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Psychological Presence in Immersive Virtual Environments

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PSYCHOLOGICAL PRESENCE IN IMMERSIVE VIRTUAL ENVIRONMENTS

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ABSTRACT

PSYCHOLOGICAL PRESENCE IN IMMERSIVE VIRTUAL ENVIRONMENTS

by Steven Wu

Immersive virtual environments are simulated locations that attempt to create a sense of presence, or the psychological feeling that an individual is acting within the simulated environment rather than their physical one. When interfacing with an interactive virtual environment, evidence suggests that aspects of psychological presence are affected, such as time perception and situation awareness. As such, this study hypothesized presence as the construct by which immersive virtual environment usage influences time perception and situation awareness. Two levels of presence were manipulated using a monitor and Oculus Rift. Forty-one participants were tasked with a scavenger hunt in both monitor and virtual reality conditions, reported their perception of how much time has passed, and answered probe questions testing their situation awareness. Manipulating level of immersion did not significantly affect presence between conditions. Time perception was not significantly correlated with presence scores in either condition. Situation awareness was not significantly correlated with presence in the virtual reality condition but was found to be negatively correlated with presence in the monitor condition. Presence was not found to have a positive relationship with situation awareness and time perception as predicted, but higher levels of immersion was found to increase situation awareness and lengthen subjective experience of time. Presence does not appear to be the construct responsible for changes in situation awareness and time perception and further study is required.

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Introduction

The recent development of relatively cheap and accessible head mounted displays (HMDs) have made immersive virtual environments (IVEs; e.g., Oculus Rift, Vive, PlayStation VR) widely available to everyday consumers for the first time. What once was reserved for fighter pilots and exhibition theaters, requiring thousands of dollars of equipment, can today be simulated in the comfort of one's home for less than the price of a computer. In early 2017, Sony reported that they had sold a million PlayStation HMD units in only four months, exceeding expectations for sales by a large margin (Wingfield, 2017). Also in early 2017, less than a year after the release of Oculus Rift, the first major consumer HMD, more than six million HMDs had been sold, far exceeding predictions (Durbin, 2017). The virtual reality(VR)/IVE industry is projected to see $38 billion in revenue by 2020 (SuperData, 2017). The quickly increasing popularity of IVEs in the general public, in addition to implications for use in professional settings such as training and therapy, has brought attention to the need for research in this area.

IVEs are virtually-rendered, three-dimensional spaces and stimuli that attempt to elicit feelings of being in the mediated environment rather than in the current physical environment. IVEs can be generated by various means but nowadays are most commonly constructed using HMDs, as projection-based displays are often cost-restrictive (Sharples, Cobb, Moody, & Wilson, 2008). The simulated environment is presented to HMD users through two slightly different displays for the two eyes, mimicking binocular disparity. Contemporary HMDs are able to provide wide, high resolution displays, allowing for a naturalistic field of view with relatively high visual fidelity.

Pilots and soldiers can practice and train in scenarios in IVEs that would be dangerous or expensive to recreate in reality (Pleban, Eakin, & Salter, 2001; Waller, Hunt, & Knapp, 1998). Patients with phobias can be safely exposed to their fears without the danger of physical harm (Garcia-Palacios, 2002) and cancer patients can be distracted while undergoing chemotherapy (Schneider & Hood, 2007). In these implementations and examples, the degree to which individuals feel like they are experiencing the IVE is an important consideration when evaluating use of VR (Slater & Wilbur, 1997). For instance, evidence has shown that aircraft inspectors who felt more present in their simulated environments in VR training programs significantly decreased visual search time and significantly increased number of defects found compared to traditional training methods (Vora et al., 2002).

One challenge to implementation of IVEs in these contexts is ensuring the psychological fidelity of the users in the virtual environment. A necessary component in eliciting genuine responses and experiences is the feeling that an individual is truly in the simulated environment (Slater & Wilbur, 1997). An improved understanding of the psychological experience of IVEs would help trainers, patients, researchers and developers to better utilize this technology. Understanding the aspects of the environment that are perceived and utilized by individuals experiencing psychological presence in IVEs would give insight into how the technology can best be put to use.

The insights gained from this research could potentially influence implementation of IVEs in training of professionals, law enforcement, armed forces and in clinical settings, including therapy for cancer patients and treatment of different phobias. Improving knowledge of the psychological experience of IVEs could benefit researchers and developers who would employ the technology in practice. Researchers investigating fear reactions could present fearful stimuli to their participants in a controlled environment. Law enforcement could train their detectives to examine crime scenes created in IVEs. Understanding the experience and limitations of IVEs would inform the potential uses for this technology.

Psychological Presence

Stereoscopes were popularized in the mid-1800s after Sir Charles Wheatstone invented the device in 1838. The device directs the viewer's binocular vision towards two slightly shifted viewpoints of a scene, mimicking the sensation of depth. Stereoscopes had a sensational reception at the time; people had parties and paid money for a chance to see the Grand Canyon or the Sphinx of Giza without actually having to travel there. The psychological experience of being in another place enraptured the audience, as Oliver Wendell Holmes expresses in this quote:

> The shutting out of surrounding objects, and the concentration of the whole attention . . . produces a dream-like exaltation . . . in which we seem to leave the body behind us and sail into one strange scene after another, like disembodied spirits. (Holmes, 1861, p. 1)

Presence is a construct defined by Slater and Wilbur (1997) as "a state of consciousness, the (psychological) sense of being in the virtual environment" and captures the idea that "participants who are highly present should experience the virtual environment as more the engaging reality than the surrounding physical world…" (Slater & Wilbur, 1997, p.4). Presence refers to a psychological experience of an environment as seeming real, whether it is simulated or not. Though the term can be applied to any situation, presence is typically used while referring to IVEs, with our normal, unsimulated environment as reference. Stereopsis is a powerful depth cue and the experience of the simulated environment is not spatially removed from our perception; spatial depth is not extrapolated from a single two-dimensional (2D) display by our cognition. Additionally, factors such as real-time updating of the simulated environment with respect to natural head movement allow for a more convincing experience. Thus, presence is a context-dependent user response. Each user of an IVE may have a different level of presence and the same user may have different levels of presence at different times in response to the same stimuli, depending on factors like state of mind and recent history (Bowman & McMahan, 2007). According to Bystom, Barfield and Hendrix's (1999) immersion, presence, performance model, presence is theorized to be a necessary component for task performance in IVEs. As a construct, presence must be distinguished from immersion.

Immersion is “the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the sense of a human participant” (Slater & Wilbur, 1997, p. 3). Immersion is limited to the capability of hardware and technology to produce an environment, whereas presence refers to a human individual’s psychological feeling of being in that environment. Immersion provides the stimulus and psychological presence is a response. The two constructs have been found to be positively correlated (Barfield & Hendrix, 1995; Welch, Blackman, Liu, Mellers, & Stark, 1996), and immersion can be considered a precursor to presence (Hendrix &

Barfield, 1996). Immersion is also strongly related to simulator sickness, a negative psychological experience described later in this proposal.

Time Perception in Virtual Reality

Time perception is an important factor to consider when using IVEs for training and therapy. The perception of time can vary in IVEs, much like in other contexts, but has not been studied to the same extent. The dominant model in conceptualizing time perception is the pacemaker-accumulator model (Buhusi & Meck, 2005). In this model, a hypothetical internal pacemaker sends time pulses at regular intervals to an "accumulator." The pulse must pass through a "switch" that activates as a pulse passes through and deactivates after it has done so. The total number of accumulated pulses leads to the perceived duration of time. An inaccurate assessment of elapsed time is referred to as time distortion or time perception distortion. In the literature, time perception has been shown to both increase and decrease internal clock speed depending on factors such as emotional state (Droit-Volet & Meck, 2007), drug intake (Meck, 1996), and neurochemistry (Terhune, Russo, Stagg, & Kadosh, 2014).

The scientific literature concerning the perception of time and IVEs seems to be limited to investigations of patients in chemotherapy, and the mechanism of time distortion in these situations has not been fleshed out. There are only a few studies of time perception in IVEs, but the studies that are available suggest that, from a person's subjective point of view, IVEs make time seem to pass more quickly. These studies examined time perception in IVEs as a distraction intervention during chemotherapy and found that use of an IVE makes time seem to pass faster (Schneider, Kisby, & Flint, 2011; Schneider & Hood, 2007; Schneider, Ellis, Coombs, Shonkwiler, & Folsom, 2003; Chirico et al., 2016) leading to underestimates of elapsed time. This study aims to investigate how implementation of IVEs influences time perception in populations and contexts beyond chemotherapy patients and also proposes that presence is the factor that influences this relationship, following the theory of flow (Csikszentmihalyi, 2000).

Flow is described as a psychological state of consciousness in which the individual is wholly engaged with the task at hand (Csikszentmihalyi, 2000) and is a concept that mirrors the involved engagement that characterizes presence. One of the defining characteristics of the flow state is the distortion of temporal experience; the subjective experience of time is altered in some way (Nakamura & Czikszentmihalyi, 2009). Though the flow state is similar to presence, this study opts to focus specifically on presence. Presence is not a state that either occurs or not, but rather, it is a continuous aspect of the psychological experience (Bowman & McMahan, 2007). Presence is felt and updated continually and, as mentioned previously, the literature suggests that IVEs will have an influence on it.

Situation Awareness

Situation awareness (SA) is a construct popularized by Endsley (1995) that measures "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." As theorized by Endsley (1995), SA is divided into three different levels. The three levels reflect degrees of SA and are not necessarily linear stages of SA (Endsley, 2015). In ascending order: Level 1 SA is the perception of elements, Level 2 SA is the comprehension of the current situation, and Level 3 SA is the projection of future status.

Perception of elements refers to the awareness of task-relevant stimuli. Perception of elements in the SA literature is different from perception in general in that SA contexts look not at what can be perceived, but whether the stimuli that are being perceived contribute to the individual's goals. The second level of SA is comprehension of the current situation which refers to the cognitive conceptualization and integration of the stimuli that are perceived. Comprehension of the current situation is necessarily an integration of the data received from level 1 SA, as well as the goals and expertise of the individual; comprehension of the current situation is simultaneously a bottom-up and top-down process (Endsley, 2015). The third and highest level of SA is projection of future status. Level 3 SA integrates information from both Level 1, perception, and Level 2, comprehension to formulate predictions and expectations that allow individuals to better anticipate the demands needed for completing their goal. Level 3 SA is especially specific to tasks and more dependent on prior knowledge and expertise.

Because SA is closely tied to the task being performed, the medium in which the task is completed, if unobtrusive, should have little effect on SA. The state of VR, however, is that IVEs are not yet able to fully simulate the incredible amount of detail provided by the real world.

