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# The Effects of Interactivity on Memory Relating to Presence in Virtual Environments

Jenny Wong

**The Effects of Interactivity on Memory Relating to Presence in Virtual Environments**

An *Honors Thesis Proposal* submitted in partial fulfillment of the requirements for Honors Studies in Psychology

By

Jenny Wong

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J. William Fulbright College of Arts and Sciences

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**Abstract**

The overall effectiveness of virtual environments is often linked to and measured by degrees of presence, commonly defined as the psychological sensation of “being there” (Schubert et al., 1999). Psychologists agree that attention and involvement through interactivity play a role in presence (Hartmann et al., 2015; Schubert et al., 1999; Witmer and Singer, 1998). Because attention is critical in encoding information into memory storage, looking at how memory relates to presence is another topic of interest. In this study, participants ($N$ = 30) played through a 3D virtual reconstruction of a Pompeian house under one of two conditions: free-roam and task-oriented. No significant difference emerged between the conditions for feelings of presence. There was also no difference between conditions in terms of memory recognition of the virtual environment. However, as predicted, a significant difference emerged for the memory recall test, as participants in the interactive task-oriented condition exhibited higher accuracy in vase placement relative to the original target locations compared to the free-roam condition. This difference suggests improved memory recall due to interactivity rather than presence.

Keywords: Presence, Virtual Environments, Memory, Interactivity, Attention

# Introduction

As the use of virtual environments (VEs) expands in education, medicine, physical and psychological therapy, corporate training, and the military, research on how the experience of presence is created in VEs and possible ways to increase it will be crucial in future VE studies. Given the impact and interest VEs have sparked across a range of industries, it is only appropriate for further research to focus on better understanding presence and its relationship with cognitive processes--in this case memory.

The findings from this study are intended to provide insight into the impact of attention and interaction on presence, and the validity of using memory recall as a gauge of presence. Data from this study falls within a larger context of prior studies about presence in VEs generally, and more specifically about how modern people navigate VEs constructed from the archaeological evidence of past cultures. Within archaeology, there is considerable interest in using VEs to explore and reconstruct past cognitive and sensory experiences, including Pompeii. This is one main reason why this study utilized a virtual recreation of a Pompeian house. The other reason lies in the fact that the spatial plan and decoration of Pompeian houses are not widely familiar to contemporary people outside of classics and archaeology, ensuring that this VE would be a new and unexpected experience. Further description of the house used, the House of the Fontana Piccola (Small Fountain), will be addressed in the materials section of this study.

## 1 Presence

The original concept of presence dates to Marvin Minsky's research on telepresence in 1980 (as cited in Hartmann et al., 2015). Telepresence was first defined as the illusion of being in a real, physical space through manipulation of remote access technology (Minksy, 1980). Since then, telepresence has been shortened to simply "presence" and generalized as the sense of being transported to *any* space, real or fictional, through media (Böcking et al., 2004). Although there is a consensus of the broad definition of presence, there are disagreements about the subtypes of presence. For example, Lombard and Ditton split presence into two categories: physical and social (Lombard and Ditton, 1997). On the other hand, Draper, Kaber, and Usher identified three categories: simple, cybernetic, and experiential, while Heeter splits it into personal, social, and environmental (Draper et al., 1998; Heeter, 1992). This study will focus primarily on spatial presence, so when using the term "presence" I am referring to spatial presence. Spatial presence can be defined as the perception of being in an environment apart from the location of one's physical body through the manipulation of technology and media (Youngblut, 2003).

### 1.1 Measuring Presence

Presence in VEs is what distinguishes them from other computer-generated simulations and is a common measure of VE effectiveness (Youngblut, 2003). The problem that many researchers face is how to accurately measure presence and how to define and evaluate the variables that produce presence. While a few studies use physiological measures, many studies use presence questionnaires as the main measure due to presence itself being subjective in nature (Böcking et al., 2004; Schwind et al., 2019). A previous study by Valentin Schwind (2019) sought out to determine the efficacy of three widely used questionnaires: Witmer and Singer's Presence Questionnaire (PQ), Slater-Usoh-Steed questionnaire (SUS), and the iGroup Presence Questionnaire (IPQ). All three questionnaires are intended to provide measures of presence but focus on varying aspects. The PQ consists of 32 items that focus on involvement/control, how natural the VE feels, and interface quality (Witmer and Singer, 1998). The SUS questionnaire consists of 6 items that focus on the sense of presence, how dominant the VE is in the perceptual continuum of the user compared to reality, and the extent to which the VE is remembered as an actual place (Slater et al., 1998; Usoh et al., 1999-2000). The IPQ consists of 14 items that focus on spatial presence, involvement, and experienced realism (Regenbrecht et al., 2001). From his experiment, Schwind found that the longer a questionnaire is, the more fatigued participants would become while trying to complete it. Because the PQ is a much longer questionnaire, consisting of 32 items, it is likely to result in a decrease in accuracy of presence measurement (Schwind et al., 2019). Overall, Schwind concluded that the IPQ was the best reflection of the construct of presence due to having three questions that intercorrelate all three questionnaires' themes and aspects of presence. Not only do these three questions directly relate to the feeling of presence in a VE, but the IPQ can also be completed within a reasonable timeframe (Schwind et al., 2019). For these reasons, the IPQ was used to measure presence in this study.

### 1.2 Presence Theories in Existing Literature

Despite decades of research, there are still no comprehensive theories or conclusive measures of presence (Lombard et al., 2017; Schwind et al., 2019). Theories have been proposed, but no firm consensus has been reached regarding the determinants of spatial presence (Hartmann et al., 2015). Below are brief summaries of the most significant theories of presence presented over the past three decades as the technology for creating "realistic" VEs has advanced at an exponential rate.

Steuer's explication of presence theory in 1992 argued that sensory stimulation is the key determinant of spatial presence (Steuer, 1992). He stated that the more senses (vision, sound, haptics, smell, taste) a system addresses the higher the presence and vividness would be for the user. Another determinant Steuer mentioned is the role of interactivity. He defined interactivity as "the extent to which users can participate in modifying the form and content of a mediated environment in real time" (Steuer, 1992). Steuer's recognition of the importance of interactivity has a strong connection with using game engines and their ability to construct interactive mechanics, as opposed to other VEs which allow only navigation at best.

