digital learning experience. This paper documents a study that does a simple comparison between two presentations of a language lecture in Virtual Reality. Through this, the study aims to look at whether a 3D model in VR is more effective than a video. It also aims to look at using cheap consumer motion capture hardware to create educational content. Finally it attempts to use a simplified language as a starting point to give people a taste of what learning a second language might be like. The results of the study were mixed. In general, both the video and the motion capture version of the experience had positive results across the board. But the increase in results was observed to be more positive in the video than in the motion capture version. This paper discusses some improvements to be made in a future version in order to better understand why.

Keywords: computer science, language acquisition, virtual reality, acting, education

5.1 Introduction

Many digital independently-paced learning tools feature static videos, variably coupled with flash cards using SRS for vocabulary, quizzes with voice recognition, and discussions of contemporary issues related to learning the target language, peppered throughout the book. These materials can serve the needs of many students as an evolution of a textbook. But what they often lack is an immersive element that challenges the learner to communicate and solve challenges. This paper documents an application that was built to experience in Virtual Reality. Cheap consumer Virtual Reality equipment is used for producing the motion capture of the actors, as well as playback of the experience. This paper also evaluates the module in the form of a user study and asks participants what they learned from experiencing it. The target language used for this experiment is Toki Pona, a language with only 120 words.

This paper explores two main research questions.

Question 1: Is a flat video better than a motion captured puppet animation in VR for teaching a language?

Question 2: Is it possible to use consumer VR hardware (in general) to improve confidence in peoples' ability to learn a language?

5.2 Background and Literature Review

There are many ways of teaching a language in a self-paced format. Lately one buzzword is “comprehensible input,” which refers to a style of learning in which input is prioritized. Input refers to target-language material that goes into the learner through visual or text experiences. The main idea is that, if the content is just able to be understood, the student will learn [19].

An experiment of comprehensible input and Toki Pona has been running for the past year, by a person who goes by Jan Telakoman. Jan Telakoman interviews participants who went through the challenge and has conversations with them in a regular podcast [26].

A book that is well-known and celebrated in the modern Latin-learning community is *Lingua Latina per se Illustrata: Familia Romana* [31]. This book uses a self-contained method of teaching Latin that requires no other languages. It provides a map and other pictures, and provided the student be familiar with at least one European language, the student should be able to figure out what the text says. The first sentence of the book is simple, and it continues to build from there.

Japanese resources such as Wani Kani, Bunpro, and Pimsleur are examples of learning resources that use a Spaced Repetition System (SRS) [3]. An SRS can be thought of as an advanced form of flash cards. When the system is working correctly, the student will be asked to recall an item at a moment in time that is near when they'd forget it. By playing close to this time boundary, the argument is that the memory will be formed even stronger than basic memorization. Wani Kani and Bunpro use web server-based tracking that is personalized for each student based on their correct and incorrect responses. Pimsleur uses a one-size-fits-all approach, due to it being prerecorded audio distributed on fixed media like CDs (and other analogous media).

As for learning Toki Pona, the 120 word language [12] used in this paper, since the publication of the original book in 2014, it's been able to be learned in a front-to-back book format. Previous guides and communities existed to learn the language, sometimes focusing more on linguistic definitions of how the language worked, rather than a learning guide to speaking the language. Guides that teach the languages have since been released [11].

5.3 Software Functional Specifications

Three general modes of VR immersion will be used in this effort and future ones. The least immersive is watching a non-interactive motion capture replay. A second approach that pauses the replay at key moments and allows the learner to take action is more immersive. Finally fully immersive experiences involve characters reacting to your actions in real-time and making decisions of their own.

This paper will use the first level of immersion. The experience will take place in a classroom. As the story goes, your friend is willing to teach you Toki Pona in the university in the evening after classes let out. The experience lasts for about 8 minutes, then concludes with the user taking off their headset.

High-level requirements

The first outcomes for this experiment are going to be whether participants can learn the basics of Toki Pona to be able to describe things around them. The user will learn exactly 20 new words. The user will have an opportunity to learn some of the basic Toki Pona grammar, as well as a subset of the vocabulary.

The Toki Pona ability of the participant will be evaluated by comparing their results between a pre-test and a post-test.

5.4 Software Design

Grammar Lesson: The initial grammar lesson is 8 minutes long. The Toki Pona student will be presented with a brief history and given a short introduction to the basic features of the language. The grammar lesson will likely have more content available than the student is able to learn in the 8 minutes. This is understood as part of the design in the first version of this experiment. To reduce complexity in running the experiment, no interactions will be required from the participants. A future version of the experiment will have some interaction.

Visual Work: Motion capture is the main animation technique to be used in this project. Consumer VR equipment, such as the Valve Index and Quest 2, coupled with the VIVE trackers, will be used to gather animation data. Shadermotion will be used to record animation data directly from within VRChat, using the exact models that will be applied to the final production.

Logic Work: The basis platform for this experience is going to be Unity-based VRChat. VRChat is the most popular Social VR platform as of this writing, and it is cross platform. It works on Windows and Android-based VR headsets. It is a useful platform to build from as it has a complete avatar IK system, multiplayer networking, as well as many accessibility features already implemented.

5.5 User Study Procedure

5.5.1 Participants

Participants were recruited through email, and were able to find out about the study through word-of-mouth. The motivation for the study and requirements for participants were described in the recruiting email. Participants chosen were students or faculty of the University of Nevada, Reno. Participants were required to be over the age of 18 and be willing to wear a VR headset. Thirty-six participants joined the study. Participants involved in the study were not compensated.

5.5.2 Procedure

The Oculus Quest Pro VR headset was the main piece of equipment used for the study, shown in Figure 5.1. All participants used this headset. The participants all showed up in the same location for participating in the study: a fourth floor laboratory of the William N. Pennington Engineering Building of the University of Nevada, Reno. Prior to performing the study, participants received instructions through the original recruitment email, or verbally, in the case they dropped-in due to word-of-mouth awareness. The consent form provided to participants included additional information about the study, and was provided upon the participant's arrival to the laboratory. The participants were not required to bring any materials of their own in order to participate. After signing the consent form, the study begins.

First, the participant was asked to complete a pre-test survey, as shown in Figure 5.2. This included basic demographic information, a question about VR usage



Figure 5.1: The hardware used for this experiment was the Oculus Quest Pro. This headset was chosen due to its adaptability for glasses, as well as the hope that new users would be less worried about being cut off from real life.

Language Questions

1. Have you wanted to learn a language before?
 1. Yes
 2. No
 2. Do you speak any other languages?
 1. Yes
 2. No
 3. Do you think there are any benefits to learning another language? If so, what might they be?
-

VR Questions

1. Have you used VR before?
 1. Yes
 2. No
2. Do you own a VR headset?
 1. Yes
 2. No
3. If you use VR regularly (at least once a week), how long is your average session?
 1. Less than 1 hour
 2. 1 hour
 3. 2 hours
 4. 3 hours or more
 5. I don't use VR weekly.

Figure 5.2: The pre-quiz aimed to gain basic information about the participants' experience with language and VR

frequency, and a question asking opinion on VR comfort. The survey also included likert scale questions, shown in Figure 5.3. Next, participants were given a quiz on the Toki Pona language, shown in Figure 5.4. It's expected that a participant unfamiliar with the language would get a score of zero. The purpose of the pre-quiz is to determine if the participant knew anything about Toki Pona, and if so, be able to measure any improvement in knowledge. Once the pre-quiz is completed, the participant was told about the Quest Pro headset and instructed to put it on.

This study is a between-subjects study, designed to test for differences between playback of motion captured animation between two modes: a flat video or an animated avatar. Depending on the group in which the participant was placed, one of two things can happen. If the participant is in the flat video group, they will watch the Toki Pona lecture as if it's just any other video projected onto the wall of a virtual classroom, as shown in Figure 5.5. If the participant was placed into the animated avatar group, they will see equivalent content, except an avatar is animated directly

Scaled Questions

From a scale of 1=Strongly Disagree to 5=Strongly Agree, please answer these questions.

1. I feel confident in my ability to study a new language.
2. I want to learn another language.
3. I feel like learning a new language can be enjoyable.
4. Toki Pona seems like a useful language for beginners to language learning.
5. I feel physically comfortable after wearing the VR headset.
6. I want to learn more about Toki Pona.
7. I want to try studying another language.
8. I want to travel to another country.

Figure 5.3: These likert scale questions were included in both the pre-quiz and post-quiz. The hope is that the scores would improve between the two

in front of them, and there is no video screen, as shown in Figure 5.6. In the actual study, there was no difference between the content except for the presentation mode.

After the lecture concluded, participants were instructed to remove the headset and fill out a post quiz. Then the participant were instructed to fill out a post survey. After that, the participant concluded their role in the study and may leave.

5.6 Results and Discussion

The results of this study were interestingly mixed. Thirty-six participants were willing to participate. The next few subsections outline the results found in this study.

5.6.1 Quiz Results

Starting with the positive results, nearly every participant who went through the study improved their scores for the post test. Grouping results into 9 buckets based on initial score, the results are as follows:

A total of 18 users scored 0 on the pre-test. Of these users, all showed improvement, with an average of 5.77 and median of 6 points out of 8 in the post-test. Only two users got below 50 percent of the questions correct.

A total of 8 users scored 1 on the pre-test. Of these users, all showed improvement, with an average of 5.75 and median of 6 points out of 8 in the post-test. All

Pre-Quiz

Please choose the best answer for each question. All questions are optional--if you don't want to or cannot answer a question, choose "no answer" or leave it blank. Please let the lab assistant know when you are finished.

Question 1:

When was Toki Pona initially invented?

1. 1890
2. 1887
3. 2001
4. 2014
5. No answer

Question 2:

About how many words does Toki Pona have, in the version we discussed today?

1. 60
2. 120
3. 200
4. more than 1000
5. No answer

Question 3:

How do you say "thanks?"

1. sina ni
2. sina pona
3. sina ike
4. sike palisa
5. No answer

Question 4:

Which of the following is a food?

1. tawa
2. sike
3. anpa
4. pan
5. No answer

Question 5:

What might "tawa wawa" mean?

1. Wait patiently
2. Look closely
3. Move quickly
4. Try again
5. No answer

Question 6:

Consider the following sentence: "mi pali e moku." What does "pali" most likely mean in this context?

1. make
2. eat
3. give
4. try
5. No answer

Question 7:

Which is the best way to say banana?

1. pan suwi
2. kili palisa
3. soweli loje
4. kipsi
5. No answer

Question 8:

Read the following passage.

mi moku e pan.
waso li moku e kili.
soweli li moku e waso.

What did the bird eat?

1. fruit
2. bread
3. bird
4. animal
5. No Answer

Figure 5.4: These eight quiz questions were given to participants before and after the lecture content.



Figure 5.5: The B group of participants, a total of 18 people, were shown an equivalent motion-captured performance of the flat video content while wearing a VR headset, as shown in this scene.

