Evaluating the Translation of Episodic Memory Familiarity from Real Environment Spaces to Virtual Environment Spaces

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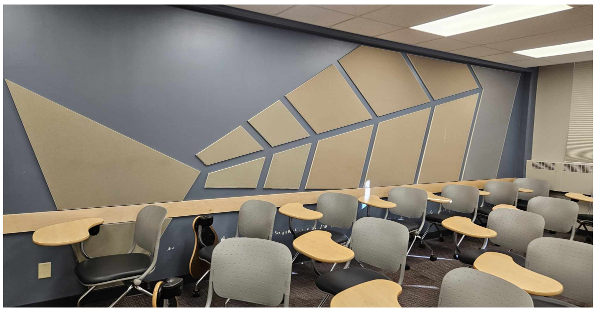

Figure 1: Image of the Chosen Real-World Environment

Figure 2: Image of the Virtual Environment

Abstract

This study aimed to explore the effect of object prioritization on recognition time and immersion in virtual reality (VR) environments. Participants were exposed to a series of VR scenes where objects were added in either high-to-low or low-to-high priority orders. We measured the time taken for participants to recognize the environment and assessed their sense of immersion through a Likert scale. Our findings revealed no significant differences in recognition speed between the two object priority conditions, but immersion increased steadily as more objects were introduced. Notably, objects like student desk chairs, classified as low-priority, were identified as key to recognition. This study emphasizes the importance of object abundance over prioritization for immersion, offering insights for designing more effective VR environments in applications such as training and education.

Keywords: Presence, Immersion, Virtual Reality, Virtual Environment, Real-World Environment, Episodic Memory, Passive Perception, Gray-Scale, Color and Texture, Between Subjects, Participant Immersion Ratings, T-Test, ANOVA, Likert-Scale.

1 Introduction

Virtual Reality(VR) aims to create an immersive, interactive, and realistic experience that enables users to engage and feel present within digital environments as though they were real. This goal will eventually provide a unique and realistic environment for individuals to explore, learn from, and manipulate. Currently VR is making massive headway on blurring the boundaries between reality and fiction with technical advancements that expand what is possible for scientific research. Researchers can now place participants into virtual environments without having to physically model the environment or subject the participant to physical dangers found in real world environments.

1.1 Significance

This new avenue of research often comes with the issue of whether the model is realistic and immersive enough to be an effective proxy for experimental assessments. The implications of research involving immersion in VR applications are promising for the future of various different real-world applications. Most notably, VR could be used for education within a multitude of learning environments. We aim to explore this known issue by modeling real world environments that our participants frequent in VR and evaluating their familiarity and recognition of said environments. As a result, in this report, we develop the following research questions: "Can we quantify the number of objects necessary to evoke environmental recognition?" and "can we qualitatively and quantitatively identify the level of detail in a virtual environment that starts to trigger a feeling of de-realization or place illusion?"

1.2 Problem Statement & Research Objectives

Through our research we have found that while there are a multitude of experiments testing individuals' memory in various virtual environments, none have attempted to quantify immersion. Most found that those who were more immersed in the environment produced stronger results, so we seek to attempt and fill this gap in knowledge by quantifying what number of objects is ideal for an individual to consider themselves immersed. We do not claim to be experts of neuroscience, that understand the granular processes in the brain that correlates with recognition, but with our experimental design we produce a level of quantifying immersion based on the number of objects in a virtual environment. This experiment itself can be taken and expanded upon to build a further understanding and quantification of immersion. Therefore, a 7-point Likert-Scale was used to measure the level of immersion each participant felt during each stage of the experiment.

For this project we aim to quantify the number of objects necessary to evoke environmental recognition and evaluate the accuracy of the participants' recognition. For this evaluation we will be quantitatively and qualitatively identifying the level of detail in the virtual environment that triggers de-realization or place illusion. We believe that high priority objects (objects with a more profound presence in an environment) will allow participants to recognize an environment before color and texture is introduced. We also expect that participants will recognize an environment faster when we iteratively introduce high priority objects before introducing low priority objects (objects with minimal presence in an environment).