SA has been evaluated in simulated environments in military research by manipulating the "ground truth" of a situation and comparing it to an individual's awareness of the situation. A common method for this comparison is known as the

Situation Awareness Global Assessment Technique (SAGAT), which involves pausing the display of the simulated environment to ask probe questions corresponding to the three levels of SA. Currently, studies have mixed conclusions as to the effect and importance of presence in SA (Laptaned, 2006; Vora et al., 2002; Prothero, Parker, Furness, & Wells, 1995; Matsas & Vosniakos, 2017; Read & Saleem, 2017). A better understanding of SA will help us get users to know what they need to know for the task they are performing.

Simulator Sickness

In examining the relationships between constructs involved in IVEs, the effect of simulator sickness must be considered as a possible confound to the psychological variables in question as well as a possible risk to participants. Kennedy, Lane, Berbaum, and Lilienthal (1993) theorized the construct known as simulator sickness as distinct from the construct of motion sickness. Simulator sickness, theorized to be the result of instabilities in posture due to conflicting visual and vestibular inputs (Riccio & Stoffregen, 1991), is characterized by symptoms of motion sickness, such as fatigue, eyestrain, nausea, or dizziness, but to a lesser degree. Studies on the relationship of simulator sickness to psychological presence have produced conflicting results (Lin et. al, 2002; Witmer & Singer, 1994). Given the potential risks for negative effects of using IVEs and the possible effects of simulator sickness on the variables in research, experiments in this area often include it as a variable to be measured and examined.

Though no literature has examined simulator sickness's relationship with time perception, studies have shown that novel patterns of visual-vestibular intersensory stimulation, including time delays, are capable of inducing simulator sickness (Draper, Viirre, Furness, & Gawron, 2001). To my knowledge, no study has directly examined the influence of simulator sickness on SA. Simulator sickness, as a negative experience, is hypothesized to have a negative relationship with time perception accuracy in the opposite direction of presence, such that higher levels of simulator sickness would predict an overestimated time elapsed.

Significance of the Study

Understanding the mechanisms behind time perception distortion would allow hospitals to have stronger support for using IVEs as a potential distraction therapy for those undergoing chemotherapy or other distressing procedures. This study expands the literature by examining IVE users in a (presumably) non-distressing context as well as provide context to how time perception is affected by IVEs when the user is performing a task rather than passively experiencing an IVE. Beyond medical applications of IVEs, this study also adds to the understanding of presence, a construct that has not been heavily investigated in relation to task performance, historically, and fills a gap in the literature between psychological and clinical understanding of time perception in IVEs. IVEs present a novel tool which could be used in a variety of contexts to craft and control a simulated environment or experience. Pilots can practice flying under extreme conditions having to wait for those potentially dangerous conditions to occur. Teachers could allow their students to experiment and view chemical reactions in real time. Understanding of how time perception and SA are affected in IVEs are instrumental in the wealth of applications that IVEs could see in the near future.

Experiment

The purpose of this experimental study is to examine the relationship of psychological presence in an IVE to time perception and SA, facilitated by immersion. To measure presence, time perception accuracy, and SA in relation to a task, the experimental design employed a scavenger hunt within a virtual environment, completed in both an IVE using a VR display and on a traditional monitor. Participants searched for instances of a target object in their environment, which were distributed throughout and often hidden by parts of the environment.

The variable of interest, presence, is defined as the extent to which an individual reports feeling a sense of actually being in an environment, simulated or otherwise. The independent variable of immersion was defined as the technological capability of producing detailed, simulated environments and was manipulated by alternating between two levels: a computer monitor and an Oculus Rift. The dependent variable of time perception was defined as the accuracy with which an individual discerns the amount of time that has elapsed during a given task. Time perception accuracy was evaluated as the absolute value of the time deviation to account for both overestimates and underestimates of elapsed time.

The dependent variable of SA was defined as the number of correct responses to probe questions that query various aspects of the participant's current situation during the task.

Hypotheses

The literature suggests that presence would likely influence the dependent variables of time perception accuracy and SA in the consumer population using a commercial HMD. Schneider, Kisby, and Flint (2011) suggest that time perception accuracy will be negatively related to presence, such that higher levels of presence would result in less accurate assessments of time passage. Additionally, Schneider's study suggests that the decrease in time perception accuracy will occur such that the subjective experience of time will feel shorter than reality. SA has been found to be positively related to presence, though this study could provide updated evidence, given the speed of technological advancement. Consequently, I developed the following hypotheses (Figure 1):

Hypothesis 1: Immersion will have a positive relationship with presence, such that presence scores will be higher in the high immersion condition.

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Hypothesis 2: Presence will have a negative relationship with time perception accuracy, such that those who are more present in the virtual environment will be worse at evaluating elapsed time.

Hypothesis 3: Presence will have a positive relationship with SA, such that those who are more present in the virtual environment will be more aware of task relevant stimuli and information.

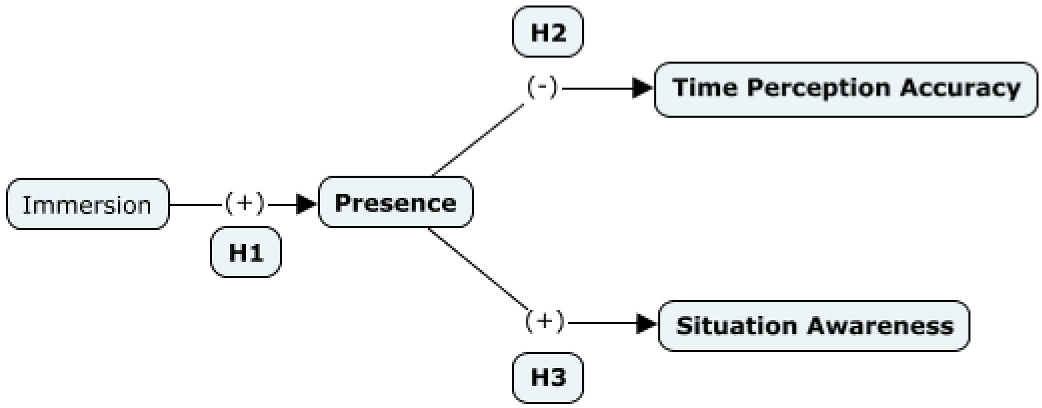


Figure 1. Theoretical model for the experiment.

Method

Participants

The participants were undergraduate psychology students from San Jose State University (14 males, 27 females), recruited through the SONA system and compensated with partial course credit. The study was approved by the SJSU IRB before being conducted. Participants were only included if they had the ability to give informed consent and had normal or corrected to normal vision. Participants were excluded if they had a history of seizures or were prone to motion sickness. The selection process for participants was a sampling of college-aged students (M = 18.78, SD = 2.16). Participants were informed of and monitored for simulator sickness effects throughout the study and were allowed to leave the study at any time, for any reason. Information regarding health services was prepared for any who felt sick, though none required it.

The literature investigating the effect of VR on time perception has found a medium effect size, Cohen's d = .51 (Schneider, Kisby, & Flint, 2011). Based on the reported means, we estimated that there would be a medium effect size for the within-subjects t-tests, d = .5. The study used a paired design with one condition representing each level of the independent variable. With power set at .9 and alpha set at .05, G-Power suggested 34 participants were needed to achieve an effect size of d = .5. Forty-one participants were recruited to account for attrition.

Materials

There were two different display conditions. The IVE condition was presented using the Oculus Rift which has a 2160 x 1200 resolution, 110-degree field of view, and refresh rate of 90Hz. The monitor display condition was presented using an AOC Gaming monitor with a 1920 x 1080 resolution and 144Hz refresh rate but was scaled down to 90Hz through the software. Frames per second in both conditions were capped at 90. The experimental task was conducted on the video game "The Elder Scrolls V: Skyrim" in the monitor condition and on the video game "The Elder Scrolls V: Skyrim VR" in the VR condition. The in-game avatar was controlled using mouse and keyboard in the monitor condition and the Oculus Touch controllers in the VR condition to best represent the interaction interface that a regular user would experience. Two in-game locations were identified for the scavenger hunt: the inns in the towns of Riften and Solitude, which both have three floors and are approximately the same size. Experimenters tracked the movements of participants in the virtual environment using floor plans of the two locations to test levels of SA.

Measures

Presence was measured using the Presence Questionnaire developed by Witmer & Singer (1998). The questionnaire has 19 items rated on a seven-point Likert scale for each item (Appendix A). The extremes of each item are anchored by a specific descriptor that corresponds to opposite ends of a continuum (e.g., "not compelling" to "very compelling"). The Presence Questionnaire has been seen to have excellent reliability, Cronbach's alpha = .88.

SA was evaluated using a series of probe questions that related to participants' perception, comprehension, and projection of task relevant stimuli (Appendix B). Participants were stopped two times during the task and asked several questions corresponding to each of the three levels of SA. This study used the Situation Awareness Global Assessment Technique (SAGAT) to evaluate SA (Endsley & Garland, 2000). In accord with the SAGAT procedure, the screen of the environment was removed from view during these stops, eliminating possible task-relevant perceptual information. The SAGAT was chosen as the method for evaluating SA because the effect of interruption was expected to be equal in the two conditions. The questions were: How many targets have you found? What floor of the building are you located? What direction is the door from your position? SA was operationalized as number of correct responses to probe questions.

Time perception was measured as the difference between the participants' reported time elapsed and the actual time elapsed during the task. Participants were queried for the amount of time that they have thought to have elapsed two times during the task. These queries coincided with the stops for the SA probe questions and occurred once more after the completion of the entire task. Time perception accuracy was recorded as the absolute value of the difference between estimated and actual time. These scores are represented as difference of seconds; all times reported are converted to seconds elapsed and difference in seconds perceived to have elapsed.

Simulator sickness was evaluated using the Simulator Sickness Questionnaire developed by Kennedy, Lane, Berbaum, and Lilienthal (1993; Appendix C). Participants selected one of four descriptions (none, slight, moderate severe) to relay their symptomology. The measure has been widely used in the past two decades as the main measure of simulator sickness and has been found to have high reliability, Cronbach's alpha = .79 (Yoo, 1999). The measure is based on the Pensacola Motion Sickness questionnaire (Graybiel & Miller, 1968) and has been modified using factor analysis to more closely relate to the symptomology found in simulator sickness.

Participants were asked to fill out a demographics survey including information regarding age, gender, general video game experience and VR experience, as well as experience with the Skyrim video game. Information on video game experience and VR experience were used to evaluate novelty effects.