Draper's attention-based model of spatial presence in 1998 proposed that attention is the key determinant of spatial presence, with presence increasing in proportion to the attentional resources allocated towards a stimulus (Draper et al., 1998). Many researchers acknowledged and agreed that attention is necessary for spatial presence; what Draper's theory lacked was a clear exposition of what kind of spatial arrangements and embedded content would stimulate and hold attention to induce spatial presence.

Slater's theory developed between 1993 to 2005 argued that presence depends on media environment, user characteristics, immersion, and natural mapping (Sanchez-Vives and Slater 2005; Slater et al., 1996; Slater and Steed, 2000; Slater and Usoh, 1993-1994; Slater et al., 1994; Slater and Wilbur, 1997). He claimed that sensory richness, interactivity, and attention are key variables, but significantly shaped by the background and traits of the user. Slater instead focused on the cultural and personal differences in cognition and navigation of individual users that affect presence. For example, not everyone learns and takes in information the same way--one person could be a more visual learner while another could be a hands-on learner. This can greatly affect what sense a media system should focus on, and what content it should present to its users. More visual learners will likely feel more present in a VE when provided with a lot of engaging visual stimuli, while hands-on learners will likely feel more present when provided with movement of the virtual body and interactivity with the VE. Slater also stressed the importance of making the VE feel natural, using the phrase "natural mapping" to refer to the translation of physical cause-effect relationships and expectations into the VE, producing a higher sense of presence (Sanchez-Vives and Slater, 2005). It is important to remember, however, that what seems "natural" and the same in the physical world for all humans can in fact be perceived and experienced very differently in different cultures, and that most VEs have been developed within the context of Western habits of representation and technology.

Schubert’s embodied cognition framework of spatial presence developed between 1999 to 2001 conceptualized spatial presence as a mental representation of actions in the VE (Schubert et al., 1999; Regenbrecht and Schubert, 2002). He stated that this embodied mental model is necessary to trigger the feeling of spatial presence in a user. What VEs needed was the ability to create this effect of an embodied mental model without placing the physical body in a real space and having it interact with that space. This is virtual embodiment--and so actions must be done using inputs that are not like swinging a real hammer with your whole arm, or picking up a vase with your whole body, but nonetheless answer to some of the physics and material logic of doing these things. Schubert and his colleagues suggested that mental representations of possible actions that provide predictable and expected outcomes in the VE increase spatial presence, which mirrored Slater’s idea that natural mapping is a key determinant (Schubert et al., 1999; Regenbrecht and Schubert, 2002). There are themes that span across these theories, but psychologists continue to grapple with a theoretical framework that can encompass the evolving technologies and design approaches of VE, and thus the measurements of presence and strategies for achieving it (Hartmann et al., 2015).

## 2 Involvement and Interactivity

Although not all presence theories align with one another, they all provide strong evidence that subjects must exhibit a significant level of involvement and interactivity for presence to occur (Hartmann et al., 2015; Schubert et al., 1999; Witmer and Singer, 1998). Involvement is a psychological state experienced when users devote attention to stimuli or are interactively engaged within the virtual space (Witmer and Singer, 1998). In general, as users allocate more cognitive resources to stimuli through interactivity, their level of involvement with the VE increases, leading to a higher sense of presence (Witmer and Singer, 1998). Interactivity was briefly defined in section 1.2 using Steuer's definition that focused on a user's action in a VE. An example of interactivity according to Steuer would be users knocking on a door within the VE. However, what this definition lacks are the completeness of action *and* reaction. Instead, interactivity is better defined using Heeter's definition as the action and reaction of a user with the VE (as cited in Straaten, 2000). An example of interactivity according to Heeter would be users knocking on a door and hearing feedback sound from their knock in the VE. Because of this reason, this study will be using Heeter's definition when referring to interactivity or interaction.

### 2.1 Interactivity and Memory

Several studies have examined interactivity and memory, but this study will focus on the effects of interactivity on memory specifically within digital media. A study conducted by Xu and Sundar (2016) had participants split into nine groups and explored an e-commerce website with varying levels of interactivity. Interactivity was manipulated by the number of interactive content/features present on the website. Xu and Sundar (2016) found that higher interactivity increased memory recognition and recall of interactive content, but lowered recognition and recall of non-interactive content. Recall involves retrieving information from memory with little to no cues, while recognition involves picking out information from a group of alternatives. An example of recall would be describing one's experience at an event, whereas recognition would be identifying a person from a line of suspects. Another study by Gaunet et al. (2001) investigated spatial memory in VEs through manipulating the mode of exploration. The three modes of exploration used were active, passive, and snapshot. Active exploration involved participants traversing the VE via joystick. Passive exploration involved participants observing a pre-recorded tour of the VE. Snapshot exploration was the same as passive exploration, except the VE was shown through pictures and not presented continuously (Gaunet et al., 2001). These different modes of exploration could be interpreted as different levels of interactivity, where the active mode would be the most interactive and the snapshot mode being the least interactive. Participants' performance was based on scene recognition, reorientation, and path memory recall. We will only be looking at the results of scene recognition and path memory. Gaunet et al. (2001) found no significant difference in scene recognition between modes of exploration but did find an increase in path memory recall in the active and passive modes. Total distance and path reproduction from the snapshot mod showed greater error scores than the active and passive modes (Gaunet et al., 2001). Both studies conclude that higher interactivity results in better memory recall but differ when it comes to memory recognition.