2 Related Work and Background

One of our primary publications [Smith, 2019] creates an all encompassing perspective on different experiments that challenge episodic memory. One of the biggest takeaways from this paper is that quality and accuracy of episodic memory is strongly dependent on immersion in the environment. It accumulates various studies where participants would learn in a virtual environment then apply their learning to a real situation. These studies found that participants often performed similarly in real situations as they did in the virtual scenario. It also concluded that participants who found themselves more immersed produced higher levels of accuracy when tested for episodic memory.

In another publication [Tuena et al., 2017] research was conducted to determine if having control or seeming to have control of locomotion in a virtual environment improves episodic memory and feelings of presence. It was found that presence increased with better embodiment through motor control, and that full embodiment had a positive effect on episodic memory. The article also cites other studies which show that active navigation enhances episodic recall, however these studies were performed in non-immersive environments.

The research discussed in the paper, The Effects of Levels of Immersion on Memory and Presence in Virtual Environments: A Reality Centered Approach, explores participants' level of presence, task execution, and mental state when performing a mental recall tasks after being presented a seminar in a real world, 3D Desktop, 3D Head Mounted Display(HMD), or Audio-Only environment before task introduction [Mania and Chalmers, 2001]. Researchers found that presence was much higher for those who participated in a real world seminar than those who participated in one of the virtual counterparts prior to the spatial memory task, with no significant difference of performance between the virtual seminars. In their conclusion, they point at their decision to keep virtual environments as simple as possible to obtain a simple data set, while hypothesizing that having a more "vivid" or "realistic" environment "could have an effect on spatial perception retained in time" when associated with the HMD.

Our research plans to expand upon these concepts by attempting to numerically quantify the number of objects and level of detail that spark recollection in our participants. We have defined a Likert-Scale that will capture the participants feeling of immersion after we iteratively add more objects into the provided scene. This will help us determine if lower or higher priority objects have a larger impact on participants' recollection of a given space. How we determine the priority of objects will be discussed later in this paper. This is the key point of difference between our paper and previously found research. By iteratively introducing objects and texture into our scene we can quantify at what level future research should strive for to ensure a participant is properly immersed in the experiment. This will allow experiments to have a higher level of accuracy in results and aid in eliminating lack of immersion as a potential noise variable.

3 Methods

The hardware we used for this experiment was the Meta Quest 2 All-In-One VR Headset [Meta Platforms, Inc., 2020] where the user would be exposed to the scene and environment. The scene was run on a Acer Predator Helios 300, which utilized a NVIDIA RTX 3070 ti (Mobile) GPU, 16 GB installed RAM, and a 12th Gen Intel ® Core™ i7-12700H 2.70 GHz CPU [Acer Inc., 2023]. We hosted and built the scene using Unity version 6000.0.23F1 [Unity Technologies, 2024] and connected displayed the environment executable from the laptop to the headset using the Meta Quest Link software. This involved making custom objects that were a part of the scene which were modeled in Blender version 4.3 [Blender Foundation, 2024]. We hosted the experiment for Group 1 in a standard sized office room in Colorado State University's Lory Student Center's Adult Learner and Veteran Services Room 381 D and Group 2 was held in a classroom at Colorado State University's Wagar Building, room 133. The scene we modeled was that of Colorado State University's Wagar Building, room 133. We did so by taking measurements and photos of each object and its relative location in the room and rebuilt it to scale in Blender then imported the objects into Unity. We utilized free prebuilt asset package for the blinds [A.R.S|T, 2021], microphone [devotid, 2018], and ceiling texture [Loafbrr, 2023]. Our recreation includes an attempt at simulating accurate lighting, however Participant 2 of Group 2 (G2P2) made note that lack of accurate lighting from outside the window and incorrect light temperature detracted from their immersion in the scene. We have built a numerical system to categorize each object as low, medium, or high priority.