Procedure

Participants were given information about the possible risks of the experiment and asked to provide informed consent. Before proceeding with the task, the researcher requested that the participant remove their phones or watches from sight to ensure validity of the time perception task. Participants were instructed on how to use the control scheme that corresponded to their display condition; mouse and keyboard for the monitor condition and the Oculus Touch controllers for the VR condition using Oculus Rift. Participants were allowed and encouraged to practice for up to five minutes to become familiar with the equipment and controls. During this practice section, participants were also introduced to the experimental task target, and encouraged to practice the scavenger hunt task before moving on to the test environments.

After participants said they felt comfortable with the controls, they were instructed to complete a scavenger hunt task on one of the two displays. Each display condition had a different virtual environment location in which the participant completed the task. At the start of the task, an audible tone sounded. The scavenger hunt task did not require time tracking, pacing, or rhythm. Two times throughout the task, the tone played again and participants were stopped and asked how much time they perceived to have passed since the previous tone, as well as multiple probe questions assessing their SA. Though order in which display conditions were presented differed, participants were stopped at fixed timing intervals based on a fixed sequence. Participants performed the task for 4 minutes and 30 seconds on the first display before being stopped, then 3 minutes and 30 seconds, and were given one final section of 3 minutes, totaling ten minutes per display condition. The second display condition presented to the participants saw the timing intervals progress in reverse (3 minutes, then 3 minutes 30 seconds, then 4 minutes 30 seconds).

Throughout the task, the experimenter used a detailed map of the environment's floorplan to track the path that the participants took, indicating where stops occurred and the order in which targets were found. In addition to the path that the participants took, the experimenter made note of the number of rooms searched, number of rooms left to search, number of targets found, number of targets remaining, and the direction in the environment that the participant was facing during stops (see Appendix D). Each task lasted between 15 and 20 minutes. After completion of the scavenger hunt, participants were asked to fill out the presence and simulator sickness questionnaires, and to report the amount of time they perceived to have elapsed in total since the previous tone. After a short break, participants repeated this process for the other display type.

Data Analysis

Correlations and paired t-tests were conducted to explore the relationships between the independent variable presence, a precursor to the independent variable immersion, and the dependent variables of time perception accuracy and SA. SPSS was used for all analyses. For all analyses, assumptions of normality of residuals, linearity of residuals, and homoscedasticity of residuals were checked using skewness and kurtosis statistics, and outliers were identified with a cutoff of three standard deviations from the mean.

Results

Descriptive Statistics

Descriptive statistics for the three variables (presence, SA, time perception) are presented in Table 1. Using a cut-off standard of ±2 for the ratios of skewness and kurtosis to their standard errors (IBM Knowledge Center, 2012), time perception in both display conditions was positively skewed, and time perception in the monitor condition was platykurtic (flatter distribution than normal).

Table 1.

Descriptive Statistics for Measures in Monitor and Virtual Reality Conditions

Variable	Mean	Standard Deviation	Standard Error	Skewness	Kurtosis
Presence Monitor	88.17	14.34	2.05	-.528	-.321
Presence VR	87.68	12.86	2.19	-.001	-.452
Situation Awareness Monitor	4.20	1.487	.23	-.208	-.952
Situation Awareness VR	5.05	1.596	.25	-.122	-.570
Time Perception Monitor	220.00	378.11	59.05	1.044	1.64
Time Perception VR	413.54	529.12	82.64	.882	.87

Note. N = 41

Accordingly, statistical analyses were run on the log of the time perception scores, though no differences were found compared to the same analyses performed on the untransformed data. According to these suggested parameters and a review of histograms for the data, all other data appear to be normally distributed.

Preliminary Analyses

To examine possible confounding effects of virtual environment location and order, paired sample t-tests were performed. There was no significant difference between presence scores in Location 1 (M = 86.48, SD = 13.86) and Location 2 (M = 89.37, SD = 13.21); $t(40) = 1.49$, $p = .15$. For SA, there was no significant difference between scores in Location 1 (M = 4.39, SD = 1.64) and Location 2 (M = 4.83, SD = 1.51); $t(40) = 1.42$, $p = .16$. For time perception, there was no significant differences between time perception scores in Location 1 (M = 263.5, SD = 439.0) and Location 2 (M = 370.0, SD = 493.6); $t(40) = -1.03$, $p = .31$. Therefore, the particular environments used in this study did not differentially affect performance.

There was no significant difference between presence scores in the first display condition (M = 86.78, SD = 13.13) and the second display condition (M = 89.07, SD = 13.99); $t(40) = 1.17$, $p = .24$. There was also no significant difference between SA scores in the first display condition (M = 4.39, SD = 1.76) as compared to the second display condition (M = 4.83, SD = 1.38); $t(40) = 1.42$, $p = .16$. There was no significant difference between time perception scores in the first display condition (M = 354.9, SD = 470.0) as compared to the second display condition (M = 278.7, SD = 467.1); $t(40) = 1.44$, $p = .16$. The order of conditions did not significantly affect the dependent variables of interest.

Tests of Hypotheses

Hypothesis 1: Immersion and Presence. To evaluate the hypothesis that manipulation of immersion produces a significant difference in presence, a t-test was conducted to compare ratings of immersion in the monitor vs. HMD condition. Immersion is predicted to be a precursor to presence as a construct and thus greater immersion should correspond to higher levels of presence. The manipulation of display type is meant to represent a change in level of immersion, with the VR display having higher immersion.

There was no significant difference between monitor (M = 88.17, SD = 14.34) and VR (M = 87.68, SD = 12.86) on presence scores, $t(40) = -.245$, $p = .40$. Our manipulation of immersion by changing between a monitor and VR HMD did not produce higher levels of reported presence in participants.

Hypothesis 2: Presence and Time Perception. To reflect our predicted direction of effect, a one-tailed Pearson correlation analysis was conducted to identify the relationship between psychological presence and time perception accuracy. The results of the correlation analysis were expected to find a significant negative relationship between the groups' time perception accuracy and presence, such that higher levels of presence are expected to reduced time perception accuracy (Table 2).

Presence was not significantly correlated with time perception scores in the monitor condition, $r(40) = .051$, $p = .38$, and in the VR condition, $r(40) = -.099$, $p = .73$. Feelings of presence in the virtual environment were not significantly related to participants' ability to perceive time in either condition.

Table 2.

Pearson Correlations for Variables of Interest

		Presence M	Presence VR	SA M	SAVR	Time Perc. M
Presence Monitor	Pearson's r p-value	-				
Presence VR	Pearson's r p-value	0.567*** < .001	-			
Situation Awareness Monitor	Pearson's r p-value	-0.377 0.992	-0.195 0.890	-		
Situation Awareness VR	Pearson's r p-value	-0.089 0.710	0.013 0.468	0.291* 0.033	-	
Time Perception Monitor	Pearson's r p-value	0.051 0.375	-0.202 0.898	-0.120 0.772	0.221 0.082	-
Time Perception VR	Pearson's r p-value	0.085 0.298	-0.099 0.731	-0.216 0.913	0.157 0.164	0.852*** < .001

Note. All tests one-tailed, for positive correlation
* p < .05, ** p < .05, *** p < .001, one-tailed

Hypothesis 3: Presence and Situation Awareness. Correlation analysis was used to evaluate the relationship between presence and SA. Presence was predicted to have a significant positive relationship with SA such that higher levels of presence were expected to increase SA. Presence was not significantly correlated with SA scores in the monitor condition, $r(40) = -.377$, $p = .99$, and in the VR condition, $r(40) = .013$, $p = .47$.

Participants' self-reported feelings of presence in the virtual environment were not significantly related to their SA scores in either condition.

Presence in the monitor condition was strongly positively correlated with presence in the VR condition, $r(40) = .567$, $p < .001$. SA in the monitor condition was moderately positively related to SA in the VR condition, $r(40) = .291$, $p = .03$. Time perception in the monitor condition was strongly positively related to time perception in the VR condition, $r(40) = .852$, $p < .001$.

Exploratory Analyses

Pearson correlations between the monitor conditions and demographics variables are shown in Table 3, along with correlations with the varying types of experience. There was a moderate positive significant correlation between age and SA, $r(40) = .332$, $p = .03$ such that those who were older had higher SA scores. There was a significant moderately negative correlation between age and time perception, $r(40) = -.399$, $p = .01$ such that those who were older had lower time perception scores, representing more accurate time perception. Video game experience was moderately related to gender such that males had more video game experience, $r(40) = -.450$, $p = .003$. Video game experience was also moderately positively correlated with Skyrim experience, $r(40) = .417$, $p = .007$.

Table 3.

Pearson Correlations for Monitor Condition with Demographics and Experience

	Age	Gender	Presence	SA	Time Perc.	VR Exp.	Video Game Exp.
Age	Pearson's r p-value						
Gender	-0.122 0.447	-					
Presence	-0.278 0.078	-0.071 0.658	-				
SA	0.332* 0.034	-0.149 0.351	-0.377* 0.015	-			
Time Perception	-0.399** 0.010	0.137 0.393	0.051 0.750	-0.120 0.456	-		
VR Experience	-0.149 0.353	-0.049 0.761	0.033 0.838	-0.144 0.369	0.059 0.713	-	
Video Game Experience	0.014 0.932	-0.450** 0.003	-0.076 0.638	0.259 0.102	0.049 0.761	0.202 0.205	-
Skyrim Experience	-0.028 0.862	-0.209 0.189	0.065 0.686	-0.012 0.942	-0.055 0.731	0.253 0.111	0.417*** 0.007

Note. All tests two-tailed
* p < .05, ** p < .01, *** p < .001

Pearson correlations between the VR condition variables, demographics, and experience are shown in Table 4. Age was found to be moderately negatively correlated to time perception in the VR condition, $r(40) = -.367$, $p = .02$; those who were older had lower time perception scores, representing more accurate time perception, the same relationship as in the monitor condition.

Table 4.

Pearson Correlations for Virtual Reality Condition with Demographics and Experience

	Age	Gender	Presence	SA	Time Perc.	VR Exp.	Video Game Exp.
Age	Pearson's r p-value						
Gender	-0.122 0.447	-					
Presence	0.128 0.426	-0.164 0.306	-				
SA	-0.178 0.266	0.120 0.454	0.013 0.936	-			
Time Perception	-0.367* 0.018	0.075 0.640	-0.099 0.538	0.157 0.327	-		
VR Experience	-0.149 0.353	-0.049 0.761	-0.024 0.880	-0.137 0.392	-0.080 0.620	-	
Video Game Experience	0.014 0.932	-0.450** 0.003	0.075 0.641	-0.088 0.582	0.070 0.665	0.202 0.205	-
Skyrim Experience	-0.028 0.862	-0.209 0.189	0.266 0.092	-0.085 0.598	-0.060 0.711	0.253 0.111	0.417*** 0.007

Note. All tests two-tailed
* p < .05, ** p < .05, *** p < .001

Paired sample t-tests were run to examine the relationship between display condition and the dependent variables of SA and time perception, regardless of ratings of psychological presence. A significant difference was detected in SA scores between the monitor condition (M = 4.20, SD = 1.49) and the VR condition (M = 5.05, SD = 1.60); $t(40) = 2.97$, $p = .005$.A significant difference was also found in time perception scores between the monitor condition (M = 220.0, SD = 378.1) and the VR condition (M = 413.5, SD = 529.1); $t(40) = 4.33$, $p < .001$. While participants were in the VR condition, they had better SA but poorer perception of the passage of time.