## 3 Attention and Memory

The sensation of presence depends on the attentional shift between the real and virtual world, but that does not necessarily mean that the person entering the VE becomes unaware of the real world. Rather they are often cognizant that technology is generating their experience (Lombard et al., 2017). However, the selective attention towards the VE surpasses this awareness to some degree and allows for the sensation of presence. Attention here acts as a mediator in presence. The relationship between attention and presence was made prominent by Frank Biocca's 'reality problem'. The 'reality problem' asks how it is possible for a person to be in a space physically, yet feel little to no presence (Biocca, 2002). A common example of the 'reality problem' is when students are zoning out in class, not at all aware of what is going on around them, including (unfortunately) the content being present by the instructor. According to Witmer and Singer (1998), attention is best achieved when a set of meaningful stimuli is provided--meaningful in a sense that the information presented will be of interest and use to the individual. Their findings confirmed that attention towards meaningful stimuli supports one's sense of presence (Witmer and Singer, 1998). Therefore, attention is integral to presence in a physical or VE. A VE can look and sound real, but if it does not capture their attention participants might as well be the bored students in a classroom.

### 3.1 Memory as a Measure of Presence

Memory and attention are often paired together as the allocation of an increasing number of cognitive resources to stimuli equates to an increase in the memory processes being used. Because of this relationship between memory and attention, along with the relationship between attention and presence, memory performance is a common way of measuring presence. In this study, we will primarily be looking at memory recall and recognition. Regarding the relationship between memory and presence, there are two theories. One suggests that the more present people feel, the more they will remember details and attributes of the environment (Lin et al., 2002; Mania and Chalmers, 2001). The opposing theory proposes that due to the increased feeling of presence, people will remember less about the static details and attributes of the environment, due to their increased attention to specific stimuli or features in the VE (Fox et al., 2009; Nichols et al., 2000).

## 4 Current Research

There have been varying results from past studies that have examined the relationship between memory and presence. A study done by Lin (1999) addressed the influence of field of view (FOV) and motivation on presence and memory. The study revealed that the correlations between memory tests scores and presence were highly significant, with a positive correlation between performance on memory structure test and presence, but cautioned that drawing a direct connection between a high sense of presence and better memory performance may not be warranted (Lin et al., 1999). Mania and Chalmers (2001) primarily focused on three VE types (desktop, head mounted display, audio only) compared to the control group, the physical world, and its effects on memory and presence. *Physical world* is defined as the real-world environment, without mediation by any digital representation or simulation. They found that presence was not positively associated with accurate memory recall in all conditions (Mania and Chalmers, 2001). Sutcliffe (2005) conducted a similar study to Mania and Chalmers where he evaluated three VE types (CAVE, Interactive WorkBench, and Reality Room) to assess presence, but focused more on usability errors, emotion, and tools of interaction. CAVE, or cave automatic virtual environment, is an immersive environment where the VE is projected on two to six walls and a special set of glasses is needed to resolve the stereoscopic projection in the CAVE and produce the sense of depth in three dimensions. The Interactive WorkBench is essentially a CAVE, but with only one wall faced by the user, so the 3D content does not wrap around the user in 360º. He found no correlation between memory and presence, but instead connected memory to the positive or negative emotion related to what is being remembered (Sutcliffe et al., 2005). Another study by Bailey (2012) looked at how presence in VEs affects memory performance in the physical world. The results showed a significant negative association between presence in the VE and memory in the physical world (Bailey et al., 2012). The purpose of Bailey's study is slightly different from this current study, but it shows that presence does have an effect on memory. These results not only contradict one another, but also the logical progression from increased attention and involvement (through interaction) to a deeper experience of presence, reflected by more accurate and persistent memory recall. Hence more research is required to better understand if and how this assumed progression is valid.

This study will primarily investigate if and how the level of interactivity increases attention within VEs, and if this deepened sense of presence correlates to more accurate and sustained memory recall. This study will use data collected from player behavior in the VE together with post-navigation surveys to provide a quantitative and qualitative picture of attention, presence, and memory recall. *I hypothesize higher interactivity with the VE will have a deeper experience of presence, leading to an increase in memory due to higher interaction with the VE.* By establishing the positive correlation between interactive involvement, presence, and memory, this study aims to show that presence in VEs is not solely created by digital technologies for achieving hyper-realism as a visual attribute of the VE but has a demonstrable relation to interactive affordances presented in the VE. The creation of presence in VEs is not an either/or between the quality of the environment and systems of interaction, but the complex weave between them. As it stresses the balance between technology, environmental art, and interaction design, this would be a valuable result for the range of industries exploring real-time 3D VEs for education and training.

## Methods

### 1 Participants

All procedures and materials described were submitted and approved by the University of Arkansas IRB. 55 consenting participants were recruited from the University of Arkansas undergraduate population who were either compensated with extra course credit or took interest in the study and participated without compensation.

## 2 Materials

**Figure 1. View of the second atrium and fountain area in the VE.**

This study was conducted remotely and unproctored with the VE, constructed in the Unity3d game engine, displayed on participants' personal desktop or laptop through WebGL. WebGL is a platform that allows real-time 3D content to be played directly through the user's web browser, without a plugin or additional application. The VE consisted of a digital recreation of the House of Fontana Piccola (Small Fountain) and was a part of Pompeii Regio VI Insula 8--Regio meaning region and Insula showing the number of blocks of houses and shops bounded by roads. The house comprises two atriums, an outdoor fountain area, corridors, and 13 small rooms with fully decorated walls and foliage, but no large pieces of furniture. The overall layout of the house consists of open spaces with no doors in the environment, only doorways. The digital reconstruction was produced using 3D modeling software common in game creation workflows (Autodesk Maya and Blender), with lighting, sound, and interactive coding produced through the Unity3d game engine. Audio appropriate to this area of Pompeii, such as the soft bustle of outdoor street vendors and water fountain sounds, was also included in the VE to provide a more immersive experience. Participants were instructed to put on headphones and turn up the volume to hear the audio.