We will be measuring objects in two categories, each with a score of 1-3 and the sum of the score will determine what category it falls into (low priority: 2-3, medium priority: 4, high priority: 5). The first categorical measure we have is the uniqueness of the object. If there is only one of that object type in the room it will be given a score of 3, if there are 2-3 of the object type in the room it is given a score of 2, and if there are 3+ of the object type it will be given a score of 1. The next measure is awareness. Due to our participants being students, we plan to host this experiment from a student's perspective, which is facing the front of the classroom. If the object is actively in a students view it will be given a score of 2, and if the object is passively in a students view it will be given a score of 1. The objects in our environment and their relative priority can be found within the Appendix A: Item Priority Ratings.

3.1 Participants

For our experiment we selected 6 total participants, all of which were members of our class, so were known to be familiar with our chosen environment. They were selected through request for participation in a forum and in person. In exchange for their participation we offered to be participants in their experiment as well. Participants were of the age range 18-35, with a wide range of experience in VR. For example, G2P1 rated themselves as a 1 out of 7 on familiarity with VR and G1P2 rated themselves as a 7 out of 7 on familiarity with VR.

3.2 Experimental Design

The experiment was a 2-level between subject study. We assigned participants randomly into either Group 1 or Group 2. Group 1 would experience the objects and textures being introduced in the following order: high, medium, low. Group 2 would experience the objects and textures being introduced in the following order: low, medium, high. The participants would experience 7 total scenes in the environment where Scene 4 would show all the objects in gray-scale and Scene 7 would show all of the objects in color with their texture. This means each participant took 7 total guesses at the environment and rated their immersion 7 times during the experiment. Independent and Dependent variable can be seen in the table below (Figure 3).

3.2.1 Experimental Variables

Independent Variables	Dependent Variables
Color vs Grayscale Object spawn priority	Level of detail until recognition (Time) Accuracy (Number of guesses until correct) Level of immersion felt (Likert Scale)

Figure 3: The independent variables and dependent variables tested in this experiment

Color vs Gray-scale is the independent variable that represents when we start adding texture and detail into the scene. We anticipate this to have a large impact on the level of immersion felt. Object spawn priority is related to which objects are introduced to the environment in which order. This is our main independent variable we are testing to see if different priority of objects have more or less of an impact on the dependent variables. Level of detail until recognition is measured in time per scene. This will help us evaluate if object spawn priority has a high impact. Accuracy is the correctness of the guess of the scene location. Level of immersion is a Likert-Scale measure that helps us determine when and if the participant felt truly immersed in the environment.

3.2.2 Experimental Task

During the experiment, participants are tasked to press a button when they recognize the environment. This will pause the simulation bringing the user into a black box where they will be asked to make a guess at the specific environment location and how immersed they feel on a scale of one to seven. Afterwards the simulation will continue by incrementing the number of objects in the next scene. By measuring the time it takes a user to guess the scene it gives us a value in which we compare the speed of accuracy giving us an idea as to if high priority or low priority objects spark faster recollection. We anticipate participants will recognize the environment before texture is added, so this measure is mostly prevalent for the first portion of the experiment. We ask participants to rate their level of immersion to see if participants felt a higher sense of presence when more texture and detail is added. By measuring the level of immersion of the participant we gain insight on whether introducing higher or lower priority objects first invokes a higher sense of immersion.

3.2.3 Experimental Procedure

The experiment procedure began with us setting up the Meta Quest 2 and the Acer Predator Helios and testing the system to ensure when the participant arrived it was in functioning order promptly followed by the sanitation of the space. Participants were asked to stand outside of the room until they were called in to begin the experiment. This was to avoid potential spoiling of the environment or bias introduced from other participants. We would bring in the participants one at a time and greet them introducing ourselves and randomly assigning the participant a group number (1 or 2) and a participant ID. From there the participant would sign off on the consent form before they begin filling out the pre-experiment questionnaire. The questionnaire contained demographic questions, such as age range. We also wanted to analyze participants' prior experience in VR and their personal rating of their passive perception. This data was collected with the intent to help us explain potential outliers in the data we collected. We also followed VR research standards by providing a list of safety questions when utilizing a VR headset, including asking for potential symptoms associated with cybersickness [Services, 2024]. Once the questionnaire was filled out we reminded the participants of their right to withdraw from the experiment at any time if they felt uncomfortable or did not wish to continue participation.