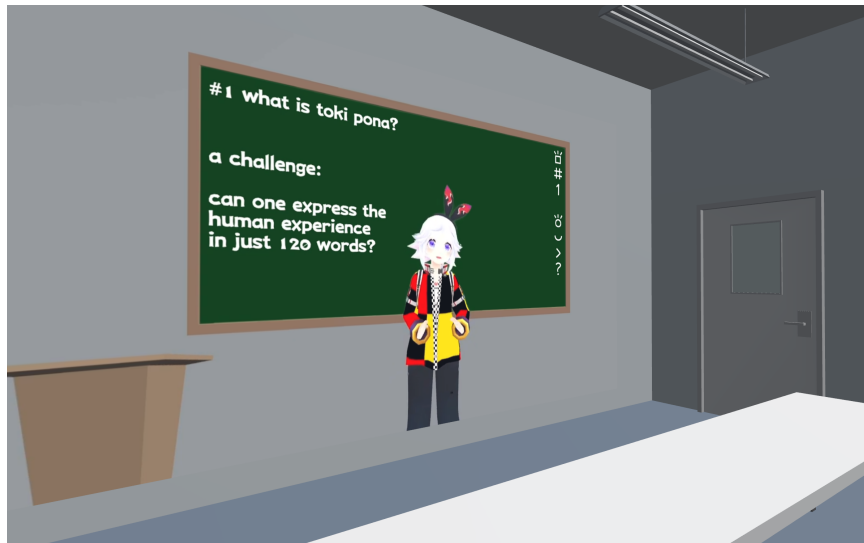


Figure 5.6: The A group of participants, a total of 18 people, were shown a flat video while wearing a VR headset, as shown in this scene.

users got at least fifty percent in the post-test.

Two users scored a 2 in the pre-test. Both users scored 6 in the post-test.

Four users scored a 3 in the pre-test. The post-test scores were 7, 7, 6 and 4.

Two users scored a 4 in the pre-test. The post-test scores were 6 and 5.

One user scored a 6 in the pre-test showing no improvement in their post-test score of 6.

One user scored an 8 in the pre-test, repeating their perfect score of 8 in the post-test.

5.6.2 Likert Scale Results

The Likert Scale results generally showed a positive trend. As a generalization, the average and the Each of the eight questions asked is described in this section.

- **Question 1:** I feel confident in my ability to study a new language.

The pre-survey had an average of 3.57 and median of 4 in the 35 usable responses. The post-survey showed an average of 4.09 and median of 4, with an average improvement of 0.51.

- **Question 2:** I want to learn another language.

The pre-survey had an average of 4 and median of 4 in the 35 usable responses. The post-survey showed an average of 4.43 and median of 5, with an average improvement of 0.43.

- **Question 3:** I feel like learning a new language can be enjoyable.

The pre-survey had an average of 4.14 and median of 4 in the 35 usable responses. The post-survey showed an average of 4.57 and median of 5, with an average improvement of 0.43.

- **Question 4:** Toki Pona seems like a useful language for beginners to language learning.

The pre-survey had an average of 3.31 and median of 3 in the 35 usable responses. The post-survey showed an average of 4.26 and median of 5, with an average improvement of 0.94.

- **Question 5:** I feel physically comfortable after wearing the VR headset.

The pre-survey had an average of 3.74 and median of 4 in the 35 usable responses. The post-survey showed an average of 4.14 and median of 4, with an average improvement of 0.4.

- **Question 6:** I want to learn more about Toki Pona.

The pre-survey had an average of 3.74 and median of 4 in the 35 usable responses. The post-survey showed an average of 4.03 and median of 4, with an average improvement of 0.29.

- **Question 7:** I want to try studying another language.

The pre-survey had an average of 4.11 and median of 4 in the 35 usable responses. The post-survey showed an average of 4.37 and median of 5, with an average improvement of 0.26.

- **Question 8:** I want to travel to another country.

The pre-survey had an average of 4.43 and median of 5 in the 35 usable responses. Two participants reported -1, and two reported +1. Thus, no improvement is observable from the median or average.

In general the results seem encouraging. But there were some flaws with the questions. Question 4 and Question 6 assumed that the participant knew about Toki Pona. While some already did due to incidental factors, there was no explicit procedure that guaranteed a participant knew about the language. Some participants who did not know what Toki Pona was asked for clarification. For those participants, it was instructed to select the number 3 as the response option. Because of this mistake, question 4 and 6 should be considered flawed data and care should be taken to improve them for the next run of this experiment, to get more useful data.

5.6.3 Qualitative Results

The qualitative results of this study are encouraging. In the post survey, participants were asked for their opinions, and nearly all were positive. Figure 2 shows the questions asked in the qualitative section.

- **Question 1:** Did you feel any kind of physical discomfort issues while wearing the headset?

This experiment used the Oculus Quest Pro for every participant. Out of the 36 responses, 10 were unfavorable. Reasons listed were mostly due to the minor issues with the weight or blurriness. There were no complaints about wanting to take the headset and end the experiment. Positive responses praised the headset's ability to compensate for glasses spacing.

- **Question 2:** Would you like to share any suggestions you have to improve the lesson?

There were many good suggestions for improving the lecture. Importantly, it was mentioned multiple times that having a running glossary available during the entire experience would have helped. A few mentioned a desire for interactive parts to occur during or after the lecture. A few mentioned they liked the anime characters due to reducing the classroom anxiety they normally deal with. A few responses touched on proctoring issues that can be fixed in future runs of this study. One said that the brightness was too high. Another said the virtual desk was too low. In a future version of this study, making sure to allow users a chance to check their comfort before starting playback of the lecture might help.

- **Question 3:** Would you like to share any suggestions you have to improve the supporting educational material?

Most responses asked for more practice, such as breaking up the lecture with more call-and-response prompts. Introducing a recap at the end was another

popular suggestion. Another mentioned that it would be better if the virtual chalkboard would be left un-erased for the duration of the lecture. Another popular suggestion was to add a handout that would allow participants to review the content before the quiz.

- **Question 4:** Do you have any other comments?

Most comments said that the experiment was fun to go through, and that they thought Toki Pona seems interesting. One suggested that VR didn't add anything over a plain video. Another comment said that repeating words during the first half of the lecture was helpful.

5.7 Answering the Research Questions

The answers of Research Question 1 (Figure 5.3) are mixed. The results showed a generally positive trend in likert scale questions for both group A (flat video) and group B (motion capture). The flat video had slightly better results, which was unexpected and discussed in Section 5.6.1.

The answers of Research Question 2 (Figure 5.4) have positive results. Because of the general trend of participants improving their test scores in responses after the experience, it suggests the answer may lean toward yes. But until Question 1 can be fully figured out, it's hard to say whether VR adds anything unique to what was observed when answering Question 2. Still, it was encouraging that people enjoyed an experience that can be created on a budget of less than \$500 USD.

5.8 Short-Term Future Work

There were some issues with the methodology as presented in this version of the experiment. As a result, this experiment will be re-performed based on discussion on this section.

5.8.1 Methodology Changes

Based on the data, the flat video performed better. The reason for this might be due to issues in data collection. The experiment was performed over a period of five days. On day one and day two, the flat video was shown to participants. On day three and day four, the motion capture version was shown. On the final day, it was a mix. The participants in the first two days were generally more eager to try and already had a bit of familiarity with VR as well as with the language, at least in concept. This could have influenced the results.

Another reason the flat video might have performed better could have been due to the fact that most participants didn't have much VR experience, or didn't use VR regularly enough. This means that the experience could be distracting. The participants might have been thinking about how the experience stacks up as a person who had never used a headset.

More data needs to be asked for in future versions of the study as well. For example, two questions need to be added: "what is your first language," and "what languages do you speak?" These questions are important because people who already speak multiple languages are much more likely to catch onto an additional language. The target audience and primary motivation for this experiment is to see if monolingual speakers can increase their confidence. So it's important to know when a participant is not monolingual.

One way of potentially fixing the sampling bias is to change the way of recruiting participants. Instead of asking people who may be new to VR, it might be prudent to ask people who are daily users of VR instead. For this purpose, an existing social VR platform that's popular and users choose to spend many daily hours in, such as VRChat or Resonite, might be a more appropriate base of participants for the study. By creating the apparatus in Social VR and allowing participants to use their preferred control scheme and avatar, less bias might be present that results from an unfamiliar VR application.

5.8.2 Introducing Interactive Material

One of the considerations made when writing this application was to make the VR experience as simple as possible. The apparatus contained a simple, non-interactive video. The hope was that distractions would be kept to a minimum. But since the next version will take place in a Social VR environment where the participants are very familiar with locomotion and interaction options, the apparatus can be expanded slightly. The original intention was to have the lecturer give the student a ten-minute break. The student would then walk around the lecture hall and be able to interact with various objects. For example, a poster that pictures two people, one of whom walking toward a house, the other attempting to push the house, illustrates the usage of a particle that indicates the object of a sentence. When the participant clicks or otherwise approaches the poster, the lecturer might comment and explain the nuance behind the grammatical structure to help resolve such confusion. This poster serves to help reinforce what was taught during the lecture.

5.8.3 On Negative Feedback

In Mike Long's book, *Second Language Acquisition and Task-Based Language Teaching*, a term, "recasting," is used as an example of negative feedback [14]. Long describes negative feedback as important to the Task-Based Language Teaching way of teaching languages. Recasting occurs when a native speaker of a language fixes a learner's incorrect sentence by repeating it back to them, but keeping it conversationally consistent. For example, if an English student said something like "This pizza hot way too much" the recast by the native speaker might be, "Yeah, this pizza is much too hot!" It might be difficult for this testing environment to support recasting. But another type of gentle negative feedback might substitute instead.

This type of negative feedback might be self-administered by the student. Essentially, seeing the correct form appear immediately after the student makes an attempt, regardless of the system's ability to process the input, may help. In a language like Toki Pona, the orthography is incredibly simple, so pronunciation and pacing isn't

going to be an issue generally. As long as the student is occasionally reminded of the few basics (ex: the only stress should be the unconditional stress that occurs at the beginning of each word) the student can listen to the examples given back and make sure they are speaking it correctly. Another option might be to play back the student's voice a few seconds after the student says something. More literature review needs to be done here.

5.9 Long-Term Future Work

After re-performing the study with the previously-described changes, the next steps are going to be to expand the study to cover more scenarios.

This study incorporates module one of a planned six module experience. Each module will touch on different aspect of Toki Pona, and teach exactly 20 of the 120 words. Each module is hard-coded to be no longer than 24 minutes, no matter what. The modules in the complete version of the study are based on a real experience traveling to Japan and giving a presentation about a work project.

Each of these modules explores different aspects of language instruction. They also explore different types of interaction with motion captured characters.