This study consisted of two condition groups. Group 1 (n=15) was instructed to freely explore the VE until a timer set to four minutes expired. Group 2 (n=15) was instructed to find and open a total of 8 vases distributed across the VE until a timer set to four minutes expired. Because of the differing conditions, two builds of the VE were made and distributed to participants to produce a balanced number of subjects in each condition. The vases had the same location in each build, but only the task-oriented build allowed participants to interact with the vases during their navigation of the VE. Before beginning playthrough of the VE, participants were given instructions on their screen of what they would be doing, free-roam or finding vases, and how to use the controls. Participants moved around the VE by using the ‘WASD’ keys and looked around by moving their mouse. To interact with the vase, participants had to left click on the vase. Once the player performs this action, the lid of the vase comes off, providing visual feedback to confirm the action. Participants could also refresh on the instructions and controls by pressing the ‘P’ key, which brought them to a pop-up options panel. The options panel allowed participants to adjust their mouse sensitivity. Pressing the ‘P’ key again would close the options panel. The timer was shown to participants at the top right of the screen and continued to run when in the options panel.

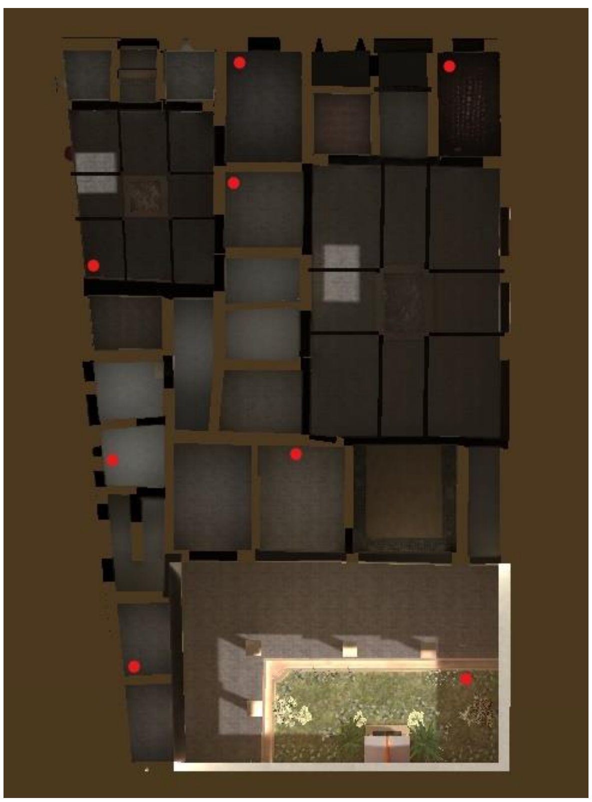

**Figure 2. An overhead shot of the virtual environment. The red dots show the locations of the vases.**

The presence questionnaire used for this study was the iGroup Presence Questionnaire


**Figure 3. Participant view of the options and timer in the top right corner.**

(IPQ) developed by Regenbrecht, Schubert, and Friedmann (2001). All other surveys and questionnaires (demographics, memory, and feedback) were self-designed. The IPQ consisted of 14 items using a Likert scale from 1 to 7. Examples of items are “how real did the virtual environment seem to you?” and “how much did your experience in the virtual environment seem consistent with your real-world experience?” Examples of response options are “completely real to not real at all” and “not consistent to very consistent”. A prior study found the IPQ as a reliable measure of presence with $\alpha=0.87$ (Schwind et al., 2019).

This study also included two memory tests. The first memory test was in the form of a questionnaire that consisted of 13 questions. These questions tested memory recognition of the VE. The first eight questions required participants to choose the image that was in the VE from the set of three images given. Only one of the images was from the VE while the other two were from other virtual houses in Pompeii developed prior to this study. These questions progress in difficulty from images of the more open, spatially connected parts of the VE to narrow shots of specific rooms and walls with small-scale details, but little to no spatial context (shown in Figures 4). The next four questions had participants choose the image that was *not* in the VE from the set of three images given. One question had participants choose the image that shows where they started in the VE. The last question had participants choose the floor plan of the house just explored out of four floor plans.