Once the experiment began the participant was fitted with the Meta Quest 2 VR headset and walked through the controls of the experiment. The participant was instructed to press 'Start' on the left controller once they were ready to attempt a guess at the location of the scene. This will pause the environment bringing the participant into a gray pause menu where they will be tasked to to make a guess at the environment, and rate their immersion on a scale of 1 to 7. Once the participant understood the controls and were comfortable we placed them in the first environment. During the guessing stage between each scene we manually record the location guess of each participant and our system records the time spent in that scene leading up to the button press.

The base environment would be a blank, gray room with the same structural design as its counterpart. This meant the walls were to scale and openings where the windows were located were present. The environment will first improve by the number of objects, adding in a gray-scale version of the objects categorized in each priority dependent on the group the participant was assigned. For example a member of Group 2, which has high to low priority, would see the podium, trash can, whiteboard, etc., added to the environment on the second scene, then see the projector screens, computer chair, corner desk, etc., added to the environment on the third scene, finally ending with the low priority objects. Members of Group 1 will see low priority objects added to the environment first, ending with high priority objects.

When all objects have been added to the room in scene 4 we begin adding texture and color to the objects in the same order as they were introduced. For example a member of Group 1 will first see color and texture added to the student desk chair, outlets, fire alarm, etc. in scene 5, then in scene 6 they will see color and texture added to projector screens, computer chair, corner desk, etc., then finally the whole scene will be revealed with all the textures and colors applied appropriately to each object.

After the experiment the participants are subjected to a post-experimental questionnaire where they are asked questions related to their experience in the scenes. They are asked to indicate how familiar they are with the environment prior to the scene, indicate which object or objects made the environment most familiar, and if there were any areas that detracted from their immersion in the environment.

4 Result and Discussion

4.1 Overview of Results

The results of our experiment were obtained by measuring the time (in seconds) that each participant took before recording a guess of where each participant perceived the current environment to be located. Parametric tests are most commonly used for both interval and ratio data. As a result of measuring the time it takes each participant to postulate the environment in seconds, it was determined that a parametric test would be appropriate, given the quantitative and numerical nature of the data that was measured. ANOVA was the primary statistical method considered, due to its ability to determine if the independent variable contributes a significant and measurable difference on the outcome of the dependent variable.

4.2 Time to Recognition (Object Spawn Priority and Level of Detail)

H1: Object Priority and Gray-Scale Recognition Speed.

We hypothesized that introducing objects in order from high to low priority would lead participants to recognize the environment faster, before the addition of color and textures. However, our findings do not support this hypothesis.

Stage 1 (empty gray-scale room) and Stage 3 (gray-scale objects) exhibited the longest average task completion times across all participants. The empty room in Stage 1 provided minimal environmental cues, leading to slower recognition. Stage 3, which featured the medium priority gray-scale objects for both groups, also presented a complex environment that required more time to analyze.

4.2.1 Lack of Significant Effect of Object Priority on Recognition Speed

We hypothesized that adding color and texture to the previously gray-scale environment would significantly increase the level of immersion felt by participants. This assumption was based on the idea that visually richer environments provide more sensory input, which could enhance the user's sense of presence and engagement in the virtual environment.

In Stage 1, the VR environment contained only an empty, gray-scale box. The lack of environmental objects made it more difficult for participants to guess the location, which likely explains the longer time spent in this stage. Similarly, in Stage 3, participants often took additional time to examine the environment more thoroughly.

Additionally, we hypothesized that participants would recognize the environment more quickly when high-priority objects were introduced before low-priority objects. However, our findings did not support this hypothesis either (See Figure 7).