- Module 1, this module, is a simple classroom exercise. It covers the basic forms of Toki Pona. It gives a brief moment to practice, then wrap things up. It demonstrates using cheap consumer VR equipment (As of this writing, the Oculus Quest 2 is only 200 USD) to do motion capture and develop a VR experience. This is one of the least interactive motion capture experiences, as the lecturer will generally not respond to the user, except during the free-roam break section described earlier.
- Module 2 explores the casual usage of Toki Pona while on a backpacking trip with a friend who is experienced with the language. The lesson gives students an opportunity to try describing the world around them. 20 more words are introduced. The content in this section is self-paced. If the learner can use

their information and synthesize things quickly, then they will be given more prompts and more opportunity to use the language. Like every other episode, the lesson will end at exactly 24 minutes.

- Module 3 is all about commands. At the end of the backpacking trip, it's time to set up the campsite. During this the learner will both give and receive commands related to pitching a tent, cooking food, etc. There will be no way to fail in this exercise. If the user cannot understand or otherwise is unable to complete a part of the exercise, the NPC will solve the issue instead, keeping the 24 minute timeline intact.
- Module 4 is another exercise in small talk. On your flight to the foreign country, you can choose to talk to your neighbor.
- Module 5 is about interacting with the written form of the language. The user is at the platform of a train station that is in the North/South direction. On the left platform, trains are going north. Two different colors of cars arrive and leave. On the southbound side, some of the same colors are present, and some different ones appear, too. The participant is given a map in toki pona and must figure out which car to board.
- Module 6 is the final synthesis of everything learned. The user will be presenting at a conference. Strangers will approach the booth and ask questions.

Once the user has completed all six modules, they will have been exposed to all 120 words of the language, and been able to touch on all the grammar concepts. Due to the fixed time nature of each of the episodes, the student might not get all the content in the first play through. Some thought needs to be put into how to do a study that makes use of the episodes when they are made. Each of the modules is designed to be re-playable. If the student goes in with a higher skill level, more content in that episode may be enjoyable, and a second or third attempt would still provide benefit to the student. If a long-term study were to be performed, a consideration might be

whether to allow replays of episodes, and maybe to ask the student how many times a replay was attempted.

Chapter 6

Future User Study: Multi-user Language Learning

6.1 Introduction

In the previous two chapters, we looked at two user studies. We examined their research questions, procedures, and outcomes. We looked at how the user studies were run, how the data was collected, and how the data was analyzed. Then we critiqued how they answered the original research questions and suggested improvements. This chapter builds a new user study based on the lessons learned from the previous two. The research question that prompts this chapter's user study is examining whether VR applications can help with language learning, as compared to a traditional mouse and keyboard PC application. During the planning phase, a complication is encountered. A smaller-scale scaffolding study is proposed to learn about the nature of the complication so that the larger study can be run, once resolved.

Our goal is to learn the limitations of VR so we can build a good multi-user VR application to assist with language learning. We will perform user studies to evaluate this application. As of this writing, we have implemented the application but we have not run user studies. This chapter is a description of the application followed by a proposed method for evaluating it with a user study.

6.2 An Overview of the Multi-User Language application

The novel aspect of this application is a social context-aware prompting system. The application is designed for two simultaneous users. These two users can pick a language they would like to learn. As the users experience the virtual world around them, prompts with suggested sentences in the target language will appear, as seen in in Figure 6.1. A user may select one of these prompts to display it above their head, as seen in Figure 6.2 The intention for this is to enable beginners to the language to speak the language without having to study it prior. The system is not intended to act as a translator, despite having a database of many sentences for many situations. It's a tool that is designed to strategically expose language learners to common forms in the target language and have them develop confidence through speaking the language.



Figure 6.1: The user's wrist has a prompting system that dynamically shows relevant phrases to the current social context. The first row of the prompt is the idiomatic phrasing for a particular sentiment in the user's first language. The second row is an example Toki Pona phrase that may be used to communicate the sentiment. The bottom row is a word-for-word substitute between the user's first language and Toki Pona. In the substitute, Toki Pona particles are omitted due to their language-specific grammar function that wouldn't be able to have a direct translation in another language.



Figure 6.2: One user tells another user that the axe can be used to chop the tree.

Users are able to use this application with a VR headset or with the mouse and keyboard. The first target language implemented is Toki Pona, with a Japanese option planned for the next version. Toki Pona was chosen as it is a very simple language to work with for both development of learning tools and testing language teaching in a short amount of time. Toki Pona is also very useful for user studies due to its relative obscurity. Participants likely have little to no prior exposure to Toki Pona words or grammar. The current implementation of this application uses the popular Social VR platform, VRChat, as a base framework. VRChat was selected because it offers a reliable networking option with a realistic avatar IK system. It is also free.

6.2.1 Prompting Design

There are many types of situations that are covered by the prompting system. These situations are grouped into several categories. Some example categories include the following: Event, Held, Location, and ContextFree. The Event category shows prompts that occur due to some global world event. When rainfall begins, prompts to display the sentiment of “It’s raining!” will appear, as seen is Figure 6.3. The Held category shows prompts that should be displayed when a user picks up an object. If the user picks up an axe, for example, a prompt such as “chop the trees using this



Figure 6.3: Global world events such as weather and time changes are contexts that have prompts available.

tool” will appear, as seen in Figure 6.2. The Location category prompts appear when the user stands in a specific place in the world. If the user stands next to a campfire, prompts such as “This fire is hot” will appear. The ContextFree category shows prompts that result from context created by users rather than anything observable by game logic or events in the world. For example: “Where are you?” or “Wait here.” are both contexts created by users, rather than the world. These types of sentences make sense to say in any situation, at any time.

There are two main reasons for categorizing prompts. The first reason is for display. The prompting system is not a translator and cannot guess what the user wants to say. It uses a simple heuristic to hopefully display helpful tips, at best.

To help show a balance of different context sources, multiple categories of prompts will always be shown as suggestions. The ContextFree category will always have at least one prompt represented. This is important because the relevance of prompts in this category cannot be guessed by the system. The system cannot guess the future strategic moves that players will make to solve the objective. The purpose for grouping the rest of the systems is for history purposes. As users interact with the world, new prompts appear and replace the old ones. Sometimes the new prompts come in too quickly for the user to click on the button with their desired sentiment.

For example, consider a user picking up an axe while walking toward the fire pit. The axe prompts will immediately show and then be quickly replaced with the fire pit prompts. If a time-decaying weight is introduced for previous categories to remain as prompt candidates, there is still a chance the user will see something related to the axe that works for them.

One question that might remain is, “why not simply display all prompts as a history?” That is a valid question that may be reserved for a future user study. The choice of a small selection in the current implementation stems from the fact that screen space and physical world space in VR are both limited. A large list of prompts would take up too much of the user’s view, and scrolling might cause distraction from the conversation. The hope for this prompting system is to avoid users dwelling too much on it. The system is purposely meant to not be relied on too much; the intention is that users will grow out of needing it over time once they have been exposed to forms present in the target language and built up some confidence in speaking the target language.

6.2.2 Intended Usage

The system in this application is designed to build confidence in the users ability to speak the target language. The system does not work as a translator, and it cannot guess what the user needs to say. However, it will hopefully expose the user to common forms in the target language.

The system can be applied to various different environments. The application in this paper demonstrates its usage in a simple survival-crafting game. This system has also previously been implemented by the author for a social contexts around visiting a friend’s home. A future adaptation the author wishes to create is a coffee shop role play.

6.2.3 Environment Scenario

The implementation described in this paper provides a two-user learning environment. The two learners are given simple survival scenario, in which they are to work together to build a raft to escape from a deserted island. To build the raft, the learners must chop down trees and place them into a raft construction template, as shown in Figure 6.4. The two learners will try not to use any language other than the target language for communication. Body language is also acceptable.



Figure 6.4: Participants must chop down trees and place the logs into the blue template. Once all four log templates have been filled, the objective is complete.

As the learners build the raft, certain world events will occur. A rain storm will pass through, lightning will strike, and then it will become a dark night. During the night, learners will have the opportunity to figure out how to light up the environment. Sticks from the ground may be picked up and lit, but they will burn out after a few seconds. There are campfires placed around the world. If the learners can figure out how to cooperate and pass a flame from stick-to-stick, they will be able to reach campfires farther away in the world, as shown in Figure 6.5. Future iterations of the application will add more types of interactions like this.



Figure 6.5: Torches can be lit when placed in fire. To light objects in far away places, participants must work together to beat the in-game torch burn-out timer.

6.3 Study Design

The design of this study is of an exploratory nature. Many factors can influence how people engage with a VR experience. Researchers may be aware of some of these factors ahead of time, simply through their personal experiences with designing user studies. For example, in our experience, first-time VR users have a tendency to get VR sickness. This leads to us to generally design studies that default to teleport locomotion setting. Similarly, avatar customization in Social VR platforms is one of the most important aspects of Social VR. New users have not had a chance to understand what kind of avatar they would like to use. To help facilitate this, a simple selection of different common types of avatars is provided at the beginning of the study. Finally, wearing a VR headset is taxing on the body. The weight of it can be unfamiliar and adjustments or eye breaks may be necessary. The study is designed to hopefully give users a break when they need it, so that fatigue will be less of a factor when running the study.

In each run of the study, five people will be present. The two participants will each need to wear a VR headset and be in a different physical room from each other. This means two researchers or assistants will be present to act as proctors. In addition,

a lecture will be given inside of VR. This requires a third researcher or assistant, in a third physical location, to act as a moderator.

In the study, participants are taught to speak a new language called Toki Pona. Toki Pona is a small spoken language with only 120 words. Toki Pona has only a few grammar rules and follows a particle grammar system, similar to Japanese or Korean. Toki Pona has been shown that it can be learned in a few months. The study proposed in this chapter is only one session, so a small language was a preferred choice.

When the participants arrive in the VR world, they will be in a scene with a campfire. The moderator will be present. The moderator will give a fifteen minute lecture on Toki Pona, and touch on three main grammar points. These grammar points will be all that is necessary to experience the world.

The style of lecture will be based around writing using in-world air pens, as seen in Figure 6.6. These pens allow an instructor to write text without having a board. The lines and strokes written with one of these pens can stay in the world as long as people are in it. This leaves a helpful spatial memory tool for learners of the language. For example, if a question was asked during the lecture about spatial prepositions, the diagram and arrows will linger for the entire session, even after the instructor leaves.

After the lesson, the players are given a task. Their situation is that they are stuck on an island and it's time to leave. The participants need to work together, using any scraps of Toki Pona they can use, or any body language they can use, in order to build a raft and get off the island. The gameplay is simple: to win, the participants will need to chop down four trees and construct a raft on top of the template, as shown in Figure 6.4. Once the template is fully filled, the objective has been met.

The task is very simple, and the participants are encouraged to try to enjoy using the task as a talking point for exploring the language they were taught, rather than as the primary challenge that must be overcome. In other words, it's not a game that features a language learning tool; it's a language learning tool that looks like a game.



Figure 6.6: The instructor teaches Toki Pona using air pens. The ink left behind will persist for the duration of the study. Learners can come back at any time to reference the written notes.