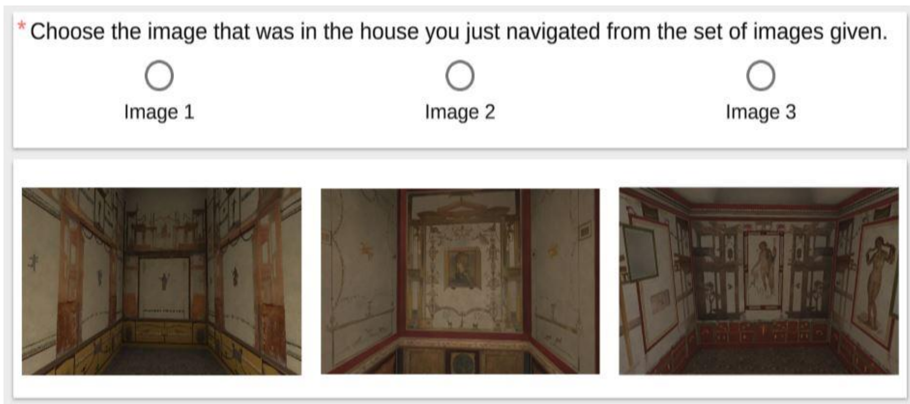


**Figure 4. Example of a question on the memory test.**

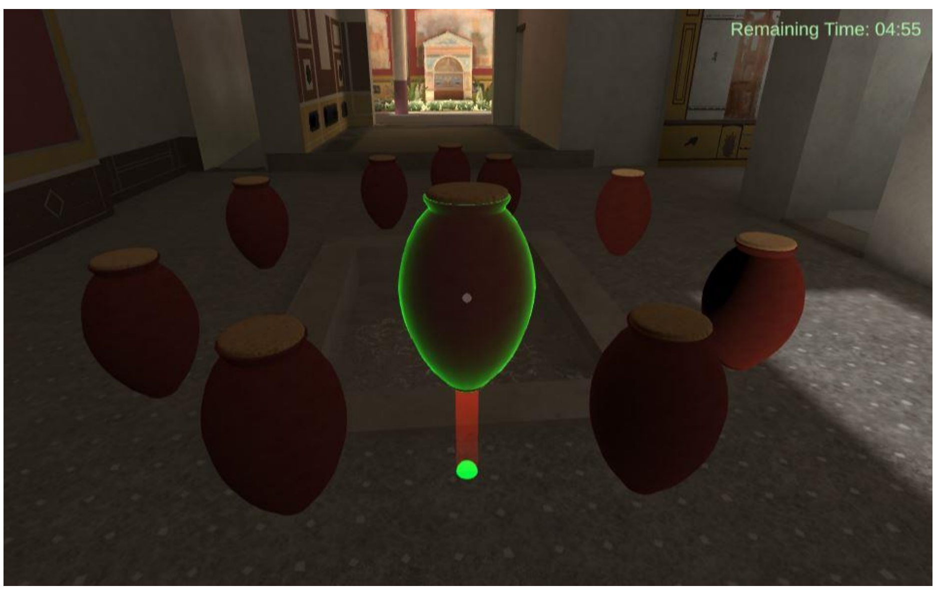


**Figure 5. Participants' view when picking up and placing the vases.**

The second memory test required a second playthrough of the VE and tested memory recall. Here, participants were asked to recall object placement by placing vases where they believe they were in their first playthrough of the VE. 10 vases were provided, but participants were instructed that not all vases had to be used. Participants had to press left click to pick up and place the vases. Scrolling the middle mouse wheel moved a grabbed vase forward and back. The 'R' key reset a grabbed vase close to the participant. Participants had five minutes until time ran out. The timer was visible to participants at the top right corner of the screen.

A feedback survey was presented at the end to track what distractions, frustrations, and/or computer issues participants had during the study. Excluding the consent form, all of the surveys, questionnaires, and the application described above were contained within the web application and at no point did participants leave that environment.

## 3 Procedure

A between-subjects study design, where two or more groups are tested by a different testing factor simultaneously, was implemented to explore the relationship between interactivity, memory, and presence within a VE. Participants were recruited through extra credit opportunities offered in large enrollment classes in Classical Studies. The class was randomly split into two groups, and an email with the link to the free-roam condition was sent to one half of the class, while the other link to the task-oriented condition was sent to the other half. We could not account for how many participants would be in each condition, so we ended up recruiting through other classes in which instructors agreed to share information about this study and students voluntarily participated without any compensation. Because this study was conducted remotely and unproctored, participants who had computer issues or major distractions while exploring the VE are not included in this study. I personally reached out to students who took interest in the study and assigned them to a condition based on the number of participants we recruited with usable data for the two conditions from the large enrollment classical studies course in order to get an equal number of participants for both conditions. All participants recruited did not know there were two conditions and did not know what condition they would be in.

Before volunteering for the experiment, participants were informed through the email message that the study would involve playing through a virtual environment and answering questions about it. Because this study was conducted remotely and unproctored, instructions were provided digitally through the application. The experiment was presented via Google Forms and WebGL. The mean session time was 20.4 minutes (*SD* = 6.7).

The first page presented to the participants was the consent form hosted via Google Forms. Participants were required to complete the consent form before they could continue to the application. Once completed, at the end of the consent form there was another link that brought them directly to the application where the rest of the study took place. Here they were greeted with a welcome to the study and their unique identifier. In order to receive extra credit for their participation in the study, subjects were required to copy their unique identifier, a randomly generated string of letters and numbers located at the bottom right corner, retain that and email it to their professor to obtain extra credit. If they forgot to do so, the unique identifier was also presented at the very end of the study. Afterwards, participants took a brief demographics survey. Next, instructions for the virtual environment playthrough were given and the participant played through the virtual environment for four minutes, either free roaming or finding vases, until time ran out. Participants could see the timer on their screen. Once the playthrough was completed, participants took the presence and memory questionnaire described in the materials section. Then, they moved on to another memory test that required playing in the virtual environment again. Here, participants were asked to recall object placement by placing the vases where they believe they were in their first playthrough of the environment. They were given seven minutes to do this with the timer shown on the screen. Finally, a feedback survey was given and upon completion, participants were taken to a thank you screen that thanked them for their participation, reminded them to copy and retain their unique identifier, and told them they can close out of the tab.

| **Order of Steps in Procedure** | **Summary of Steps** |
|---|---|
| Consent form | Gave information about the study and must be signed to gain access to the link of the application. Participants provided their email here to receive a copy of their consent form. |
| Welcome to the study | One slide that provided a short and brief introduction to the study, along with the unique identifier. |
| Demographic survey | 17 questions regarding sex, gender, age group, interest in Rome, experience in video games, and navigation behaviors. |
| First VE playthrough | One slide of instructions was shown before the playthrough. For four minutes, participants had to complete their group condition: free-roam or task-oriented. |
| Presence survey | 14 items on a 1 to 7 Likert scale about spatial presence, involvement, and experienced realism (Regenbrecht et al, 2001). |
| Memory recognition test | 13 questions testing scene recognition. |
| Memory recall test | A second playthrough within the VE testing memory recall by having participants place vases where they were in their first VE playthrough for five minutes. |
| Feedback survey | 11 questions to assess distractions, computer issues, and frustrations during the study. |
| Thank you for participation | One slide to thank participants and a reminder to copy the unique identifier for extra credit, provided again in this slide. |

**Table 1. A step-by-step summary and brief description of the procedure (demographic survey, presence survey, memory recognition test, and feedback survey will be provided in the appendix).**

## 4 Player Data Measures

All player data and responses were exported from the application to Google Sheets and transferred to a Microsoft Excel document. The memory recall vase placement test recorded in meters the amount of space between the original location of a given vase, and where the participants placed the vase. The lower the distance recorded, the more accurate the vase placement was to the original spot. The number of vases used by participants was also recorded. It is important to note that distances of vases placed near or on a spot where the participant already set down a vase were not recorded to cull out desperation or laziness in placement; for example, if a participant just picked up every vase and placed it next to the same spot. This means that a participant could have used all 10 vases, but only six of those vases have recorded distances.