4.3 Immersion Ratings: Color and Texture

H2: The addition of color and texture to the virtual environment will significantly increase participants' immersion ratings. To test this hypothesis, we used both T-tests and ANOVA to compare immersion ratings across different scenes and trials as participants experienced the addition of color and texture to the virtual environment. To analyze the data we utilized pythons matplotlib for our graphical data and scipy f_oneway for our ANOVA testing. The T-test results showed no significant differences in immersion ratings between the two groups for any of the scenes, suggesting that the addition of color and texture did not significantly affect immersion. Additionally, ANOVA tests were performed across the trials to examine whether there was a significant difference in immersion levels within each group across the stages of the experiment.

Scene	t-statistic	F-statistic	p-value	Significance
Scene 1	0.400	0.16	0.7096	No significant difference
Scene 2	1.492	2.23	0.2099	No significant difference
Scene 3	1.118	1.25	0.3262	No significant difference
Scene 4	1.265	1.60	0.8746	No significant difference
Scene 5	0.866	0.75	0.4353	No significant difference
Scene 6	0.866	0.75	0.4353	No significant difference
Scene 7	0.632	0.40	0.5614	No significant difference

Figure 4: Participant Immersion - ANOVA and T-Test Results. Check Figure 5, within Appendix B: Participant Data Graphs for participant responses.

Across all scenes, the p-values were well above the 0.05 threshold, indicating no significant difference between the groups. The ANOVA results also show no significant differences between the groups across the seven trials, further supporting the lack of a measurable effect of color and texture on immersion.

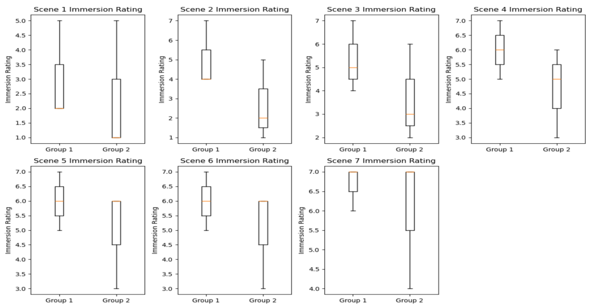

Figure 5: Group Immersion Ratings Per Scene

The hypothesis that the addition of color and texture would significantly increase immersion ratings was not supported by the results of either the T-tests or the ANOVA analyses. Both tables contain The lack of significant differences suggests that, under the conditions of this study, color and texture did not have a noticeable impact on the participants' immersion ratings.

- **Expectation Bias:** Participants may have expected color and texture to be part of the virtual environment, which could have led to a ceiling effect in their ratings. If participants anticipated these visual elements, they may not have viewed their introduction as particularly significant, leading to relatively consistent immersion ratings across conditions.
- **Small Sample Size:** The study's sample size might have limited its statistical power to detect significant differences. A larger sample size might have been needed to reveal more subtle differences in immersion ratings that could be attributed to the introduction of color and texture.
- **Environmental Characteristics:** The virtual environments used in the study might have lacked the level of complexity or realism needed for color and texture to significantly affect immersion. In some cases, environments that are too simple or overly complex may not elicit the expected levels of immersion, regardless of visual enhancements.
- **Methodological Considerations:** While immersion was measured across the different scenes, the participants' engagement or emotional responses to the environment may have varied for reasons not captured by the immersion ratings alone. Future studies might consider additional measures, such as physiological responses or more detailed subjective reports, to better understand the factors influencing immersion.

The results of this study do not support the hypothesis that the addition of color and texture significantly increases immersion ratings in virtual environments. Both the T-test and ANOVA analyses indicated no significant differences between the groups, suggesting that the visual enhancements did not have the expected effect.

4.4 Inconsistencies in Speed and Object Priority Assignments

Overall, the speed at which each participant postulated their location guess was inconsistent throughout each of the trials. This is most likely attributed to mistakes in how priority was assigned to each object. As an example, we defined student desk chairs to be low priority objects based on our priority criteria. However, upon further reflection, it seems very likely that these chairs immediately make the environment recognizable as a classroom. One very illuminating question asked by the post-experiment questionnaire was, "What object or objects made the environment seem most familiar to you? Please provide each object on a separate line, starting with the object that had the most impact." Out of our 6 participants, 3 of them mentioned chairs in response to this question, even though we had defined the student desk chairs to be low priority.