The participants are encouraged to look around the world and see what other kinds of interactions they can find. For example, the torches can be lit when placed into a campfire. Some unlit campfires are placed in further away areas. These fires can only be lit through cooperation of the players, as shown in Figure 6.5 due to torches burning out after few seconds. There are several interactions around the world that are designed to allow players to explore the language without worrying about the main goal directly.

A limitation of this study is that participants must be willing to learn a new language and be creative enough to try experimenting with it. The tool and environment are provided in the hopes they can help facilitate and inspire creativity, but at the end of the day, the willingness to use a language comes from within the learner, rather than as an external demand. Another limitation in the current implementation of the study is that it is possible to build a raft without cooperation between players. Currently, a log can be carried by a single user, but a desired change for a future version is to require both players to move logs, perhaps by means of a simultaneous lift, or by tying logs with a rope and having another player pull. (As a side note: a potential issue with a simultaneous lift approach is that it is incompatible with

teleport locomotion.)

6.4 Research Questions

The broad research question for this study is whether VR has any advantage over traditional mouse and keyboard inputs. This study also aims to explore the challenges of running a complicated multi-user study and collect feedback from participants on their experience. The study's many moving parts can lead to complications, so keeping an open mind and observing how to better isolate variables for implementing more precise studies in the future is a goal.

To measure the effectiveness of the Toki Pona lesson, a pre and post quiz are given. It is an eight-question, four-multiple choice quiz with only one correct answer per question. To help with the goal of improving user study methodology, Users are asked for their usage experience with Virtual Reality, and the Multimodal Presence Scale (MPS) by Makransky, Lilleholt, and Aaby will be used to assess presence. A post-questionnaire will ask about the participants outlook on language learning in VR. Finally, the participants will be asked to write in suggestions if they have any. While running the study, the moderator will need to note down observations. For example, users might not be able to break the social ice and talk to each other. The moderator can help conversations start so that the study can keep running. The goal is to minimize the need for moderator involvement by adjusting the future versions of the apparatus to match the needs of what the moderator was able to handle.

6.5 Protocol

This multi-user study involves two participants simultaneously working together to solve a challenge using an unfamiliar language. Both participants will meet physically on UNR campus with a researcher involved with this study, but in different rooms. A third researcher, referred to as the “moderator” for the remainder of this section, will be in a separate room and will help with running the study from within virtual reality

only. This study aims to compare using a VR headset against using a typical mouse and keyboard. The procedures described below are symmetrical for both participants.

6.5.1 Procedure for Group A (Both participants use VR headsets)

1. The participant will arrive in Room 1 or Room 2 as instructed by recruitment email communication.
2. The participant will be asked to complete the consent form (see the informed consent process section in this document for detailed information on this process).
3. After filling out the consent form, the participant will be asked if they are familiar with VR. A brief rundown of the hardware will be provided.
4. The participant will then be seated in a non-rolling chair if they prefer to sit. They may also stand if they prefer to stand.
5. The participant will be helped into the VR headset (Meta Quest Pro) by the researcher. Specifications of the headset are included.
6. The participant will be informed of VR comfort options, such as snap-turning, teleport locomotion. The participant will also be able to select an avatar to represent themselves in the virtual world.
7. After both participants have made their decisions, the moderator will bring both participants into the same virtual world, where they can meet each other and have a short conversation. Their identities will remain private. This should allow them to gain some familiarity with VR multi-user basics such as muting the microphone, making eye-contact and using body language in VR.
8. After five minutes, the researchers will remove the headsets from each participant. The participants will be offered food or drink and asked if they would like to stand up and stretch, and other types of comfort-related things.

9. The participant will be asked to complete the pre-test survey titled “A1.docx”. The researcher will also move away from the participant as described in the informed consent process section.
10. The participant will be asked to complete the pre-quiz titled “Q1.docx.” The participant will be informed they can take as much time as they need, and they can skip questions if they don’t want to or cannot answer them.
11. After that, the participant will wear the headset again. This time they are in a world that simulates a simple outdoor camping environment. The other participant and the moderator will be there as well.
12. Once both participants are fully present, the moderator will begin an explanation that includes the following points: - We are building a language learning tool with game-like features. - This study will have you try your best to speak a new language. - You aren’t expected to learn the language; instead try your best to use the little bits of knowledge you have and supplement them with the tools and resources provided in the virtual world. - Don’t worry about winning or losing, try to enjoy exploring the nature of speaking a new language. Use your imagination and have fun. - Try not to speak English or other languages. But it’s no problem if you accidentally say things in those languages here and there. The goal is to see how tools can help with language learning, not to test you.
13. After that, a short introduction to the target language, Toki Pona, is provided. Three simple grammar rules are demonstrated (noun phrases, subject-verb-object word order, and how to state commands). Protocol – SBER and Records 080921 UNR Research Integrity
14. The users are shown that they have a tool that has a dictionary, a cheat sheet with the explanation content, as well as a context-aware prompting system that

shows sentences based on what the users have done or might need to do next in order to continue the scenario.

15. Finally the users are told that that the scenario is that the participants are on an island and need to work together to leave. The goal is to build a raft.
16. The moderator leaves the scene but can still observe.
17. At this point, the participants are left to try their best to follow the instructions. If they get stuck or cannot figure out how to start working together, the moderator will help by appearing and solving any technical or other multiplayer-related issues.
18. After fifteen minutes, the experience concludes and the participants will remove the headsets. If the participants finish early, they may continue to socialize for 3 more minutes while the end animation plays.
19. After removing the headset, the participant will be asked to fill out a post-experiment quiz titled “Q2.docx”.
20. After the quiz, participant will fill out post-experiment survey titled “A2.docx”.
21. Once finished, the participant will be asked to leave the room and this portion of the user study will be completed.

6.5.2 Procedure for Group B (Both participants use typical mouse and keyboard)

1. The participant will arrive in Room 1 or Room 2 as instructed by recruitment email communication.
2. The participant will be asked to complete the consent form (see the informed consent process section in this document for detailed information on this process).

3. After filling out the consent form, the participant will be seated in a non-seated rolling chair.
4. The language learning application will be launched, and the participant will be able to choose an avatar to represent their in-world character. The participant will be provided with a headset and microphone for voice communication.
5. After both participants have chosen their avatars, the moderator will bring both participants into the same virtual world, where they can meet each other and have a short conversation. Their identities will remain private. This should to allow them to gain some familiarity with the application such as muting the microphone and using in-game emote gestures.
6. After five minutes, the researchers will disconnect the players from the shared world. The participants will be offered food or drink and asked if they would like to stand up and stretch, and other types of comfort-related things.
7. The participant will be asked to complete the pre-test survey titled “B1.docx”. The researcher will also move away from the participant as described in the informed consent process section.
8. The participant will be asked to complete the pre-quiz titled “Q1.docx.” The participant will be informed they can take as much time as they need, and they can skip questions if they don’t want to or cannot answer them.
9. After that, the participant will use the application again. This time, the application loads the participant into a world that simulates a simple outdoor camping environment. The other participant and the moderator will be there as well.
10. Once both participants are fully present, the moderator will begin an explanation that includes the following points: - We are building a language learning tool with game-like features. - This study will have you try your best to speak

a new language. - You aren't expected to learn the language; instead try your best to use the little bits of knowledge you have and supplement them with the tools and resources provided in the virtual world. - Don't worry about winning or losing, try to enjoy exploring the nature of speaking a new language. Use your imagination and have fun. - Try not to speak English or other languages. But it's no problem if you accidentally say things in those languages here and there. The goal is to see how tools can help with language learning, not to test you.

11. After that, a short introduction to the target language, Toki Pona, is provided. Three simple grammar rules are demonstrated (noun phrases, subject-verb-object word order, and how to state commands).
12. The users are shown that they have a tool that has a dictionary, a cheat sheet with the explanation content, as well as a context-aware prompting system that shows sentences based on what the users have done or might need to do next in order to continue the scenario.
13. Finally the users are told that that the scenario is that the participants are on an island and need to work together to leave. The goal is to build a raft.
14. The moderator leaves the scene but can still observe.
15. At this point, the participants are left to try their best to follow the instructions. If they get stuck or cannot figure out how to start working together, the moderator will help by appearing and solving any technical or other multiplayer-related issues.
16. After fifteen minutes, the experience concludes and the participants will log off. If the participants finish early, they may continue to socialize for 3 more minutes while the end animation plays.

17. After removing the headset, the participant will be asked to fill out a post-experiment quiz titled “Q2.docx”.
18. After the quiz, participant will fill out post-experiment survey titled “B2.docx”.
19. Once finished, the participant will be asked to leave the room and this portion of the user study will be completed.

6.6 Iterating on a study

While doing preliminary development of the study method, some interesting issues manifested. First, users who had never used a Social VR platform like VRChat had a very particular sort of alienation from their body. In other words, a lack of sense of embodiment. Regardless of whether in VR or in Desktop, preliminary observations suggest there is an embodiment development phase that needs to occur when introducing a player to VRChat.

To address this issue, we are led to further literature review the topic of sense of embodiment. Embodiment is covered thoroughly in [Embodiment-Kilten] and [24], and the questionnaire for embodiment can be found at [23] in several languages.

We will instead run a simplified study that include qs only one participant at a time. There will be a VR group and a mouse and keyboard group. The updated protocol steps are the following:

1. The participant will arrive in the room as instructed by recruitment email.
2. The participant will be asked to complete the consent form.
3. After filling out the consent form, the participant will be seated in a non-seated rolling chair.
4. The participant will fill out a pre-experiment questionnaire.
5. The participant will wear the VR headset, if in VR group.

6. The application will be launched.
7. The participant will be asked to change their comfort settings and choose their avatar.
8. The researcher will ask the participant questions about how they feel while also in the application using the same medium (VR or mouse and keyboard).
9. After the questions, the application will close. If the participant was wearing a VR headset, they will remove it.
10. The participant will fill out the post-experiment questionnaire.
11. After finishing, the participant will be asked to leave the room and the user study will be completed.

We hope to find if there are any significant differences in the sense of embodiment between the VR user and the desktop user. We also hope to see if there's any other distracting elements that may cause issues down the line for running the full version of the study. If we find that there is a low reported sense of embodiment in VR users for this scaffolding version of the study, we will need to figure out a better way of on-boarding users. Perhaps the study needs to take place over multiple sessions. Perhaps the participants may need to be frequent VR users to qualify as participants.

Chapter 7

Conclusions and Future Work

7.1 Conclusions

This thesis described how user studies are a powerful tool for improving the outcomes of software development and for improving how resources are used during development. A brief history of Virtual Reality devices, their uses, and some tools for developing multi-user VR applications are provided. After describing the concepts behind running user studies, two user studies that have been run are presented and critiqued. During the critique, the studies were assessed on how they were able to answer the research questions, and suggestions for improvement were provided. Finally, an in-depth look at a currently in-development user study is discussed. In particular, the final user study that is discussed had to be broken into a separate, smaller scaffolding study because a potential issue that might cause unreliable results had made itself known. In conclusion, using VR for education can be challenging, but by performing user studies and continually iterating on observations, it is possible to improve development outcomes and inform decisions on development resource allocation.