# Results

The final sample (n=30) consisted of sixteen females and fourteen males 18 to 50 years of age, with 90% of participants being 18 to 25 years of age. A sensitivity analysis indicated that we were adequately powered to detect large effects (Cohen's $d$=1.06, 1-β=0.80). Additionally, this sample is comparable to previous studies assessing similar processes (Bailey et al., 2012; Sutcliffe et al., 2005). 63.3% (n=19) of participants stated they either did not play video games or spent less than three hours a week doing so, 10% (n=3) normally spent four to eight hours a week, 13.3% (n=4) normally spent nine to fifteen hours a week, and 13.3% (n=4) normally spent over fifteen hours a week. 40% (n=12) of participants were somewhat familiar to familiar with

Roman culture and history, with the remaining 60% (n=18) being unfamiliar or neutral. 33.3% (n=10) of participants have somewhat studied or fully studied Roman art and architecture, with the remaining 66.7% (n=20) having not studied or barely studied it. Only one of the participants responded that they had visited the archaeological site of Pompeii.

I conducted three separate independent samples t-tests comparing performance and experiences in both conditions. The IPQ had acceptable reliability (α=0.87). As seen in Table 2, no significant difference emerged between the conditions for feelings of presence, suggesting this manipulation did not successfully induce a significant difference in the experience of presence. Overall, the mean presence for both conditions was relatively low, with the free-roam group (M=3.89) having a slightly higher presence score than the task-oriented group (M=3.38). Because presence between the two conditions was not significant, no conclusions could be drawn as to whether presence and memory are related.

There was also no significant difference between conditions in terms of recognition of the scenery or floor plan of the VE (as shown in Table 2). However, as predicted, a significant difference emerged for the vase recall section where participants exhibited higher accuracy in vase placement relative to the original target spot in the task-oriented condition compared to the free-roam condition; this difference suggests better recall occurs when provided a task.

| | Free-Roam | Task-Oriented | *t* | Cohen's *d* | *p* value |
|---|---|---|---|---|---|
| Presence | 3.89 (0.69) | 3.38 (1.11) | 1.49 | -0.03 | 0.15 |
| Recognition | 0.51 (0.17) | 0.52 (0.15) | -0.84 | 0.54 | 0.93 |
| Recall | 3.30 (1.54) | 2.14 (0.87) | 2.53* | 0.92 | 0.02* |

**Table 2. Means (and standard deviations) for both experimental conditions for each outcome variable. *$p<0.05$**

Participants in the task-oriented condition grabbed an average of 8.4 vases, while the participants in the free-roam condition grabbed an average of 7.3 vases. Thus, it can appear that those who used more vases had a higher chance of placing them more accurately. Because of the possibility that this conditional difference could be due to a difference in number of vases grabbed by the participants, I conducted a supplemental one-way analysis of covariance, or ANCOVA, for the recall test using the number of vase grabs as a covariate. Even when the number of grabs is accounted for through ANCOVA, participants in the task-oriented condition still demonstrated more accurate recall, as indexed by the reduced distance to the target, $F(1, 27)=4.80$, $p=0.037$, $\eta_p^2=0.151$.

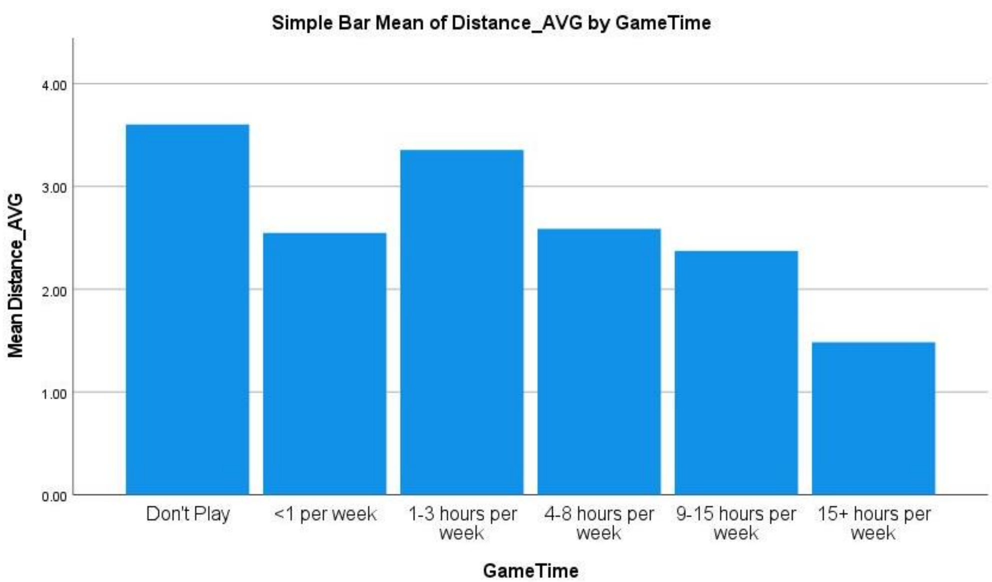


**Table 3. Average distance (in meters) between target spot and placed vase spot for the recall test based on how often participants played video games (in hours) a week.**

Participants who frequently played video games also performed better on the recall test as shown in Table 3. Due to the possibility of this conditional difference, I conducted another one-way ANCOVA to determine whether time spent playing games affected performance in the recall test using the average amount of time spent a week playing video games as a covariate. Even when co-varying out the time participants played games, a conditional effect emerged, showing time spent playing video games could have affected the conditional difference in recall between groups, $F(1, 27)=4.71$, $p=0.039$, $\eta_p^2=0.149$.