4.5 Correct Recognition from Stage 2 Onward

From Stage 2 onward, each participant correctly guessed the location of the environment from stage 2 onward. We believe that this is also due to the initial assignment of priority to objects. Since the high to low priority group was first introducing recognizable objects, such as the podium and whiteboard, and the low to high priority was first introducing what we now believe to be incorrectly labeled objects of low priority, it is plausible to us that the environment was immediately recognizable in both cases.

4.6 Main Findings

The first independent variable, object spawn priority, was discovered to not possess any major impacts on the first dependent variable, level of detail until recognition (time). However, it seems that object spawn priority was influential in producing different levels of immersion felt by the participants. According to the results portrayed in Figure 6, the level of immersion felt, held a constant increase on each of the participants, save a few outliers. However, in general, the level of immersion was lower for the participants of Group 2 than it was for Group 1, possibly indicating that object priority possesses better immersion for low to high priority than it does for high to low priority.

4.6.1 Interaction Effects

As we introduce more objects to the environment, and once colors and textures are introduced, the interaction between color and object spawn priority can cause certain visual objects of one priority group that are more influential or pronounced than the other. This can be something that can influence the immersion ratings –especially if certain objects are more immediately recognizable than others.

4.6.2 Effects size

Since the ANOVA and T-Test tests reveal there is no significant difference between the conditions, the effect size of these variables are accordingly zero.

4.6.3 Statistical Significance of Speed

Although the speed of the participants varied, there was no statistical significance between Group 1 and Group 2 for the averages of each participants' speed: $F = 3.31, p < 0.05, p = 0.0940$. As previously stated, the measurement of both speed and accuracy seem to have been tainted by the labeling of the priority of the objects, which we believe to be a contributor to the very sporadic data that was recorded in terms of participant speed.

However, participant immersion was found to be increasing when additional objects were introduced to the environment. On top of this, the addition of color and texture to our gray-scale objects saw an overall steady increase in the participant immersion ratings. The speed of that participants' task completion time was more or less the same after being presented with the second scene. This is in line with our participants' accuracy. Every single participant got the correct result from stage two onward, so it is analogous that the speed of completion time would be the same from the second stage on-wards as well.

5 Conclusion

In this experiment we attempted to quantify immersion in VR spaces by assigning priority levels to objects in a room and iteratively adding them to a scene based on this priority. We analyzed participants' sense of immersion throughout various scenes through a Likert scale model. This led us to finding that participants feel more immersed when a large quantity of similar objects, such as student desks, were added to the scene, rather than unique or more prominent objects.

Despite the lack of significant findings, our study provides a numerical foundation to understanding object prioritization in virtual environments. Our results highlight that object abundance plays a significantly more crucial role in immersion than we initially anticipated. This insight could benefit immersion reliant VR applications such as training simulations, education, and virtual tourism.

A key limitation to our experiment was the subjective nature of object priority, which relied heavily on assumptions about object importance. A potential flaw in our definition of priority could be emphasizing uniqueness when most participants found higher levels of immersion and recognition when the student desks were added in. Proving that it is highly important for experimenters to determine which objects should be emphasized in a virtual environment to provide the most immersion for participants. Future research could incorporate participant-driven object prioritization to better align the experiment with user expectations.

This experiment was further limited by only containing one environment and a small sample size due to time constraints. Future work should focus on a better way to define priority of objects in a room that can be broadly applied to test multiple environments to more accurately evaluate the levels of immersion that individuals experience when they are in a VR environment.