7.2 Future Work

For the future, the updated study proposal for Actions Teach needs to be run. Actions Teach presents a fully single-user VR language learning experience that's driven by a simple storyline. The experience is designed to be run in a single study session.

However, with more time available, doing a redesign involving running this study in a long-term fashion over multiple months is desired, as properly learning a language cannot be done in 30 minutes.

Additionally, running the multi-user study redesign would be beneficial. The starting point will be to run the scaffolding study. Assessing whether that study was able to capture the necessary information to determine whether the sense of embodiment is a factor in running the study. If it's determined that the sense of embodiment affects the outcomes in a significant way, the full study needs to be redesigned to be more accommodating. Perhaps making it take place over multiple months could be a way of allowing participants to build their familiarity with the social platform and have more of a sense of embodiment with their avatar as a result.

The full multi-user study is a large one, and there may be more confounding variables that reveal themselves. Keeping an open mind toward these and continuing to engage with the latest literature on related topics is going to be important. The scaffolding studies that emerge from needs of running the desired study can be helpful in their own right and if designed well, can serve the needs of other researchers.

On other notes, during literature review, some other areas of research that are under developed became apparent. Notable, there seems to be a lack of research into effectively creating subtitles in VR. There also is a notable lack of platform support for displaying subtitles in VR. For example, the Unreal game engine has a built-in subtitles feature for traditional flat monitor-based games. It has a way of playing back subtitles with very limited customization of presentation. While Unreal has a native ability to parse .srt subtitle files, Unreal does not expose the necessary functionality to its Blueprint scripting language. A C++ programmer must create a class that can forward the information to a Blueprint-based UI widget. Unity on the other hand, does have myriad options for accessibility prefabs and VR subtitles. That being said, there is not much empirical research on effective ways of displaying subtitles. A naive approach to displaying subtitles would be to mount a text box to the player's camera. This is simple but has issues. The roll of the user's head can cause the subtitles to

also roll, making the text harder to read.

In addition to the sensory issues, rendering issues are present with this approach. The text box needs to somehow render on top of everything else. If world objects occlude the text box, the subtitles cannot be read. Several games make different choices on how to resolve this. In Valve's *The Lab*, the subtitle plane is a world-space object that has a loose connection to the user's hand. It allows the user to push the subtitles out of the way if the user wishes to look down. The subtitles also avoid intersecting with world objects. There are other potential ways to render subtitles, and performing some empirical studies would help future game designers make a decision on what strategy to use.

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Appendix A

UNR IRB Application for Chapter 4 User Study

A.1 Consent Form

**University of Nevada, Reno
Social Behavioral Research**

Title of Study:	Options Matter: Exploring VR Input Fatigue Reduction
Principal Investigator:	Sergiu Dascalu, PhD
Co-Investigators /	Michael Wilson
Study Contact:	Michael Wilson
Study ID Number:	1992315-1
Sponsor:	N/A

SUMMARY OF KEY ELEMENTS:

Introduction

You are being invited to participate in a research study. Before you agree to be in the study, read this form carefully. It explains why we are doing the study; and the procedures, risks, discomforts, benefits, and precautions involved.

At any time, you may ask one of the researchers to explain anything about the study that you do not understand.

You do not have to be in this study. Your participation is voluntary. If you do not agree to participate, you will receive the care/education you would have received if the study was not taking place.

Take as much time as you need to decide. If you agree now but change your mind, you may quit the study at any time. Just let one of the researchers know you do not want to continue.

Why are we doing this study?

We are doing this study to learn about how to make VR more comfortable by providing options for input methods. We would like to find out which input methods are preferred as well as if mixing inputs during a session can improve comfort.

Why are we asking you to be in this study?

We are asking you to be in this study because you are an adult who is willing to wear a VR headset.

How many people will be in this study?

8-16 participants are expected to enroll in this study.

What will you be asked to do if you agree to be in the study?

If you agree to be in this study, you will be asked to navigate a VR preserved version of an art exhibit in the desert. You will be asked to wear a headset and sit in a chair. You will be asked to use three different input methods: gaze-based (look at an object to activate it), controller-based (point at an object and click to activate it), and finger-tracked (hold your hands in front of you and mimic a pinching motion in the air to activate an object).

How long will you be in the study?

The study will take about 30 minutes of your time.

What are your choices if you do not volunteer to be in this research study?

If you decide not to be in the study, tell the investigator and you will be allowed to leave.

What if you agree to be in the study now, but change your mind later?

You do not have to stay in the study. You may withdraw from the study at any time by leaving the room after informing the investigator.

What if the study changes while you are in it?

If anything about the study changes or if we want to use your information in a different way, we will tell you and ask if you want to stay in the study. We will also tell you about any important new information that may affect your willingness to stay in the study.

Is there any way being in this study could be bad for you?

Some users of VR headsets can experience discomfort. The headset is designed to be adjustable and compensate for glasses. But it is possible that the design is insufficient. If at any point in time you begin to experience pain, discomfort, or restlessness please remove the headset. We can repeat the test or stop altogether.

What happens if you become injured because of your participation in the study?

In the event that this research activity results in an injury, treatment will be available. This includes first aid, emergency treatment, and follow-up care as needed. Care for such injuries will be billed in the ordinary manner to you or your health insurance carrier.

Will being in this study help you in any way?

Probably not, although you may find whether or not you enjoy wearing a VR headset and using hand-tracked input.

Who will pay for the costs of your participation in this research study?

No costs are associated with participation in this study.

Will you be paid for being in this study?

You will not receive any payment for participating in this study.

Who will know that you are in this study and who will have access to the information we collect about you?

The researchers, the University of Nevada, and the Reno Institutional Review Board will have access to your study records.

How will we protect your private information and the information we collect about you?

We will treat your identity with professional standards of confidentiality and protect your private information to the extent allowed by law.

We will not use your name or other information that could identify you in any reports or publications that result from this study.

Do the researchers have monetary interests tied to this study?

The researchers and/or their families have no monetary interests tied to this study.

Whom can you contact if you have questions about the study or want to report an injury?

At any time, if you have questions about this study or wish to report an injury that may be related to your participation in this study, contact Sergiu Dascalu at (775) 784-6571 and/or Michael Wilson at (775) 784-4613.

Whom can you contact if you want to discuss a problem or complaint about the research or ask about your rights as a research participant?

You may discuss a problem or complaint or ask about your rights as a research participant by calling the University of Nevada, Reno Research Integrity Office at (775) 327-2368. You may also use the online Contact the Research Integrity Office form available from the Contact Us page of the University's Research Integrity Office website.

Agreement to be in study

If you agree to participate in this study, you must sign this consent form. We will give you a copy of the form to keep.

Participant's Name Printed:

Signature of Participant:

Date: _____

Signature of Person Obtaining Consent:

Date: _____

A.2 Cover Sheet

University of Nevada, Reno
Institutional Review Board
Part I, Cover Sheet

Last edited by: Michael Wilson

Last edited on: November 28, 2022

[\[click for checklist\]](#)

[1992315-1] Options Matter: Exploring VR Input Fatigue Reduction

Answer all questions on this form completely, include attachments and obtain signatures of Principal Investigator and the Responsible official prior to final submission on IRBNet.

I. Principal Investigator

Name: Sergiu Dascalu

Institution:

Department: College of Engineering

Telephone: (775) 784-4613

Email: dascalus@cse.unr.edu

Address: University of Nevada Reno, NV 89557 Office: SEM-236

COI Disclosure: Any financial interests related to this study?

Yes

No

If yes, COI Disclosure Explanation:

Could any external entity benefit financially from the results of this study?

Yes

No

II. Co-Investigator(s) or Research Team Member(s)

N/A

Name:

Department:

Institution:

Telephone:

Email:

COI Disclosure: Any financial interests related to this study?

Yes

No

If yes, COI Disclosure Explanation:

III. Student Investigator(s) N/A

Name: Michael Wilson

Institution:

Telephone: 7025017887

Email: michael64wilson@gmail.com

COI Disclosure: Any financial interests related to this study?

Yes

No

If yes, COI Disclosure Explanation:

IV. Project Information

Research Type:

Biomedical

Social Behavioral/Educational

Photographing or Video Recording:

Yes

Upload the Photo Release form.

No

Identifiable Information from Education Records:

Note that accessing education records for research purposes invokes FERPA regulations. In the protocol, address how records are accessed, whether researchers will access directory information only, and how written permission will be collected from students or parents for minor students. For more information on FERPA, see [IRB Policy 76](#).

Yes

No

Research Location:

VA Sierra Nevada Healthcare System

Saint Mary's Regional Medical Center

Renown Health

UNR Campus

Other -

International Research:

Yes

For international research, reference [IRB Policy 575](#) for details to address in the protocol.

No

If yes, specify the countries:

Renown Health Research Locations:

Renown Regional

Renown Pharmacy

- | | |
|---|---|
| <input type="checkbox"/> Renown South Meadows | <input type="checkbox"/> Renown Emergency Room |
| <input type="checkbox"/> Renown Pregnancy Center | <input type="checkbox"/> Renown Skilled Nursing |
| <input type="checkbox"/> Renown Outpatient Clinic | <input type="checkbox"/> Renown Hospice Care |
| <input type="checkbox"/> Renown Urgent Care | <input type="checkbox"/> Renown Home Health |
| <input type="checkbox"/> Renown Imaging | <input type="checkbox"/> Renown Rehabilitation |
| <input type="checkbox"/> Renown Lab | |

Requested Review Path:

- Expedited IRB Review
Complete Protocol - Social Behavioral Educational Research and Records Research or Protocol - Biomedical Research
- Full Board Review
Complete Protocol - Social Behavioral Educational Research and Records Research or Protocol - Biomedical Research
- Exempt Review
Complete Protocol - Social Behavioral Educational Research and Records Research
- Requesting a determination about whether a project is human research
Complete Request for Human Research Determination
- Requesting authorization to use an external IRB
Complete Request to Use an External IRB
- Reporting emergency use of an FDA-regulated drug or device
Complete Emergency Use Investigational Drug or Device
- Review of a Humanitarian Use Device
Complete Protocol - Humanitarian Use Device for Treatment or Diagnosis
- Research involving existing records or specimens
Complete Protocol - Social Behavioral Educational Research and Records Research

Risk Level:

- Minimal risk
- Greater than minimal risk (requires full board review)
- No known risk

Involvement of Vulnerable Populations:

- N/A, research will not involve vulnerable populations
- Pregnant women and fetuses
For research with pregnant women and fetuses, reference [IRB Policy 210](#) and [211](#) for details to address in the protocol.
- Prisoners
Complete Research with Prisoners
- Children (persons under 18 years of age)
For research with children, reference [IRB Policy 230](#) for details to address in the protocol.
- Adults with impaired decision-making capacity
For research with adults with impaired decision-making capacity, reference [IRB Policy 240](#) for details to address in the protocol.
- People who do not speak English

For research with people who do not speak English, reference [IRB Policy 250](#) for details to address in the protocol.