## Discussion

In this study, participants were instructed to play through a VE, each assigned to one of two conditions, free-roam or task-oriented, and evaluated on their feelings of presence and memory of the VE. I hypothesized that the task-oriented condition (Group 2) would have a deeper experience of presence, leading to an increase in memory recognition and recall due to higher interaction with the VE. Unfortunately, because there was no significant difference in sense of presence between both conditions, there is no way to know from this study if there is any correlation or relationship between presence and memory. Participants in both conditions also reported low presence scores, which suggests the VE failed to induce presence regardless of the level of interaction each group had with the VE. This current study mainly relied on the visuals and audio of the VE to induce presence, whereas similar studies relied on the different types of VEs, such as a virtual reality headset or CAVE system, that seemed to provide a higher sense of presence (Bailey et al., 2012; Mania and Chalmers, 2001; Sutcliffe et al., 2005). Another difference in methodology that may have affected presence is that this current study did not inform participants about the specific purpose of their free-roam or task-oriented condition, nor did it provide situational context when the subject was placed in the VE, whereas prior studies gave context to the environment and the assigned tasks, therefore creating meaningful attention and interactivity (Bailey et al., 2012; Mania and Chalmers, 2001; Sutcliffe et al., 2005). This brings into question what could have been done to better induce a sense of presence, as will be discussed further in the design improvements section. Because of these results, this study can neither contradict nor confirm findings from prior research as to whether presence and memory have an effect on one another.

Memory recognition in both conditions was also not significant, with little to no difference in performance between the free-roam and task-oriented groups. Many participants, regardless of condition, did poorly when asked to choose the image that does not depict the VE they just navigated. This could be due to the lack of attention when reading the questions since the memory recognition test items switched from choosing the correct image out of a set in the beginning to choosing the incorrect image towards the end. General lack of attention towards the VE may also be a factor. 22 out of 30 participants picked out the correct floor plan out of a set of images, but there was no significant difference between conditions that would suggest interactivity had an effect on spatial memory. These results are similar to findings made by Gaunet et al. (2001) where level of interaction had no effect on memory recognition of scenery (specific room details, frescoes, and architecture) from the VE, indirectly confirming Xu and Sundar's (2016) results that people do worse at remembering non-interactive content--in this case the paintings on the wall, the architecture, and the rooms.

In line with Xu and Sundar (2016) and Gaunet et al. (2001), who both found that higher interactivity results in better recall of interactive content, the current research shows that the group who interacted with the vases (Group 2) did better in recalling target vase locations in the VE. The method for measuring memory recall was more complex in this study, where participants had to remember specific locations and number of objects, than in Xu and Sundar's, where participants were asked to freely recall any information from the interactive content they remember. This suggests that interactivity has some effect on memory recall, whether it is free recall or specific location recall. Many participants used all 10 vases (n=14), but the average number of vases used by the task-oriented group (M=8.4) was slightly more accurate to the correct number of vases (8) than the free-roam group (M=7.3). The overuse of the vases could have several explanations. It is possible that participants did not clearly read the instructions that stated not all vases had to be used. Alternatively, many participants mentioned in the feedback survey that the five-minute time frame for the recall test was too long and ended up not knowing what to do with their leftover time, which could be another reason as to why all the provided vases were used; the only thing participants could do when waiting for the timer to run out was to either walk around the VE or play with the vases.

We also noticed participants who spent more time playing video games, regardless of their group condition, were more accurate with their vase placements; the only demographic group that did not follow this trend were those who played for less than one hour per week. Surprisingly, this group did about as well as those who said they played four to eight hours a week (Table 3 for reference). Participants who played 15 or more hours of video games per week did significantly better, regardless of conditions, on the memory recall test, with a mean distance of 1.48 meters. One participant in the free-roam group who said they spent more than fifteen hours a week playing video games even stated in the feedback survey that due to his experience with video games, he knew that the vases were important and spent time memorizing how many there were. This suggests that participants who have more experience with video games will perform better at object and location recall in VEs. Further literature review shows that these results loosely align with a study conducted by Clemenson and Stark (2015) that examined the potential connection between VEs (in the form of 2D and 3D video games) and improved hippocampus-associated memory. Hippocampus-associated memory tasks tested in this study included enumeration, object and pattern recognition, and spatial memory (Clemenson and Stark, 2015). We only focused on the spatial memory aspect of their study. The spatial memory test Clemenson and Stark (2015) conducted involved participants having to locate a platform within a virtual water maze. They found that participants who had two weeks of training in a 3D video game showed improvement on the virtual water maze task, whereas participants trained on a 2D video game showed no improvement (Clemenson and Stark, 2015). Clemson and Stark (2015) also suggested that individual player styles and how participants explored the VE could influence memory and performance. This leads us to a brief review of an area that studies of memory and presence in VEs, including this one, needed to consider as they construct their methodology: presence in video games.

## 1 Presence in Video Games

VE research in psychology emphasizes the importance of presence when investigating how to make a VE feel more real, whereas researchers in the gaming world focus more on immersion (Jennett et al., 2008; Michailidis et al., 2018; Weibel and Wissmath, 2011). *Immersion* can be defined as an experience when almost all attention is focused on a set of stimuli, in this case a video game, to the point where players feel like they are “in the game” (Jennett et al., 2008). How is this definition different from this study’s definition of presence? Charlene Jennett (2008) argues that presence is only a small aspect of the overall goal of immersion, where presence is a state of mind and immersion is the experience of time. In this context, presence is better defined as simply feeling like one is in an environment and perceiving it as real or close to real, while immersion is the overall enjoyment of interacting with the environment, resulting in a losing the sense of time. For example, a boring task in a realistic and well-developed environment may invoke presence but not immersion, resulting in a lack of participant interest and attention; this example loosely describes what occurred in the current study (Jennett et al., 2008). This is not to say that presence is unimportant when evaluating VEs, but rather noting the crucial role that immersion plays in creating an engaging environment and enjoyable experience. Weibel and Wissmath (2012) conducted a study which found that an immersive tendency positively affects presence. This suggests that future studies will need to incorporate the measurement and design of immersion alongside presence in the context of VEs in psychological research.