Pearson correlations between the variables of interest, enjoyment and engagement are shown in Table 5. A significant, strong positive relationship between enjoyment and presence in the VR condition was detected, $r(40) = .575$, $p < .001$; those who enjoyed the experience were more present in VR and vice versa. A significant, moderately positive relationship between engagement and presence in VR was also found, $r(40) = .464$, $p = .002$; participants who were more engaged with the experience were more present in VR and vice versa. A weak negative relationship was found between time perception in the VR condition and engagment, $r(40) =-.313$, $p = .04$. In other words, the more engaged a participant was in the VR condition, the more accurately they tracked time. Enjoyment and engagement were found to be strongly positively correlated, $r(40) = .537$, $p < .001$; those who were engaged with the experience also enjoyed it and vice versa.

Table 5.

Pearson Correlations for Variables of Interest with Enjoyment and Engagement

	Presence M	Presence VR	SA M	SA VR	Time Perc. M	Time Perc. VR	Enjoy.
Presence Monitor	Pearson's r pvalue						
Presence VR	0.567*** < 0.001	-					
SA Monitor	-0.377* 0.015	-0.195 0.221	-				
SA VR	-0.089 0.581	0.013 0.936	0.291 0.065	-			
Time Perception Monitor	0.051 0.750	-0.202 0.204	-0.120 0.456	0.221 0.165	-		
Time Perception VR	0.085 0.597	-0.099 0.538	-0.216 0.174	0.157 0.327	0.852*** < .001	-	
Enjoyment	0.128 0.426	0.575*** < .001	0.030 0.853	0.194 0.225	-0.089 0.580	-0.058 0.719	-
Engagement	0.352* 0.024	0.464** 0.002	0.075 0.642	0.227 0.153	-0.313* 0.046	-0.291 0.065	0.537*** < .001

Note. All tests two-tailed
* p < .05, ** p < .05, *** p < .001

Discussion

The purpose of the study was to investigate the influence of presence, as manipulated by levels of immersion, on SA and perceived passage of time. To explore these issues, an experiment was conducted in which participants completed a scavenger hunt two times, once with a monitor display and once with a VR HMD, incorporating pauses to query participants on their SA and time perception. It was hypothesized that going from the monitor level of immersion to the VR level would increase presence and that this increase in presence would increase SA and decrease time perception accuracy.

The results did not support the first hypothesis that increasing the level of immersion from a monitor display to a VR display would increase levels of presence. Though it is possible that the change from monitors to VR does not constitute a true improvement to the technological capability of producing a virtual environment, more research must be conducted before a conclusion like this can be made. Instead, these findings indicate that immersion, in the way that it was operationalized in this experiment, may not have an influence on levels of presence. Hendrix and Barfield (1996) claimed that immersion is a precursor to presence and that presence and immersion have a positive relationship, but it is possible that their conceptualization of presence differs from the construct of presence as we know it today. The definition of presence currently used in the field, and in this study, was presented by Slater and Wilbur (1997), after Hendrix and Barfield examined this relationship. It is possible that the referred to by Hendrix and Barfield is different from the one investigated in this study.

There was no correlation between presence and SA in either display condition when looking for a positive direction of effect. The correlation between presence and SA was negative in the monitor condition, when evaluated without a predicted direction of effect. This result for the monitor condition is directly contradictory to the predicted direction of the effect, though there may be other reasons for the observed results, discussed below. There is disagreement in the current literature about the nature of the relationship between presence and SA. On one hand, some researchers such as Prothero et al. (1995) have suggested that presence is potentially an overlapping construct with SA. In other words, presence and SA may not be able to be compared against one another, since SA as a construct encompasses the feeling of "being there" in addition to awareness of the situation. On the other hand, Matsas and Vosniakos (2017) suggest that presence is, as our hypothesis proposed, vital to task performance and SA as a contributor to task performance. They propose that presence and SA are independent constructs that interact with one another. Following their line of reasoning, presence could be a requirement for SA, but SA need not necessarily be required for presence. These data do not support the view of Matsas and Vosniakos, nor the position suggested by Prothero, instead suggesting that presence may negatively influence levels of SA, as far as completing tasks on traditional monitors is concerned.

Read and Saleem (2017) found that in a simple driving task, participants reported no difference in SA scores between scenarios carried out in reality, on a monitor, or in a VR IVE. They conclude that simulations of a real-world scenarios imposed no deficits on SA when using either a monitor or VR to complete their task. The data from this study do not support their conclusion, though differences in the studies may contribute to the discrepancy. Read and Saleem offer the possibility that their task was not sufficiently complex to detect SA differences. Additionally, their task was conducted in a setting that tried to closely represent reality, whereas the settings in the current study, while still representing reality in terms of visual fidelity, utilized a fantasy setting in which the task was performed. A study to bridge this gap between realistic and non-realistic settings, as well as complexity of the task, could clarify some of the differences in the conclusions regarding SA in IVEs.

There was no correlation between presence and time perception scores. Schneider, Kisby, and Flint (2011) and Schneider and Hood (2007) suggested that VR and IVEs provide a means to affect time perception and these results do not adhere with their conclusions and do not support presence as the construct that causes changes in time perception.

To investigate the relationships between these variables further, the effect of display condition on the dependent variables was directly examined. Interestingly, there are significant differences when display condition is compared against SA and time perception scores, without taking presence scores into account. Participants scored higher on objective SA questions in the VR/IVE condition and were also significantly worse at evaluating elapsed time. Interestingly, these results support the hypotheses of this study, once the link between immersion and presence is removed. The manipulation of display modalities from monitor to VR/IVE directly resulted in significant differences in time perception and SA. These data, when taken together with the analyses of presence, suggest that though VR displays and IVEs show a difference in SA and time perception, presence does not seem to be the construct by which this relationship occurs.

Though the increase in SA between display conditions could be attributed to a non-psychological, technical factor such as field of view, the nature of the SA construct provides a possible alternative explanation to the changes observed. SA, as theorized by Endsley (1995), is a system of not just task and environment, but also of the user's individual factors as well. Examples of such individual factors include abilities, experience, and long-term as well as psychological factors such as goals, preconceptions and expectations (Endsley & Garland, 2000). These individual factors may be affected differently by IVEs than by traditional displays. Conceptually, the scavenger hunt task and SA assessment focused primarily on the first level of SA, perception, and moderately on the second, comprehension. The third level, projection of future status, is highly dependent on the user's expertise in completing the task and is "the mark of a skilled expert" (Endsley & Garland, 2000, p. 4). There is a possibility that expertise and training act differentially upon those completing a task in a virtual environment through a monitor as compared to completing the same task in an IVE using an HMD. Reconstructing this study as a training experiment with varying levels of training in completing the task could provide more information concerning SA in IVEs. By having participants complete a task with no training, some training, and a lot of training, we could learn if higher, expertise-dependent levels of SA are similarly applied in IVEs as in reality.

One of the nuances that the research of time perception in IVEs has not examined is the level of arousal experienced by the users. Angrilli, Cherubini, Pavese and

Manefredini (1997) examined the influence of two affective factors, affective valence and affective arousal on time perception and found that in situations with low arousal, negative stimuli were judged to have a shorter duration than positive stimuli and in situations with high arousal, negative stimuli were judged to have a longer duration than positive stimuli. This coincides with the conclusions found by Schneider's (Schneider, Kisby, & Flint, 2011; Schneider & Hood, 2007) research, wherein chemotherapy patients undergoing a negative, low-arousal experience felt, subjectively, as if time had passed more quickly. In the current study, time perception scores in the VR condition were higher, suggesting that participants subjectively felt a longer duration for the same amount of time elapsed. Aligning this with the proposed relationship of affective factors and time perception proposed by Angrilli et al., if the monitor condition is used as a baseline, the VR experimental task was either judged as low-arousal, positive stimulus or a high-arousal, negative stimulus. For the experimental task in this study, the rating of subjective enjoyment was high ($M = 8.07$, $SD = 1.92$), suggesting that the VR condition in this experiment was experienced as a low-arousal, positive stimulus. Future investigations could examine effects on time perception with high-arousal stimuli or could reveal if possible interaction effects exist.

The differences observed between display conditions highlights the real effect of IVEs on SA and time perception. These results suggest that there is a substantial psychological difference between completing a task on a traditional display and using a VR HMD. These findings contribute to our overall understanding of the psychological experience with IVEs, but further investigation is required to determine what exactly contributes to these differences. Presence does not appear to be the construct by which these relationships occur, but it is possible that the relationships are more complex than what we've implemented here. More research investigating these constructs is required to identify and understand SA and time perception in relation to IVEs.

The significant effect of display on SA and time perception provide insight into the use of IVEs, but these results do not provide support for presence as the factor causing these differences. Further investigation into these constructs are necessary to better understand these constructs.

As stated previously, the relationship between presence and immersion as conceptualized by Hendrix and Barfield (1996) came before the definition of presence posed by Slater and Wilbur in 1997 that is used today. One possible direction to provide a meaningful contribution to the literature would be to investigate and confirm whether or not this relationship remains true. Most results of this study affirmed the null hypothesis and no conclusions could be drawn about this relationship, but a study designed to investigate this specifically may be informative.

An additional avenue to examine SA in IVEs is looking at decision making. SA and decision making are closely tied, as understanding of the situation in relation to a task directly informs the decisions that a user makes (Endsley & Garland, 2000). One advantage that IVEs can provide to researchers investigating decision making is the ability to control the entire environment being simulated. In the real world, especially in complex environments, variables can change beyond what a researcher can account for, know, or predict. To counteract the unpredictability and possible confounding nature of these complex environments, researchers create controlled environments, however the researcher must trade off some of the generalizability of their findings. In an IVE, however, the researcher can strictly monitor and manipulate the information available in the user's environment. The environment can be as complex as researchers wish it to be; the introduction of variables and the degree to which the environment is dynamic is up to the researcher. This implementation of IVEs could allow for better study of the interplay between users, SA, and decision making in a controlled, yet seemingly authentic, environment.