V. Funding Information

N/A

Sponsor Type:

- | | |
|---|---|
| <input type="checkbox"/> Federal Government | <input type="checkbox"/> Other Government (State/Local) |
| <input type="checkbox"/> Industry Sponsor | <input type="checkbox"/> Other Private Funds |
| <input type="checkbox"/> Departmental | <input type="checkbox"/> Subcontract |
| <input type="checkbox"/> Other: | |

Sponsor Name:

Grant/Contract Title and Number:

VI. Federal Agencies with Additional Requirements to Protect Human Participants

Please see the "Instructions to Researchers" section at the end of this form for a list of required supplemental forms and relevant policies.

- DoD
- DoE
- DoEd
- DoJ or NIJ
- EPA
- NSF
- VA
- N/A

VII. FDA-Regulated Research

- N/A, research does not involve drugs or devices
- Drug research

Trade Name

Generic Name

- Device research

Name of Device

Device Manufacturer

VIII. External Committee Approvals

- Thesis or Dissertation Committee
- Radiation Safety Committee

- Biosafety Committee
- Other:
- N/A

INSTRUCTIONS TO RESEARCHERS

[\[top\]](#)

You have completed Part I of the application process. **Preview** Part I and correct if needed. Print the last page so you have the list of the researcher forms and additional regulatory requirements expected for this research. Click **Save and Exit**. **Add** the remaining required documents (listed below or referenced in the researcher forms/applications), **address** the necessary regulatory and policy requirements in the protocol and other project documents, and then the PI should electronically **Sign** and **Submit** the project. Make sure to upload training documentation for all researchers listed on this form. If you have any questions, refer to the [IRBNet pages of the Research Integrity website](#).

Additional required researcher forms and policies/regulations:

- Complete Protocol - Social Behavioral Educational Research and Records Research

A.3 Post Questions

**University of Nevada, Reno
Social Behavioral Research**

Title of Study: Options Matter: Exploring VR Input Fatigue Reduction
Principal Investigator: Sergiu Dascalu, PhD
Co-Investigators / Michael Wilson
Study Contact: Michael Wilson
Study ID Number: TBD
Sponsor: N/A

Post-Test Survey

Participant ID #: _____

1. How do you feel right now about VR comfort? [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

2. Rate ease of use of the application generally [1 = Not easy to use, 5 = very easy to use]

1 2 3 4 5

3. Rate comfort when using gaze-based input [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

4. Rate comfort of use of the controller-based input [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

5. Rate comfort of use of the hand tracking-based input [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

6. What improvements would you recommend to make the software more comfortable?

A.4 Questions

**University of Nevada, Reno
Social Behavioral Research**

Title of Study: Options Matter: Exploring VR Input Fatigue Reduction
Principal Investigator: Sergiu Dascalu, PhD
Co-Investigators / Michael Wilson
Study Contact: Michael Wilson
Study ID Number: TBD
Sponsor: N/A

Pre-Test Survey

Participant ID #: _____

1. Please choose your age range:

18-26 27-35 36-44 45-53 54-62

60-68 Prefer not to specify.

Other, please specify: _____

2. Please select your gender:

Male

Female

Prefer Not To Say

Other, please specify: _____

3. Are you left or right handed?

Left-Handed Right-Handed

4. How often do you use VR?

Hours a day.

At least once a day

At least once a week

Less frequent than the above

Prefer not to specify.

5. How do you feel about VR comfort?

Very comfortable

A little uncomfortable

Not comfortable but still usable

Very uncomfortable, it's not enjoyable to use.

Too uncomfortable to put on.

N/A

A.5 Protocol



Protocol – Social Behavioral Educational Research and Record Research

1992315-1, Dr. Sergiu Dascalu

Background:

The latest developments related to Virtual Reality inputs offer promising glimpses into the future of accessible inputs. Since 6dof consumer VR started to pick up around 2015, players largely needed to have full motor control of their hands. This leads to an imbalance for individuals who experience discomfort when using VR with traditional controls and can make applications designed for longer experiences inaccessible to those individuals.

Study Aims/Objectives:

This study aims to learn more about what makes VR input comfortable and accessible. In concrete terms, the experiment has been set up to answer the following research questions: is there a significant improvement in comfort that can be obtained from different VR input methods for the same actions, and is there any comfort gain in allowing the users to switch between different input methods?

Study Population:

The participant will 18 years or older. Other than this, no inclusion or exclusion limitations on gender, ethnicity, or other personal details. The participant will need to be able to wear a VR headset and hold the controllers for about 15 minutes. The participant must not be under the influence of drugs or alcohol.

Vulnerable Populations:

N/A

Sample Size:

The minimum sample size target is 8, and the maximum to collect is 16.

Recruitment Process:

Participants will be recruited primarily through email. The participant will initiate the communication. The participant will be able to learn about the opportunity through fliers posted around campus. The contents of "RecruitmentEmail.docx" will be sent in response to a potential participant's inquiry.

Screening Procedures:

If participants are okay with wearing a VR headset after seeing the photo in the email, they can be included in the experiment. The headset is adjustable and is designed to accommodate different head sizes as well as glasses. However, if a participant finds they are unable to use the headset comfortably despite adjustments, they will be excluded from the experiment.

Informed Consent Process:

Before the participant puts on the VR headset and starts the experiment, they will be presented with a printed version of the file titled, "ConsentForm.docx". The researcher will then verbally read out the "Introduction" section of this document. The researcher will then ask the participant to read through the rest of the document, and then sign the document if they understand its contents. The researcher will provide a verbal explanation of the purpose of the study and answer the participants' questions and concerns. The researcher will then move away from the user to give them privacy and to set up the environment for a successful run through of the experiment.

When/if the user has signed the consent form, it will be collected into a locked file cabinet in MIKC 121. This room is protected by an additional passcode lock.

Data Collection Procedures:

1. The participant will arrive in MIKC 121 as instructed by recruitment email communication.
2. The participant will be asked to complete the consent form (see the informed consent process section in this document for detailed information on this process)
3. The participant will be asked to complete the pre-test survey titled "PreQuestions.docx". The researcher will also move away from the participant as described in the informed consent process section.
4. The participant will then be seated in a non-rolling chair.
5. The participant will be helped into the VR headset (Meta Quest Pro) by the researcher. Specifications of the headset are included.
6. The participant will be shown the title screen of the application.
7. The participant will press the start button of the application.
8. For the first portion, the participant will be asked to navigate to three different locations using gaze-based controls.
9. For the first portion, the participant will be asked to navigate to three different locations using controllers.
10. For the third portion, the participant will navigate to three locations using hand tracking.
11. For the fourth portion, the participant will navigate to three locations using the tracking method of their choice and can change method during the program.
12. After visiting the locations, the program will end.
13. The participant will be asked to remove the headset and fill out a post-experiment survey. "PostQuestions.docx"
14. Once finished, the participant will be asked to leave the room and this portion of the user study will be completed.

Study Duration/ Study Timeline:

Note the expected number and length of contacts/meetings and time commitment for participants and include an approximate end date of the study. For records research, include the time frame for records.

Study Locations:

The location in which the research will take place is in The University of Nevada, Reno's Matthewson IGT Knowledge Center (MIKC), room number 121. MIKC 121 is an office access controlled by a passcode which the researcher will have access to.

International Research:

N/A

Participant Compensation:

N/A

Risk to Participants:

There is a slight risk of discomfort caused by the shape of the HMD, as well as the imagery it produces. The headset is adjustable and designed to compensate for glasses. Despite this, the participant might have confounding issues or unforeseen that can prevent the headset from being comfortable. The risk is minimized by excusing the participant from the study if they have issues with the fit of the headset or experience noticeable discomfort. The participant will be reminded that they may quit the study at any time.

Benefits to Participants:

This research does not present any direct benefit to the participants.

Privacy of Participants:

The participant's privacy will be protected during recruitment by not telling anyone who is going to be in the study. This means only one person at a time will be emailed by the researchers and any initial recruitment will

be done via generalized emails to multiple people at a time. Informed consent will be handled on an individual basis right before the start of the study. The informed consent with their signature will then be placed in a locked cabinet in a locked room.

The only people who will have access to the data will be the researcher, Michael Wilson, and the PI, Dr. Sergiu Dascalu.

None of the data will be linked to individuals, except the informed consent form, which will not be linked to any of the data either.

Data Management and Confidentiality:

The informed consent paperwork will be kept in a locked cabinet in a locked location until all of them have been collected that are necessary for the study. Once that happens, the PI will take the paperwork and seal it in a box, to be shredded in the future per UNR policy. The data collected in the pre/post study, and from the headset itself, will be collected, analyzed for significant scientific findings, and then compressed and encrypted. This encrypted data will then be given to the PI for this project to store until destroyed, per UNR policy.

The only people who will have access to the data will be the researcher, Michael Wilson, and the PI, Dr. Sergiu Dascalu.

Approach to Analysis:

The data from the experiment will be analyzed based on the pre-test questionnaire and the post-test questionnaire. The comfort experienced will be obtained from this information. Additional analysis based on empirical data such as the time taken to complete each action as well as each task will be performed to understand the difference in task performance.

A.6 Recruitment Email

Recruitment Email Script

Hello there,

I am conducting a research study to assess the difference in comfort levels between different VR input methods. I am currently looking for 16 participants to conduct a user study to advance this research. Participants in this study will be asked to wear a VR headset while navigating a digital archival of a desert art monument. The entire process should take approximately 30 minutes. The location is MIKC 121. If you are interested in participating in this user study, please email Michael Wilson at mwil@nevada.unr.edu to set up a time that works best for you to complete the study.

Thanks,

Michael Wilson

Appendix B

UNR IRB Application for Chapter 5 User Study

B.1 Consent Form

**University of Nevada, Reno
Social Behavioral Research**

Title of Study:	Actions teach louder than words: Towards acquiring language through Virtual Reality
Principal Investigator:	Dr. Frederick Harris, Jr., PhD
Co-Investigators /	Michael Wilson
Study Contact:	Michael Wilson
Study ID Number:	2181433-1
Sponsor:	N/A

SUMMARY OF KEY ELEMENTS:

Introduction

You are being invited to participate in a research study. Before you agree to be in the study, read this form carefully. It explains why we are doing the study; and the procedures, risks, discomforts, benefits, and precautions involved.

At any time, you may ask one of the researchers to explain anything about the study that you do not understand.

You do not have to be in this study. Your participation is voluntary. If you do not agree to participate, you will receive the care/education you would have received if the study was not taking place.

Take as much time as you need to decide. If you agree now but change your mind, you may quit the study at any time. Just let one of the researchers know you do not want to continue.

Why are we doing this study?

We are doing this study to learn how to better teach language acquisition. This study compares different mediums to learn which might be more effective than others for acquiring a second language. We also want to know whether it's possible to make people more confident in acquiring a second language through the mediums used in this study.

Why are we asking you to be in this study?

We are asking you to be in this study because you are an adult who is generously willing to wear a VR headset for up to 30 minutes.