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6 Appendices

6.1 Appendix A: Item Priority Ratings

- Podium (Awareness: 2, Uniqueness: 3 — Total: 5: high priority)
- Trashcan (Awareness: 2, Uniqueness: 3 — Total: 5: high priority)
- Recycle bin (Awareness: 2, Uniqueness: 3 — Total: 5: high priority)
- Rolling Table (Awareness: 2, Uniqueness: 3 — Total: 5: high priority)
- White Board (Awareness: 2, Uniqueness: 3 — Total: 5: high priority)
- Monitor and Stand for Podium (Awareness: 2, Uniqueness: 3 — Total: 5: high priority)
- Paper Above Whiteboard with A's (Awareness: 2, Uniqueness: 3 — Total: 4: high priority)
- Projector Screens (Awareness: 2, Uniqueness: 2 — Total: 4: medium priority)

- Computer Chair (Awareness: 1, Uniqueness: 3 — Total: 4: medium priority)
- Corner Desk (Awareness: 1, Uniqueness: 3 — Total: 4: medium priority)
- Phone (Awareness: 1, Uniqueness: 3 — Total: 4: medium priority)
- Microphone (Awareness: 1, Uniqueness: 3 — Total: 4: medium priority)
- Fire Alarm (Awareness: 1, Uniqueness: 3 — Total: 4: medium priority)
- Framed Flag (Awareness: 1, Uniqueness: 3 — Total: 4: medium priority)
- Doors (with frame and stopper) (Awareness: 2, Uniqueness: 2 — Total: 4: medium priority)
- Ceiling Camera (Awareness: 1, Uniqueness: 3 — Total: 4: medium priority)
- Student Desk Chair (Awareness: 2, Uniqueness: 1 — Total: 3: low priority)
- Ceiling Pillar (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Projector (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Windows (Awareness: 1, Uniqueness: 1 — Total: 2: low priority)
- Blinds (Awareness: 1, Uniqueness: 1 — Total: 2: low priority)
- Power Outlets (Awareness: 1, Uniqueness: 1 — Total: 2: low priority)
- Ethernet Outlets (Awareness: 1, Uniqueness: 1 — Total: 2: low priority)
- Exit Sign (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Thermostats (Awareness: 1, Uniqueness: 1 — Total: 2: low priority)
- Triangle (fish tail) (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Small polygon (fish) (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Medium polygon (fish) (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Large Arrow (fish head) (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Light switches (Awareness: 1, Uniqueness: 2 — Total: 3: low priority)
- Vents (Awareness: 1, Uniqueness: 1 — Total: 2: low priority)

6.2 Appendix B: Participant Data Graphs

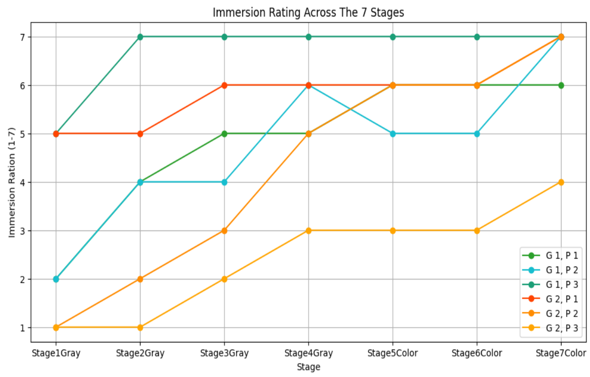

Figure 6: The Likert-Scale 1-7 immersion ratings of each participant

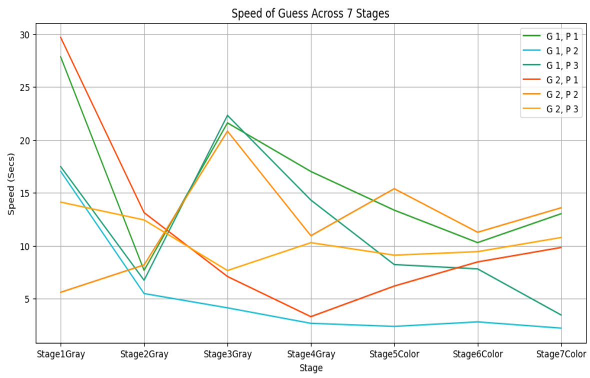

Figure 7: Measurement of participant task completion time (in seconds)