One possible explanation for the absence of an effect of display condition on presence could be our implementation of the user interaction controls. The Elder Scrolls V: Skyrim VR Edition allows for multiple configurations for different control schemes to suit a user's preference. Through pilot studies, a control scheme that minimized simulator sickness in participants was selected. This choice was successful in that no participant reported even moderate discomfort while participating in the task. Unfortunately, as evidenced by many of the participants' comments during the VR task, these control changes made the task feel "unintuitive" and "harder than it should have been". The unintuitiveness and clunkiness of the control scheme that participants used could have inhibited their sense of presence in the VR condition as compared to the monitor condition's mouse and keyboard controls. Whether or not participants had video game experience, the sample of undergraduates at SJSU would most likely have had experience using a mouse and keyboard before. For future studies, reassessing which control scheme strikes the best balance between control and sickness will be important, as both have the potential to reduce presence.

As for the difference in time perception, exploratory analyses provide a starting point to examine what factors contribute in a VR IVE as compared to a monitor. Engagement was found to be weakly negatively correlated to time perception accuracy in the VR condition, suggesting that the more engaged a user is, the more accurate their rating of time. As suggested earlier, examining time perception in IVEs with respect to varying affective factors could lead to interesting findings on perceived time. This could provide an explanation for the results of this study indicating the subjective experience of more time passing, contradicting previous research in chemotherapy settings.

The purpose of this study was to investigate the influence of psychological presence on time perception and SA across different levels of immersion. The results of this experiment did not provide support for a positive relationship between immersion and presence. Presence was found to have a negative relationship with a lower level of immersion (monitor) and no relationship at a comparatively higher level of immersion (virtual reality). Though this experiment did not provide support for a relationship between presence and time perception additional investigation determined that higher levels of immersion increased SA and lengthened the subjective experience of time. The relationships between these variables need to be fleshed out with additional research.

References

Angrilli, A., Cherubini, P., Pavese, A., & Manfredini, S. (1997). The influence of affective factors on time perception. *Perception & Psychophysics, 59*(6), 972-982.

Barfield, W., & Hendrix, C. (1995). The effect of update rate on the sense of presence within virtual environments. *Virtual Reality*, *1*(1), 3-15.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*(6), 1173.

Bowman, D. A., & McMahan, R. P. (2007). Virtual reality: how much immersion is enough? *Computer*, 40(7).

Bystrom, K. E., Barfield, W., & Hendrix, C. (1999). A conceptual model of the sense of presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 8*(2), 241-244.

Chirico, A., D'Aiuto, M., Pinto, M., Milanese, C., Napoli, A., Avino, F., ... & Giordano, A. (2016). The elapsed time during a virtual reality treatment for stressful procedures. A pool analysis on breast cancer patients during chemotherapy. *Intelligent Interactive Multimedia Systems and Services* (pp. 731-738). Springer International Publishing.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York, NY: Lawrence Erlbaum Associates.

Csikszentmihalyi, M. (2000). *Beyond boredom and anxiety* (25th anniversary ed.). San Francisco, CA. Jossey-Bass Publishing.

Draper, M. H., Viirre, E. S., Furness, T. A., & Gawron, V. J. (2001). Effects of image scale and system time delay on simulator sickness within head-coupled virtual environments. *Human Factors*, *43*(1), 129-146.

Droit-Volet, S., & Meck, W. H. (2007). How emotions colour our perception of time. *Trends in Cognitive Sciences*, *11*(12), 504-513.

Durbin, J. (2017, February 01). Report: 6.3 million virtual reality headsets shipped in 2016. Retrieved September 23, 2017, from https://uploadvr.com/report-6-3-million-virtual-reality-headsets-shipped-2016/

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors*, *37*(1), 32-64.

Endsley, M. R. (2015). Situation awareness misconceptions and misunderstandings. *Journal of Cognitive Engineering and Decision Making, 9*(1), 4-32.

Endsley, M. R., & Garland, D. J. (2000). Theoretical underpinnings of situation awareness: A critical review. *Situation Awareness Analysis and Measurement, 1*(24).

Garcia-Palacios, A., Hoffman, H., Carlin, A., Furness III, T. A., & Botella, C. (2002). Virtual reality in the treatment of spider phobia: a controlled study. *Behaviour Research and Therapy, 40*(9), 983-993.

Graybiel, A., & Miller, F. (1968). Diagnostic criteria for grading the severity of acute motion sickness. *Aerospace medicine*, 39(5), 453-355.

Hendrix, C., & Barfield, W. (1996). Presence within virtual environments as a function of visual display parameters. *Presence: Teleoperators & Virtual Environments*, 5(3), 274-289.

Holmes, O.W. (1861, July). A stereoscopic trip across the Atlantic. *The Atlantic Monthly*, pp. 13-29

IBM Knowledge Center. (2012). *Display Statistics*. Retrieved from https://www.ibm.com/support/knowledgecenter/en/SS3RA7_15.0.0/com.ibm.spss.modeler.help/dataaudit_displaystatistics.htm

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The International Journal of Aviation Psychology*, 3(3), 203-220.

Kolasinski, E. M. (1995). *Simulator sickness in virtual environments* (Report No. ARI-TR-1027). Army Research Institute for the Behavioral and Social Sciences. Alexandria, VA.

Laptaned, U. (2006). Situation awareness in virtual environments: A theoretical model and investigation with different interface designs. *UTCC Engineering Research Papers.*

Lin, J. W., Duh, H. B. L., Parker, D. E., Abi-Rached, H., & Furness, T. A. (2002). Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment. In *Virtual Reality, 2002. Proceedings. IEEE* (pp. 164-171). IEEE.

Matsas, E., & Vosniakos, G. C. (2017). Design of a virtual reality training system for human–robot collaboration in manufacturing tasks. *International Journal on Interactive Design and Manufacturing (IJIDeM), 11*(2), 139-153.

Meck, W. H. (1996). Neuropharmacology of timing and time perception. *Cognitive Brain Research, 3*(3), 227-242.

Nakamura, J., & Csikszentmihalyi, M. (2009). Flow theory and research. *Handbook of Positive Psychology*, 195-206.

Pleban, R. J., Eakin, D. E., Salter, M. S., & Matthews, M. D. (2001). *Training and assessment of decision-making skills in virtual environments*. Army Research Institute for the Behavioral and Social Sciences, Fort Benning, GA.

Prothero, J. D., Parker, D. E., Furness, T., & Wells, M. (1995). Towards a robust, quantitative measure for presence. In *Proceedings of the conference on Experimental Analysis and Measurement of Situation Awareness* (pp. 359-366).

Riccio, G. E., & Stoffregen, T. A. (1991). An ecological theory of motion sickness and postural instability. *Ecological Psychology*, *3*(3), 195-240.

Read, J. M., & Saleem, J. J. (2017). Task performance and situation awareness with a virtual reality head-mounted display. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 61, No. 1, pp. 2105-2109). Sage CA: Los Angeles, CA: SAGE Publications.

Schneider, S. M., Ellis, M., Coombs, W. T., Shonkwiler, E. L., & Folsom, L. C. (2003). Virtual reality intervention for older women with breast cancer. *CyberPsychology & Behavior*, *6*(3), 301-307.

Schneider, S. M., Kisby, C. K., & Flint, E. P. (2011). Effect of virtual reality on time perception in patients receiving chemotherapy. *Supportive Care in Cancer*, *19*(4), 555-564.

Schneider, S. M., & Hood, L. E. (2007). Virtual reality: a distraction intervention for chemotherapy. *Oncology Nursing Forum* (Vol. 34, No. 1, p. 39). NIH Public Access.

Sharples, S., Cobb, S., Moody, A., & Wilson, J. R. (2008). Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems. *Displays*, *29*(2), 58-69.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, 6(6), 603-616.

SuperData Research. (2017). *SuperData trends and insights on games and interactive media 2017: The virtual consumer (p. 12).* New York: SuperData Research.

Terhune, D. B., Russo, S., Near, J., Stagg, C. J., & Kadosh, R. C. (2014). GABA predicts time perception. *Journal of Neuroscience, 34*(12), 4364-4370.

Vora, J., Nair, S., Gramopadhye, A. K., Duchowski, A. T., Melloy, B. J., & Kanki, B. (2002). Using virtual reality technology for aircraft visual inspection training: presence and comparison studies. *Applied Ergonomics*, *33*(6), 559-570.

Waller, D., Hunt, E., & Knapp, D. (1998). The transfer of spatial knowledge in virtual environment training. *Presence*, *7*(2), 129-143.

Welch, R.B., Blackman, T.T., Liu, A., Mellers, B.A., Stark, L.W. (1996) The effects of pictorial realism, delay of visual feedback, and observer interactivity on the subjective sense of presence, *Presence: Teleoperators and Virtual Environments*, *5*(3), 263-273.

Wingfield, N. (2017, February 26). Popularity of Sony's PlayStation VR surprises even the company. Retrieved September 17, 2017, from https://www.nytimes.com/2017/02/26/business/sony-playstation-vr-sales.html?mcubz=3

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments, 7*(3), 225-240.

Witmer, B. G., & Singer, M. F. (1994). *Measuring presence in virtual environments* (Report No. ARI-TR-1014). Army Research Institute for the Behavioral and Social Sciences. Alexandria, VA.

Yoo, Y. H. (1999). *Prediction and quantification of individual differences in susceptibility to simulator sickness in fixed-base simulators*. (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. Publication Number: AAI9939131

Appendix A

Presence Questionnaire

Characterize your experience in the environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

WITH REGARD TO THE EXPERIENCED ENVIRONMENT

1. How much were you able to control events?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|________|________|________|________|________|________|________|
NOT RESPONSIVE MODERATELY RESPONSIVE COMPLETELY RESPONSIVE

3. How natural did your interactions with the environment seem?

|________|________|________|________|________|________|________|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

4. How much did the visual aspects of the environment involve you?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

5. How natural was the mechanism which controlled movement through the environment?

|________|________|________|________|________|________|________|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

13. How involved were you in the virtual environment experience?

|________|________|________|________|________|________|________|

NOT INVOLVED | MILDLY INVOLVED | COMPLETELY ENGROSSED

14. How much delay did you experience between your actions and expected outcomes?

|________|________|________|________|________|________|________|

NO DELAYS | MODERATE DELAYS | LONG DELAYS

15. How quickly did you adjust to the virtual environment experience?

|________|________|________|________|________|________|________|

NOT AT ALL | SLOWLY | LESS THAN ONE MINUTE

16. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

|________|________|________|________|________|________|________|

NOT PROFICIENT | REASONABLY PROFICIENT | VERY PROFICIENT

17. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

|________|________|________|________|________|________|________|

NOT AT ALL | INTERFERED SOMEWHAT | PREVENTED TASK PERFORMANCE

18. How much did the control devices interfere with the performance of assigned tasks or with other activities?

|________|________|________|________|________|________|________|

NOT AT ALL | INTERFERED SOMEWHAT | INTERFERED GREATLY

19. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

|________|________|________|________|________|________|________|

NOT AT ALL | SOMEWHAT | COMPLETELY

6. How compelling was your sense of objects moving through space?

|________|________|________|________|________|________|________|
NOT AT ALL MODERATELY COMPELLING VERY COMPELLING

7. How much did your experiences in the virtual environment seem consistent with your real world experiences?

|________|________|________|________|________|________|________|
NOT CONSISTENT MODERATELY CONSISTENT VERY CONSISTENT

8. Were you able to anticipate what would happen next in response to the actions that you performed?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