How many people will be in this study?

A minimum of 30 participants are expected to enroll in this study.

What will you be asked to do if you agree to be in the study?

If you agree to be in this study, you will be asked to do a few things. An opinion questionnaire will be handed to you, followed by a short pre-test of content that will be covered during the lecture. Then you will participate in a lecture by wearing a VR headset. After the lecture, you will be given a short post-test of content, and finally a post-experiment opinion questionnaire.

How long will you be in the study?

The study will take about 30 to 60 minutes of your time.

What are your choices if you do not volunteer to be in this research study?

If you decide not to be in the study, tell the investigator and you will be allowed to leave.

What if you agree to be in the study now, but change your mind later?

You do not have to stay in the study. You may withdraw from the study at any time by leaving the room after informing the investigator.

What if the study changes while you are in it?

If anything about the study changes or if we want to use your information in a different way, we will tell you and ask if you want to stay in the study. We will also tell you about any important new information that may affect your willingness to stay in the study.

Is there any way being in this study could be bad for you?

Wearing a VR headset for 30 minutes can be uncomfortable. If you begin to experience pain, discomfort, or restlessness we can take a break. We can repeat the test or stop altogether.

What happens if you become injured because of your participation in the study?

In the event that this research activity results in an injury, treatment will be available. This includes first aid, emergency treatment, and follow-up care as needed. Care for such injuries will be billed in the ordinary manner to you or your health insurance carrier.

Will being in this study help you in any way?

Probably not in any direct way. One hope is that maybe the study might people interested in learning a second language, so hypothetically there's could be a chance of that.

Who will pay for the costs of your participation in this research study?

No costs are associated with participation in this study.

Will you be paid for being in this study?

You will not receive any payment for participating in this study.

Who will know that you are in this study and who will have access to the information we collect about you?

The researchers, the University of Nevada, and the Reno Institutional Review Board will have access to your study records.

How will we protect your private information and the information we collect about you?

We will treat your identity with professional standards of confidentiality and protect your private information to the extent allowed by law.

We will not use your name or other information that could identify you in any reports or publications that result from this study.

Do the researchers have monetary interests tied to this study?

The researchers and/or their families have no monetary interests tied to this study.

Whom can you contact if you have questions about the study or want to report an injury?

At any time, if you have questions about this study or wish to report an injury that may be related to your participation in this study, contact Frederick Harris, Jr. at (775) 784-6571 and/or Michael Wilson at (775) 784-4613.

Whom can you contact if you want to discuss a problem or complaint about the research or ask about your rights as a research participant?

You may discuss a problem or complaint or ask about your rights as a research participant by calling the University of Nevada, Reno Research Integrity Office at (775) 327-2368. You may also use the online Contact the Research Integrity Office form available from the Contact Us page of the University's Research Integrity Office website.

Agreement to be in study

If you agree to participate in this study, you must sign this consent form. We will give you a copy of the form to keep.

Participant's Name Printed:

Signature of Participant:

Date: _____

Signature of Person Obtaining Consent:

Date: _____

B.2 Cover Sheet

University of Nevada, Reno
Institutional Review Board
Part I, Cover Sheet

Last edited by: Michael Wilson

Last edited on: April 10, 2024

[\[click for checklist\]](#)

[2181433-1] Actions teach louder than words: Towards acquiring language through Virtual Reality

Answer all questions on this form completely, include attachments and obtain signatures of Principal Investigator and the Responsible official prior to final submission on IRBNet.

I. Principal Investigator

Name: Frederick C Harris, Jr

Institution:

Department: College of Engineering

Telephone: 7757846571

Email: Fred.Harris@unr.edu

Address: Dept of Computer Science and Engineering / MS 171 Univ of Nevada, Reno 89557

COI Disclosure: Any financial interests related to this study?

Yes

No

If yes, COI Disclosure Explanation:

Could any external entity benefit financially from the results of this study?

Yes

No

II. Co-Investigator(s) or Research Team Member(s)

N/A

Name:

Department:

Institution:

Telephone:

Email:

COI Disclosure: Any financial interests related to this study?

Yes

No

If yes, COI Disclosure Explanation:

III. Student Investigator(s) N/A

Name: Michael Wilson

Institution:

Telephone: 17753576458

Email: michaelgwilson@unr.edu

COI Disclosure: Any financial interests related to this study?

Yes

No

If yes, COI Disclosure Explanation:

IV. Project Information

Research Type:

Biomedical

Social Behavioral/Educational

Photographing or Video Recording:

Yes

Upload the Photo Release form.

No

Identifiable Information from Education Records:

Note that accessing education records for research purposes invokes FERPA regulations. In the protocol, address how records are accessed, whether researchers will access directory information only, and how written permission will be collected from students or parents for minor students. For more information on FERPA, see [IRB Policy 76](#).

Yes

No

Research Location:

VA Sierra Nevada Healthcare System

Saint Mary's Regional Medical Center

Renown Health

UNR Campus

Other -

International Research:

Yes

For international research, reference [IRB Policy 575](#) for details to address in the protocol.

No

If yes, specify the countries:

Renown Health Research Locations:

Renown Regional

Renown Pharmacy

- | | |
|---|---|
| <input type="checkbox"/> Renown South Meadows | <input type="checkbox"/> Renown Emergency Room |
| <input type="checkbox"/> Renown Pregnancy Center | <input type="checkbox"/> Renown Skilled Nursing |
| <input type="checkbox"/> Renown Outpatient Clinic | <input type="checkbox"/> Renown Hospice Care |
| <input type="checkbox"/> Renown Urgent Care | <input type="checkbox"/> Renown Home Health |
| <input type="checkbox"/> Renown Imaging | <input type="checkbox"/> Renown Rehabilitation |
| <input type="checkbox"/> Renown Lab | |

Requested Review Path:

- Expedited IRB Review
Complete Protocol - Social Behavioral Educational Research and Records Research or Protocol - Biomedical Research
- Full Board Review
Complete Protocol - Social Behavioral Educational Research and Records Research or Protocol - Biomedical Research
- Exempt Review
Complete Protocol - Social Behavioral Educational Research and Records Research
- Requesting a determination about whether a project is human research
Complete Request for Human Research Determination
- Requesting authorization to use an external IRB
Complete Request to Use an External IRB
- Reporting emergency use of an FDA-regulated drug or device
Complete Emergency Use Investigational Drug or Device
- Review of a Humanitarian Use Device
Complete Protocol - Humanitarian Use Device for Treatment or Diagnosis
- Research involving existing records or specimens
Complete Protocol - Social Behavioral Educational Research and Records Research

Risk Level:

- Minimal risk
- Greater than minimal risk (requires full board review)
- No known risk

Involvement of Vulnerable Populations:

- N/A, research will not involve vulnerable populations
- Pregnant women and fetuses
For research with pregnant women and fetuses, reference [IRB Policy 210](#) and [211](#) for details to address in the protocol.
- Prisoners
Complete Research with Prisoners
- Children (persons under 18 years of age)
For research with children, reference [IRB Policy 230](#) for details to address in the protocol.
- Adults with impaired decision-making capacity
For research with adults with impaired decision-making capacity, reference [IRB Policy 240](#) for details to address in the protocol.
- People who do not speak English

For research with people who do not speak English, reference [IRB Policy 250](#) for details to address in the protocol.

V. Funding Information

N/A

Sponsor Type:

- | | |
|---|---|
| <input type="checkbox"/> Federal Government | <input type="checkbox"/> Other Government (State/Local) |
| <input type="checkbox"/> Industry Sponsor | <input type="checkbox"/> Other Private Funds |
| <input type="checkbox"/> Departmental | <input type="checkbox"/> Subcontract |
| <input type="checkbox"/> Other: | |

Sponsor Name:

InfoEd Proposal Number:

VI. Federal Agencies with Additional Requirements to Protect Human Participants

Please see the "Instructions to Researchers" section at the end of this form for a list of required supplemental forms and relevant policies.

- DoD
- DoE
- DoEd
- DoJ or NIJ
- EPA
- NSF
- VA
- N/A

VII. FDA-Regulated Research

- N/A, research does not involve drugs or devices
- Drug research

Trade Name

Generic Name

- Device research

Name of Device

Device Manufacturer

VIII. External Committee Approvals

- Thesis or Dissertation Committee
- Radiation Safety Committee

- Biosafety Committee
- Other:
- N/A

INSTRUCTIONS TO RESEARCHERS

[\[top\]](#)

You have completed Part I of the application process. **Preview** Part I and correct if needed. Print the last page so you have the list of the researcher forms and additional regulatory requirements expected for this research. Click **Save and Exit**. **Add** the remaining required documents (listed below or referenced in the researcher forms/applications), **address** the necessary regulatory and policy requirements in the protocol and other project documents, and then the PI should electronically **Sign** and **Submit** the project. Make sure to upload training documentation for all researchers listed on this form.

If you have any questions, refer to the [IRBNet pages of the Research Integrity website](#).

Additional required researcher forms and policies/regulations:

- Complete Protocol - Social Behavioral Educational Research and Records Research

B.3 Post Questions

**University of Nevada, Reno
Social Behavioral Research**

Title of Study: Options Matter: Exploring VR Input Fatigue Reduction
Principal Investigator: Sergiu Dascalu, PhD
Co-Investigators / Michael Wilson
Study Contact: Michael Wilson
Study ID Number: TBD
Sponsor: N/A

Post-Test Survey

Participant ID #: _____

1. How do you feel right now about VR comfort? [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

2. Rate ease of use of the application generally [1 = Not easy to use, 5 = very easy to use]

1 2 3 4 5

3. Rate comfort when using gaze-based input [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

4. Rate comfort of use of the controller-based input [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

5. Rate comfort of use of the hand tracking-based input [1 = Not comfortable, 5 = very comfortable]

1 2 3 4 5

6. What improvements would you recommend to make the software more comfortable?

B.4 Post Quiz

Post-Quiz

Please choose the best answer for each question. All questions are optional--if you don't want to or cannot answer a question, choose "no answer" or leave it blank. Please let the lab assistant know when you are finished.

Question 1:

When was Toki Pona initially invented?

1. 1880
2. 1887
3. 2001
4. 2014
5. No answer

Question 2:

About how many words does Toki Pona have, in the version we discussed today?

1. 60
2. 120
3. 200
4. more than 1000
5. No answer

Question 3:

How do you say "thanks?"

1. sina ni
2. sina pona
3. sina ike
4. sike palisa
5. No answer

Question 4:

Which of the following is a food?

1. tawa
2. sike
3. anpa
4. pan
5. No answer

Question 5:

What might "tawa wawa" mean?

1. Wait patiently
2. Look closely

3. Move quickly
4. Try again
5. No answer

Question 6:

Consider the following sentence: "mi pali e moku." What does "pali" most likely mean in this context?

1. make
2. eat
3. give
4. try
5. No answer

Question 7:

Which is the best way to say banana?