## 2 Limitations

There were many limitations set in place because of the COVID-19 pandemic. We initially planned to start conducting research in summer of 2020, but this had to be postponed due to an increase in outbreaks; research did not begin until spring of 2021. The time between summer of 2020 and spring 2021 was used to apply for grants and redesign the study so that the study's methods and procedures would adhere to the guidelines established by the Center for Disease Control and Prevention (CDC) guidelines. The short timeframe for redesigning the study was a limitation and did not allow enough time to incorporate or alter all of the planned mechanics to the VE. For example, during the recall test, instead of having to wait for the timer to run out with nothing to do, we planned for a feature where participants could stop the timer after completing the placement of the vases. A major limitation was not being able to conduct this study in person with participants. Because of this, we could not go with the original idea of using virtual reality (VR) headsets nor provide reliable and consistent equipment for all trials. This meant not being able to provide a controlled environment for participants. The feedback survey recorded several participants saying they had computer issues or distractions throughout the study, which caused us to throw out a lot of unusable data. The fact that the participant group used their own personal computers introduced a range of factors that could not be controlled:

frame rates, Wi-Fi access and quality, mouse sensitivity, audio volume, quality of headphones, and screen brightness. All these variables have likely affected the results of this study. For example, a few participants did not have a computer mouse and used their laptop touchpad instead, resulting in more excluded data. Variation in participant locations while partaking in the study was another uncontrollable factor since the entire experiment was conducted remotely and unproctored. Many participants said that they got notifications on their phone or heard people yelling around the house during the study. Not being able to control for distractions was an issue, but the lack of a proctor to verbally explain and clarify instructions to participants seemed to be a bigger issue. Having a proctor present could also result in participants taking the study more seriously, resulting in more reliable data.

## 3 Design Improvements

If I were to conduct this study again, I would design it as an in-person experiment with a proctor who gives verbal and written out instructions to participants. This will clarify any questions that participants might have during the study, while also making sure that participants are interacting with the VE as intended. Conducting this study in person would also provide a controlled testing environment so that each participant is using the same computer, mouse, keyboard, headphones, and computer settings during the experiment to prevent inconsistencies in the collected data. However, there is also a possibility of using VR headsets now that we can provide participants access to one at the testing site. The testing site would also be free of distractions, such as cell phone notifications, loud noises, and people talking in the background, resulting in a possible decrease in attentional shift between the virtual and physical environment. Adding attention checks throughout the experiment is another way to make sure participants are not just randomly choosing an answer when taking surveys or questionnaires. The recruitment process would focus more on getting all participants with an interactive tutorial prior to their first playthrough of the VE to better understand and get used to player controls. A measure of immersion would replace interactivity as an independent variable where levels of immersion vary across conditions. All tasks would have motivating interaction with the VE and would be distinguished by their level of motivation, unlike the current study that only focused on no interaction versus interaction with the VE. Possibly including monetary compensation rather than extra credit is another way to create motivation. Participants would be informed of the context and purpose of each motivating task via a Roman character within the VE, in hopes of creating a more meaningful experience through storytelling and a gamified narrative. Many participants in the feedback survey stated they expected to find objects in the vase, so an example of gamifying the VE would be collecting objects hidden inside the vases, treating it almost like a competition--the number of collected objects could be equated to a score. Presence would continue to be treated as a dependent variable and will hopefully be better induced due to the independent variable immersion.

# 4 Summary

As of yet, the relationship between presence and memory remains unclear since this study failed to find a significant difference of presence between conditions, and further research is needed to confirm or contradict prior findings. The current study did find support for the findings of Xu and Sundar. (2016), confirming that higher interactivity resulted in better spatial memory recall. Psychologists who continue to research presence in VEs should include researchers in the world of video games as there are many overlapping interests and goals within the respective research literature. More and more people are playing video games, and this medium is known for captivating people's attention and creating immersion, recognizing this, future research in the area of presence should look towards the direction of gaming.

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# Appendix A

Demographic survey.

1. What is your biological sex?
2. If prefer to self describe, please use this space here:
3. With what gender do you identify?
4. If prefer to self describe, please use this space here:
5. What is your age range?
6. Which best describes the environment in which you grew up?
7. I have a broad interest in Ancient Rome.
8. I am generally familiar with Roman culture and history.
9. I have studied Roman art and architecture in a school program.
10. I have been to Italy.
11. I have visited Rome.
12. I have visited the archaeological site of Pompeii.
13. I have significant experience playing video games on desktop platforms.
14. I typically play video games… *(measuring average time per week playing video games)*
15. When visiting a new house or apartment, I am confident about navigating the layout (for example, finding the kitchen).
16. In an unfamiliar setting, I am confident in my ability to retrace my steps without assistance.
17. In most circumstances, I rely on landmarks or objects to find my way.

## Appendix B

iGroup Presence Questionnaire (Regenbrecht et al, 2001)

1. How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?
2. How real did the virtual world seem to you?*
3. I had a sense of acting in the virtual space, rather than operating something from outside.
4. How much did your experience in the virtual environment seem consistent with your real world experience?
5. How real did the virtual world seem to you?
6. I did not feel present in the virtual space.
7. I was not aware of my real environment.
8. In the computer generated world I had a sense of "being there".
9. Somehow I felt that the virtual world surrounded me.
10. I felt present in the virtual space.
11. I still paid attention to the real environment.*
12. The virtual world seemed more realistic than the real world.
13. I felt like I was just perceiving pictures.*
14. I was completely captivated by the virtual world.

*Denotes items that were reverse-scored

# Appendix C

Memory recognition test.

***Section I***
1-8. Choose the image that was in the house you just navigated from the set of images given.

***Section II***
9-11. Choose the image that **WAS NOT** in the house you just navigated from the set of images given.
12. Choose the image that shows where you started in the house.
13. Choose the floor plan of the house you just navigated from the set of plans given.

## Appendix D

Feedback survey.

1. During the study, were you ever distracted by outside sources? (Ex: a phone call, someone walking in, a loud noise outside, etc.)
2. Were there times when you felt unengaged and/or disinterested in the virtual environment?
3. Did you feel that the time for exploration of the house was too long?
4. Did you feel that the time for exploration of the house was too short?
5. Were there times when you felt frustrated during the study?
6. Did you have any computer difficulties during this study?
7. While exploring the virtual house, I felt I was able to control my gaze to look where I wanted successfully.
8. While exploring the virtual house, I felt I was able to control my movements (forward/back, left/right) successfully.
9. While playing, I experienced a sense of being lost.