9. How completely were you able to actively survey or search the environment using vision?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

10. How compelling was your sense of moving around inside the virtual environment?

|________|________|________|________|________|________|________|
NOT COMPELLING MODERATELY COMPELLING VERY COMPELLING

11. How closely were you able to examine objects?

|________|________|________|________|________|________|________|
NOT AT ALL PRETTY CLOSELY VERY CLOSELY

12. How well could you examine objects from multiple viewpoints?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT EXTENSIVELY

IF THE VIRTUAL ENVIRONMENT INCLUDED SOUNDS:

20. How much did the auditory aspects of the environment involve you?

|________|________|________|________|________|________|________|

NOT AT ALL SOMEWHAT COMPLETELY

21. How well could you identify sounds?

|________|________|________|________|________|________|________|

NOT AT ALL SOMEWHAT COMPLETELY

22. How well could you localize sounds?

|________|________|________|________|________|________|________|

NOT AT ALL SOMEWHAT COMPLETELY

IF THE VIRTUAL ENVIRONMENT INCLUDED HAPTIC (SENSE OF TOUCH):

23. How well could you actively survey or search the virtual environment using touch?

|________|________|________|________|________|________|________|

NOT AT ALL SOMEWHAT COMPLETELY

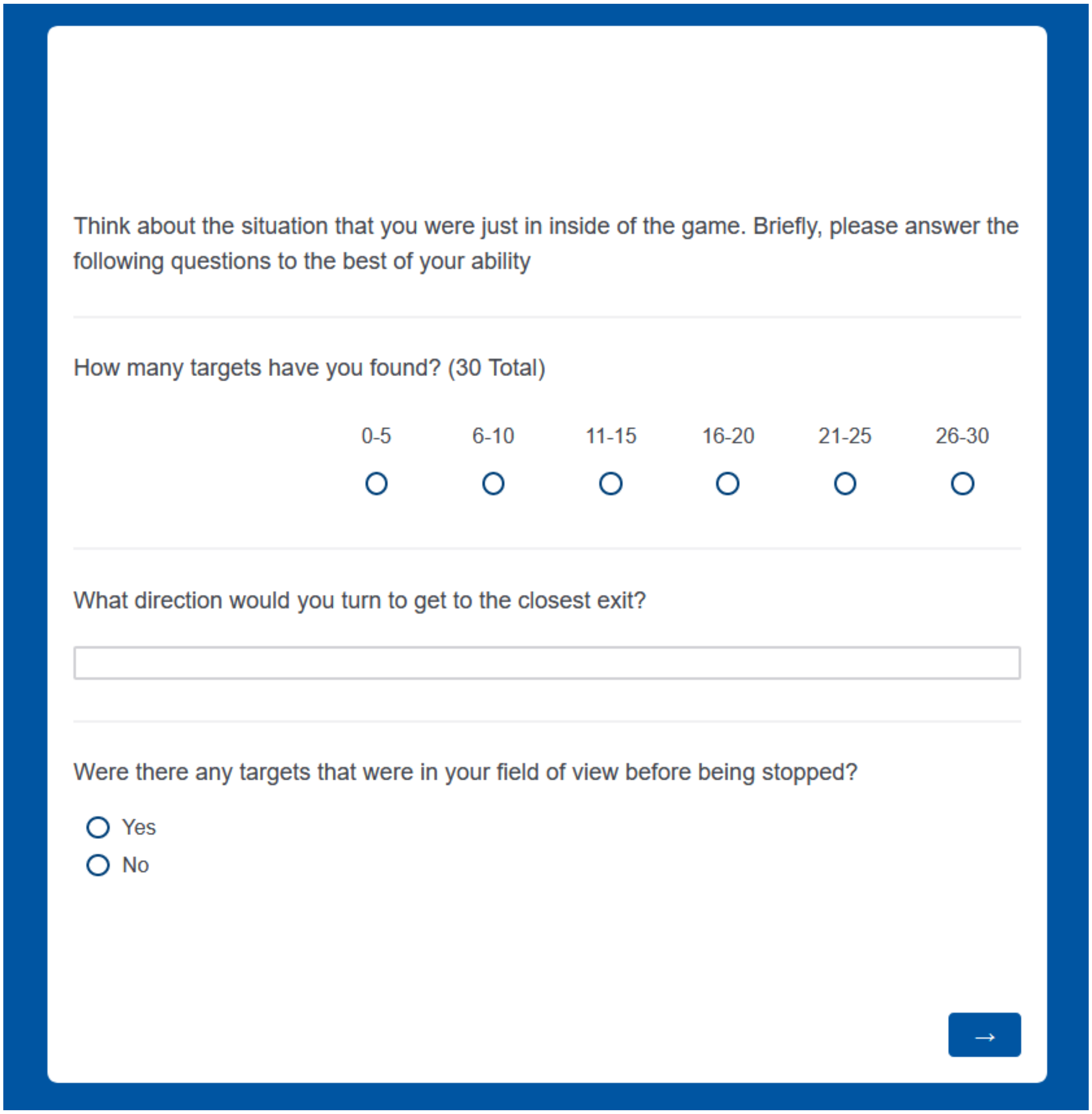
24. How well could you move or manipulate objects in the virtual environment?

|________|________|________|________|________|________|________|

NOT AT ALL SOMEWHAT EXTENSIVELY

Appendix B

Situation Awareness Global Assessment Technique Questionnaire



Think about the situation that you were just in inside of the game. Briefly, please answer the following questions to the best of your ability

How many targets have you found? (30 Total)

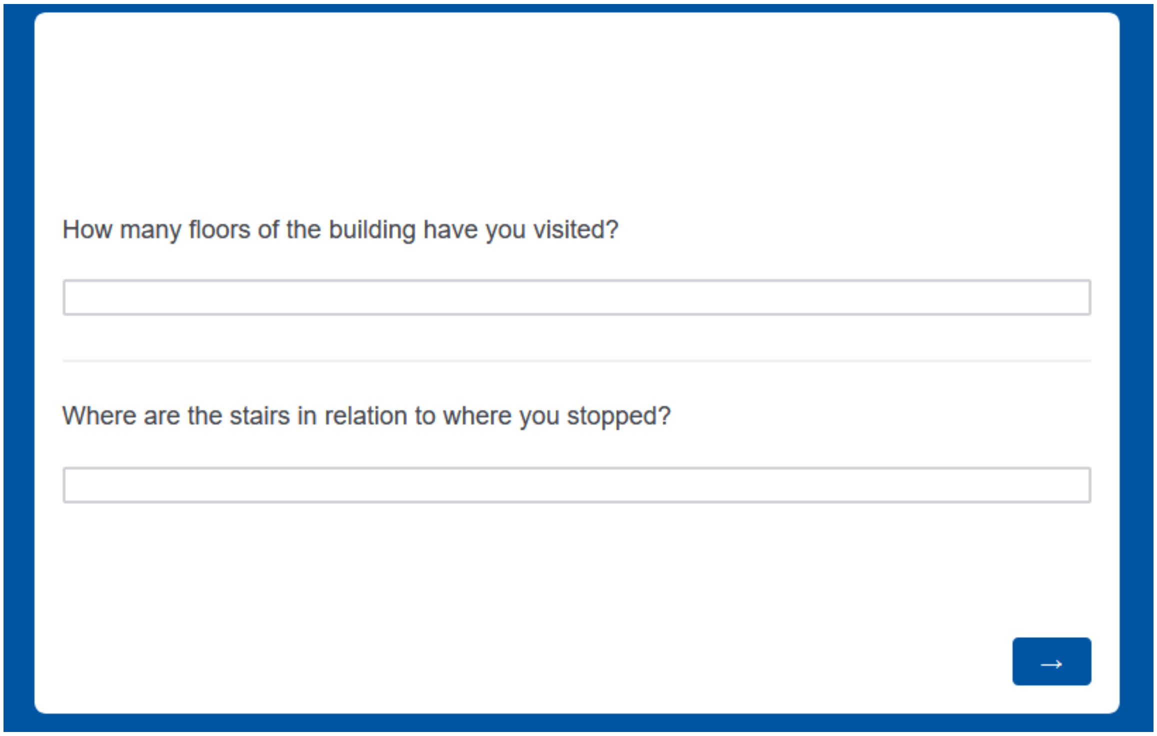
0-5	6-10	11-15	16-20	21-25	26-30
○	○	○	○	○	○

What direction would you turn to get to the closest exit?

Were there any targets that were in your field of view before being stopped?

- ○ Yes
- ○ No

→



How many floors of the building have you visited?

Where are the stairs in relation to where you stopped?

→

In a few words to a sentence or two, please answer the following questions to the best of your ability

How many targets have you found cumulatively?

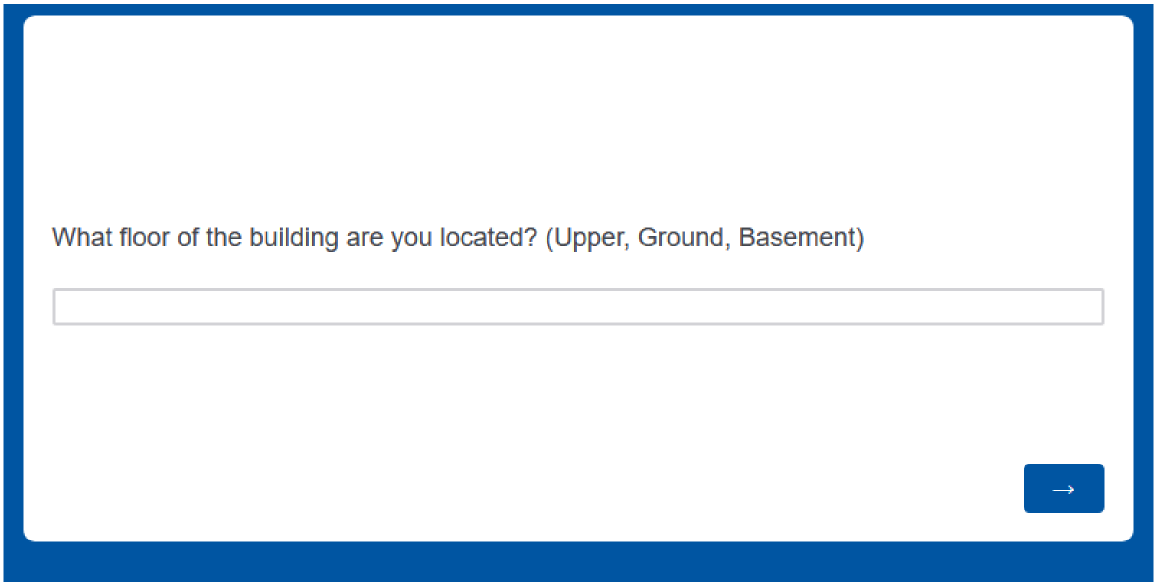
0-5	6-10	11-15	16-20	21-25	26-30
○	○	○	○	○	○

What direction is the door (towards the exit) from your position?