1. pan suwi
2. kili palisa
3. soweli loje
4. kipisi
5. No answer

Question 8:

Read the following passage.

mi moku e pan.
waso li moku e kili.
soweli li moku e waso.

What did the bird eat?

1. fruit
2. bread
3. bird
4. animal
5. No Answer

B.5 Post Survey

Post-Survey

Scaled Questions

From a scale of 1=Strongly Disagree to 5=Strongly Agree, please answer these questions.

1. I feel confident in my ability to study a new language.
2. I want to learn another language.
3. I feel like learning a new language can be enjoyable.
4. Toki Pona seems like a useful language for beginners to language learning.
5. I feel physically comfortable after wearing the VR headset.
6. I want to learn more about Toki Pona.
7. I want to try studying another language.
8. I want to travel to another country.

General Questions

Did you feel any kind of physical discomfort issues while wearing the headset?

Would you like to share any suggestions you have to improve the lesson?

Would you like to share any suggestions you have to improve the supporting educational material?

Do you have any other comments?

B.6 Pre Questions

University of Nevada, Reno
Social Behavioral Research

Title of Study: Options Matter: Exploring VR Input Fatigue Reduction
Principal Investigator: Sergiu Dascalu, PhD
Co-Investigators / Michael Wilson
Study Contact: Michael Wilson
Study ID Number: TBD
Sponsor: N/A

Pre-Test Survey

Participant ID #: _____

1. Please choose your age range:

18-26 27-35 36-44 45-53 54-62

60-68 Prefer not to specify.

Other, please specify: _____

2. Please select your gender:

Male

Female

Prefer Not To Say

Other, please specify: _____

3. Are you left or right handed?

Left-Handed Right-Handed

4. How often do you use VR?

Hours a day.

At least once a day

At least once a week

Less frequent than the above

Prefer not to specify.

5. How do you feel about VR comfort?

Very comfortable

A little uncomfortable

Not comfortable but still usable

Very uncomfortable, it's not enjoyable to use.

Too uncomfortable to put on.

N/A

B.7 Pre Quiz

Pre-Quiz

Please choose the best answer for each question. All questions are optional--if you don't want to or cannot answer a question, choose "no answer" or leave it blank. Please let the lab assistant know when you are finished.

Question 1:

When was Toki Pona initially invented?

1. 1880
2. 1887
3. 2001
4. 2014
5. No answer

Question 2:

About how many words does Toki Pona have, in the version we discussed today?

1. 60
2. 120
3. 200
4. more than 1000
5. No answer

Question 3:

How do you say "thanks?"

1. sina ni
2. sina pona
3. sina ike
4. sike palisa
5. No answer

Question 4:

Which of the following is a food?

1. tawa
2. sike
3. anpa
4. pan
5. No answer

Question 5:

What might "tawa wawa" mean?

1. Wait patiently
2. Look closely

3. Move quickly
4. Try again
5. No answer

Question 6:

Consider the following sentence: "mi pali e moku." What does "pali" most likely mean in this context?

1. make
2. eat
3. give
4. try
5. No answer

Question 7:

Which is the best way to say banana?

1. pan suwi
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4. kipisi
5. No answer

Question 8:

Read the following passage.

mi moku e pan.
waso li moku e kili.
soweli li moku e waso.

What did the bird eat?

1. fruit
2. bread
3. bird
4. animal
5. No Answer

B.8 Pre Survey

Pre-Survey

Language Questions

1. Have you wanted to learn a language before?
 1. Yes
 2. No
 2. Do you speak any other languages?
 1. Yes
 2. No
 3. Do you think there are any benefits to learning another language? If so, what might they be?
-

VR Questions

1. Have you used VR before?
 1. Yes
 2. No
2. Do you own a VR headset?
 1. Yes
 2. No
3. If you use VR regularly (at least once a week), how long is your average session?
 1. Less than 1 hour
 2. 1 hour
 3. 2 hours
 4. 3 hours or more
 5. I don't use VR weekly.

Scaled Questions

From a scale of 1=Strongly Disagree to 5=Strongly Agree, please answer these questions.

1. I feel confident in my ability to study a new language.
2. I want to learn another language.
3. I feel like learning a new language can be enjoyable.
4. Toki Pona seems like a useful language for beginners to language learning.
5. I feel physically comfortable after wearing the VR headset.
6. I want to learn more about Toki Pona.
7. I want to try studying another language.
8. I want to travel to another country.

B.9 Protocol



Protocol – Social Behavioral Educational Research and Record Research

1992315-1, Dr. Frederick Harris, Jr.

Background:

One issue that potential language learners face is lack of belief in oneself, perhaps mumbling something like, “I’m bad at learning languages.” Is this truly the case, or is it possible to give somebody an experience that inspires them to give it another try? Virtual Reality offers a potential way of immersing a language learner in an alternate environment more suited to learning. This study aims to explore aspects of language learning by presenting an introductory language lecture using of the simplest languages in the world, Toki Pona.

Study Aims/Objectives:

This study aims to learn how to better teach language acquisition, both in terms of controlling an environment and in building confidence. This study explores its questions by performing a comparison between watching and immersive motion capture lecture in VR, versus a traditional video while in VR. It seeks to explore the questions: Can VR be used to teach a language? Is it possible to use VR to build confidence in a learner?

Study Population:

The participant will 18 years or older. Other than this, no inclusion or exclusion limitations on gender, ethnicity, or other personal details. The participant will need to be able to wear a VR headset and hold the controllers for up to 30 minutes. The participant must not be under the influence of drugs or alcohol.

Vulnerable Populations:

N/A

Sample Size:

The minimum sample size target is 30, and the maximum to collect is 40.

Recruitment Process:

Participants will be recruited primarily through email. The participant will initiate the communication. The participant will be able to learn about the opportunity through fliers posted around campus. The contents of “RecruitmentEmail.docx” will be sent in response to a potential participant’s inquiry.

Screening Procedures:

If participants are okay with wearing a VR headset after seeing the photo in the email, they can be included in the experiment. The headset is adjustable and is designed to accommodate different head sizes as well as glasses. However, if a participant finds they are unable to use the headset comfortably despite adjustments, they will be excluded from the experiment.

Informed Consent Process:

Before the participant puts on the VR headset and starts the experiment, they will be presented with a printed version of the file titled, “ConsentForm.docx”. The researcher will then verbally read out the “Introduction” section of this document. The researcher will then ask the participant to read through the rest of the document, and then sign the document if they understand its contents. The researcher will provide a verbal explanation of the purpose of the study and answer the participants’ questions and concerns. The researcher will then move away from the user to give them privacy and to set up the environment for a successful run through of the experiment.

Data Collection Procedures:

1. The participant will arrive in WPEB 436 as instructed by recruitment email communication.

2. The participant will be asked to complete the consent form (see the informed consent process section in this document for detailed information on this process)
3. The participant will be asked to complete the pre-test survey titled “PreSurvey.docx”. The researcher will also move away from the participant as described in the informed consent process section.
4. The participant will be asked to complete the pre-quiz titled “PreQuiz.docx.” The participant will be informed they can take as much time as they need, and they can skip questions if they don’t want to or cannot answer them.
5. The participant will then be seated in a non-rolling chair.
6. The participant will be helped into the VR headset (Meta Quest Pro) by the researcher. Specifications of the headset are included.
7. After the participant puts on the headset, they can click the “start” button.
8. Depending on the variant of this between-subjects study, the participant may see one of two VR experiences:
 - a. The participant is in a VR classroom and a motion-captured lecturer is animated, walking around the classroom. After the lecture ends, the participant can wander the room for up to ten minutes and interact with a few objects in the room to get a feel for the language.
 - b. The participant is in a VR classroom and watching a video of a 3D animated lecture.
9. After the lecture concludes, the program will end.
10. The participant will be asked to remove the headset and fill out a post-experiment survey. “PostQuiz.docx”
11. The participant will be asked to complete the pre-quiz titled “PostSurvey.docx.” The participant will be informed they can take as much time as they need, and they can skip questions if they don’t want to or cannot answer them.
12. Once finished, the participant will be asked to leave the room and this portion of the user study will be completed.

Study Duration/ Study Timeline:

The study is designed to meet with a participant one time, for between 30-60 minutes. Approximate end date of the study is May 31, 2024. Due to the potential difficulty in finding participants to wear the VR headset, more time may be needed to achieve the desired number of participants.

Study Locations:

The location in which the research will take place is in The University of Nevada, William Pennington Engineering Building (WPEB), room number 436. WPEB 436 is a laboratory access-controlled by card key which the researcher will have access to.

International Research:

N/A

Participant Compensation:

N/A

Risk to Participants:

There is a slight risk of discomfort caused by the shape of the Meta Quest Pro VR headset, as well as the imagery it produces. The headset is adjustable and designed to compensate for glasses. The risk is minimized by excusing the participant from the study if they have issues with the fit of the headset or experience noticeable discomfort from the imagery produced by the headset display. The participant will be reminded that they may quit the study at any time.

Benefits to Participants:

This research does not present any direct benefit to the participants.

Privacy of Participants:

The participant's privacy will be protected during recruitment by not telling anyone who is going to be in the study. This means only one person at a time will be emailed by the researchers and any initial recruitment will be done via generalized emails to multiple people at a time. Informed consent will be handled on an individual basis right before the start of the study. The informed consent with their signature will then be placed in a locked cabinet in a locked room.

The only people who will have access to the data will be the researcher, Michael Wilson, and the PI, Dr. Fredrick C. Harris, Jr.

None of the data will be linked to individuals, except the informed consent form, which will not be linked to any of the data either.

Data Management and Confidentiality:

The informed consent paperwork will be kept in a locked cabinet in a locked location until all of them have been collected that are necessary for the study. Once that happens, the PI will take the paperwork and seal it in a box, to be shredded in the future per UNR policy. The data collected in the pre/post study, and from the headset itself, will be collected, analyzed for significant scientific findings, and then compressed and encrypted. This encrypted data will then be given to the PI for this project to store until destroyed, per UNR policy.

The only people who will have access to the data will be the researcher, Michael Wilson, and the PI, Dr. Fredrick C. Harris, Jr.

Approach to Analysis:

The data from the experiment will be analyzed based on the pre-test questionnaire, post-test questionnaire, pre-quiz, and post-quiz. The empirical information by measuring the amount of language learned will come from the quizzes. The opinion and insights of the viability of using VR for affecting language learning attitude will be learned from the pre- and post-questionnaire. The number of clicks/uses of classroom objects will be included in this information to help understand which were helpful.

B.10 Recruitment Email

Recruitment Email Script

Hello there,

I am conducting a research study to assess the effectiveness of language learning tools in Virtual Reality. I am currently looking for 30 participants to conduct a user study to advance this research. Participants in this study will be asked to wear an VR headset while experiencing a short language lesson. The language will likely be new to the participant. The entire process should take between 30 to 60 minutes. The location is WPEB 436. If you are interested in participating in this user study, please email Michael Wilson at michael64wilson@gmail.com to set up a time that works best for you to complete the study.

Thanks,

Michael Wilson