Were there any targets that were in your field of view before being stopped?

- ○ Yes
- ○ No

→


What floor of the building are you located? (Upper, Ground, Basement)
→

Appendix C

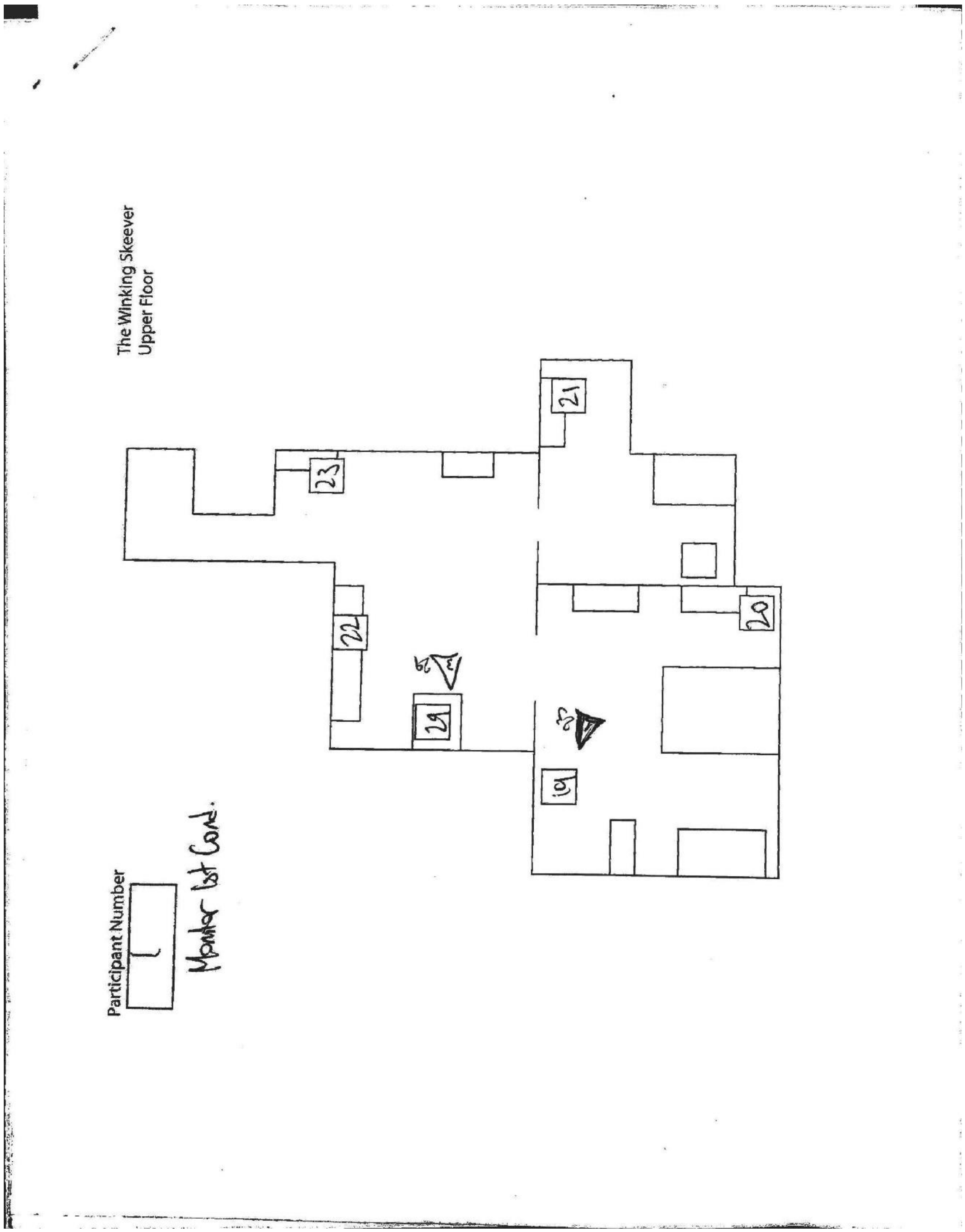
Simulator Sickness Questionnaire

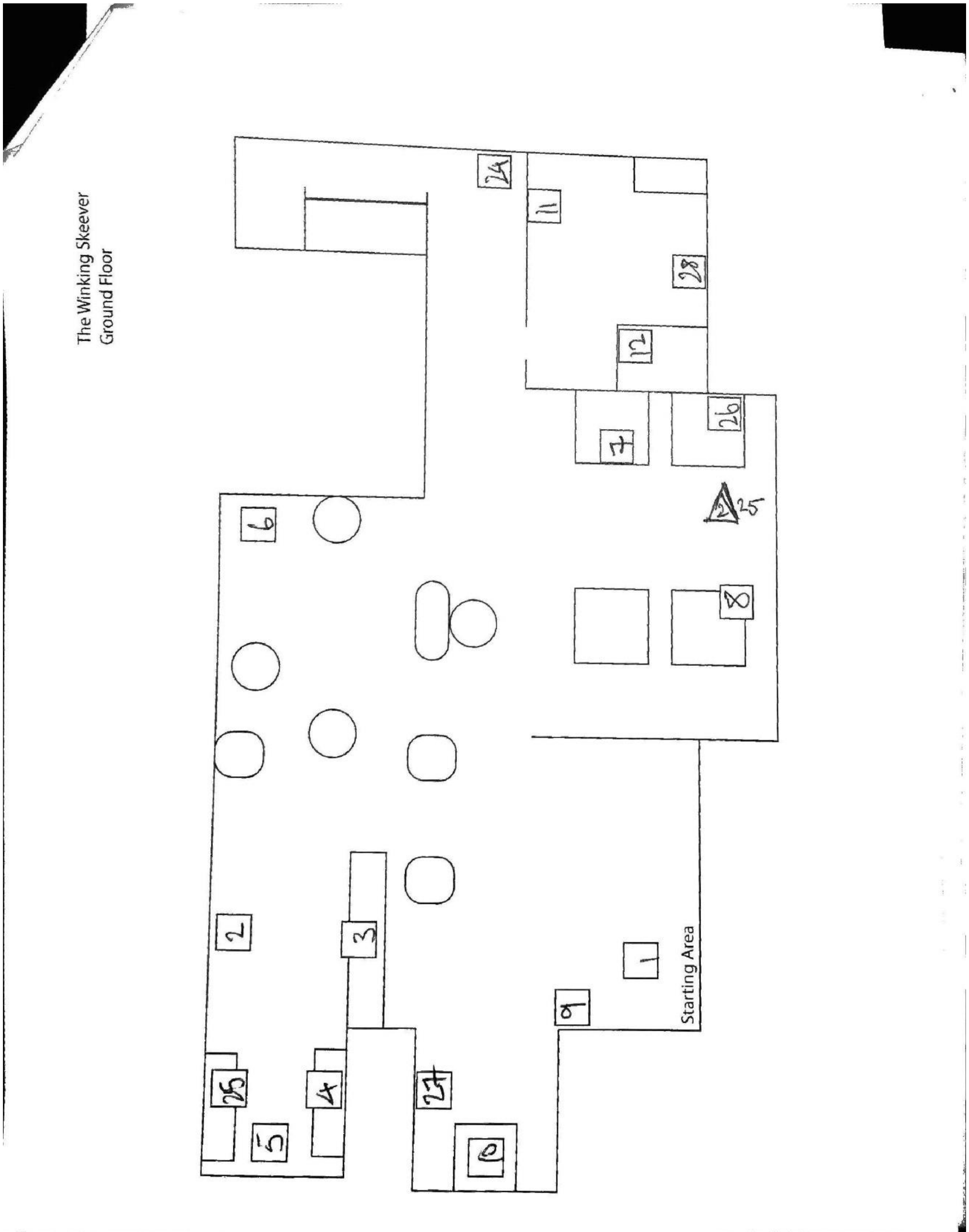
Instructions : Circle how much each symptom below is affecting you right now.

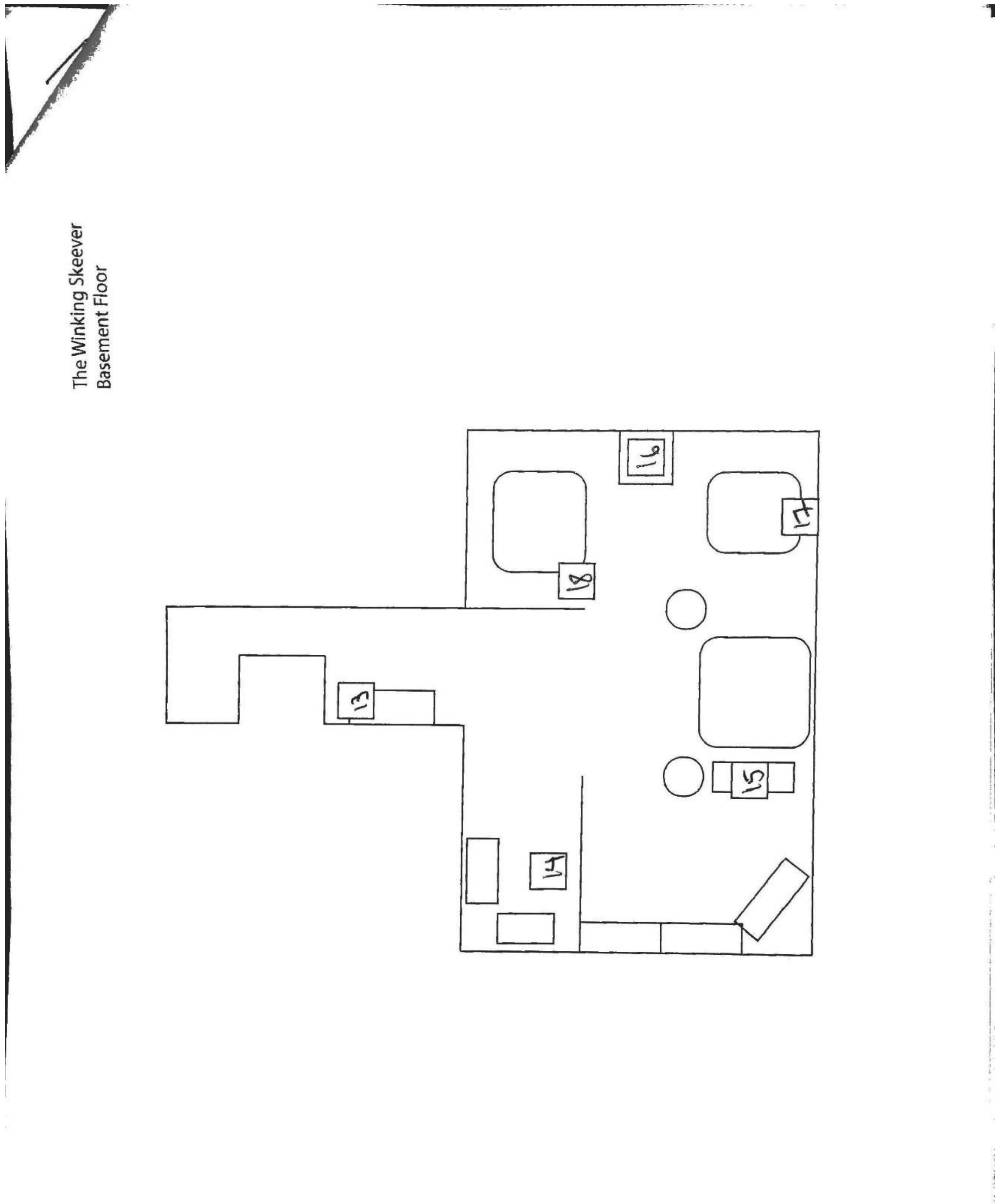
1. General discomfort	**None**	**Slight**	**Moderate**	**Severe**
2. Fatigue	**None**	**Slight**	**Moderate**	**Severe**
3. Headache	**None**	**Slight**	**Moderate**	**Severe**
4. Eye strain	**None**	**Slight**	**Moderate**	**Severe**
5. Difficulty focusing	**None**	**Slight**	**Moderate**	**Severe**
6. Salivation increasing	**None**	**Slight**	**Moderate**	**Severe**
7. Sweating	**None**	**Slight**	**Moderate**	**Severe**
8. Nausea	**None**	**Slight**	**Moderate**	**Severe**
9. Difficulty concentrating	**None**	**Slight**	**Moderate**	**Severe**
10. « Fullness of the Head »	**None**	**Slight**	**Moderate**	**Severe**
11. Blurred vision	**None**	**Slight**	**Moderate**	**Severe**
12. Dizziness with eyes open	**None**	**Slight**	**Moderate**	**Severe**
13. Dizziness with eyes closed	**None**	**Slight**	**Moderate**	**Severe**
14. *Vertigo	**None**	**Slight**	**Moderate**	**Severe**
15. **Stomach awareness	**None**	**Slight**	**Moderate**	**Severe**
16. Burping	**None**	**Slight**	**Moderate**	**Severe**

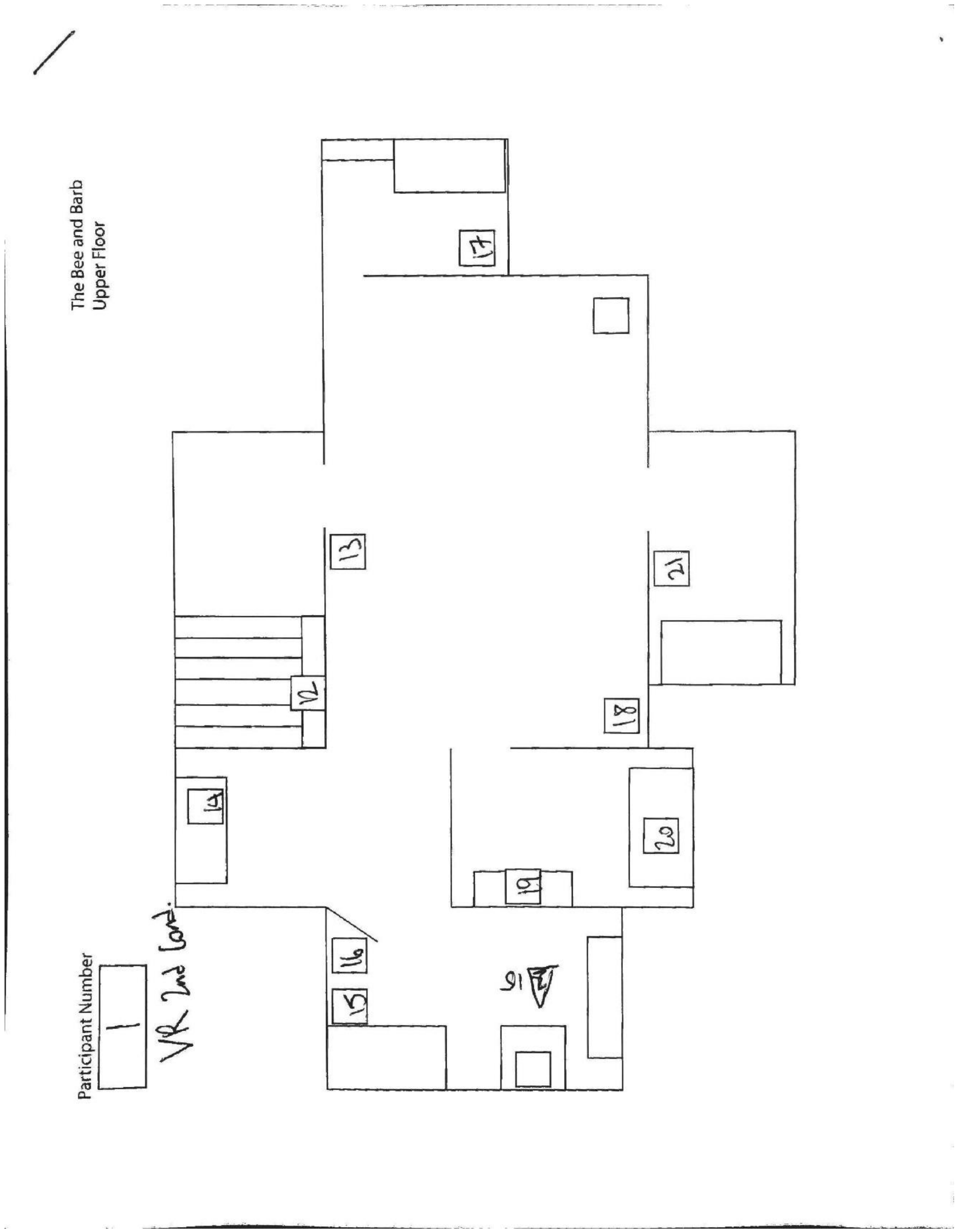
Appendix D

Map Example

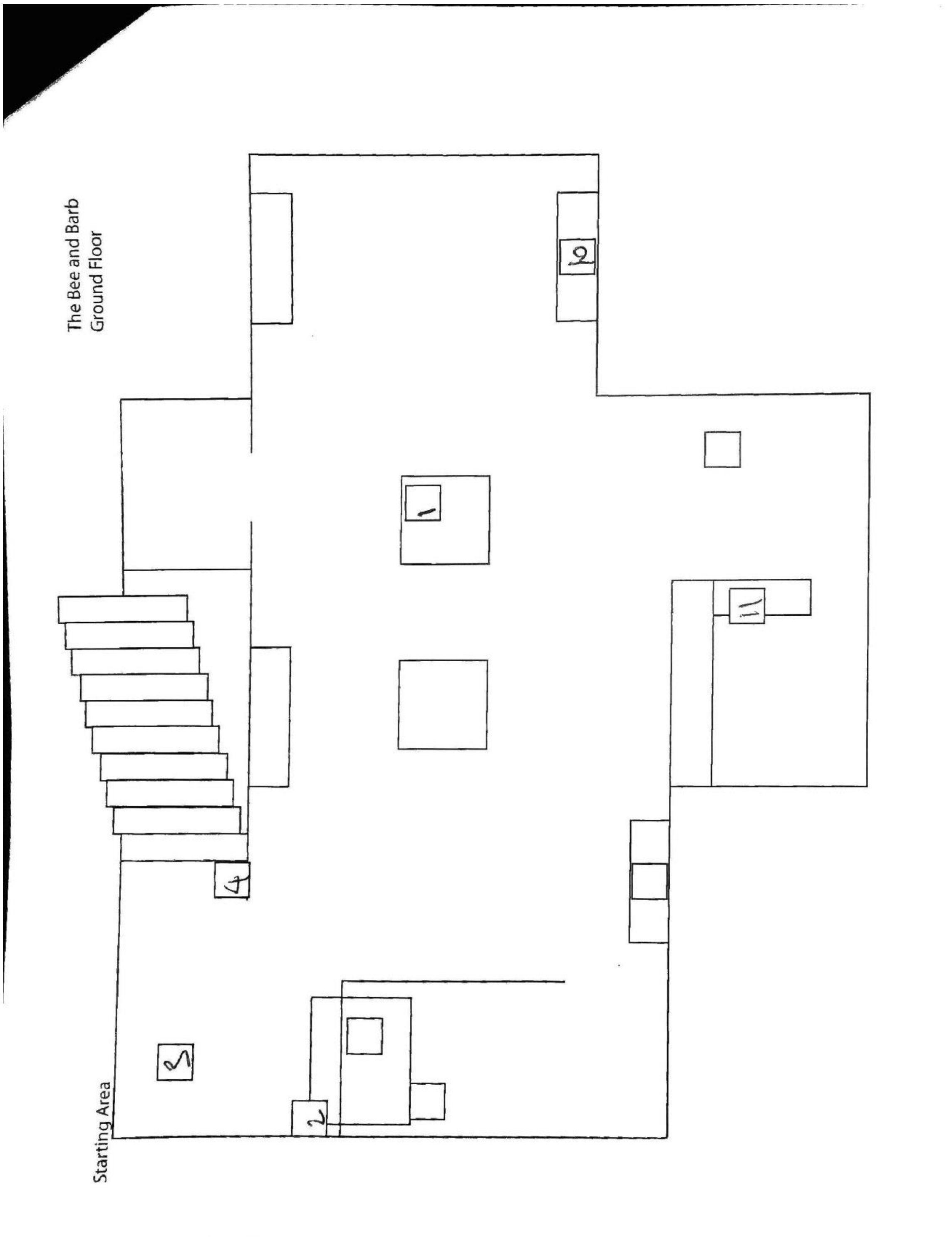


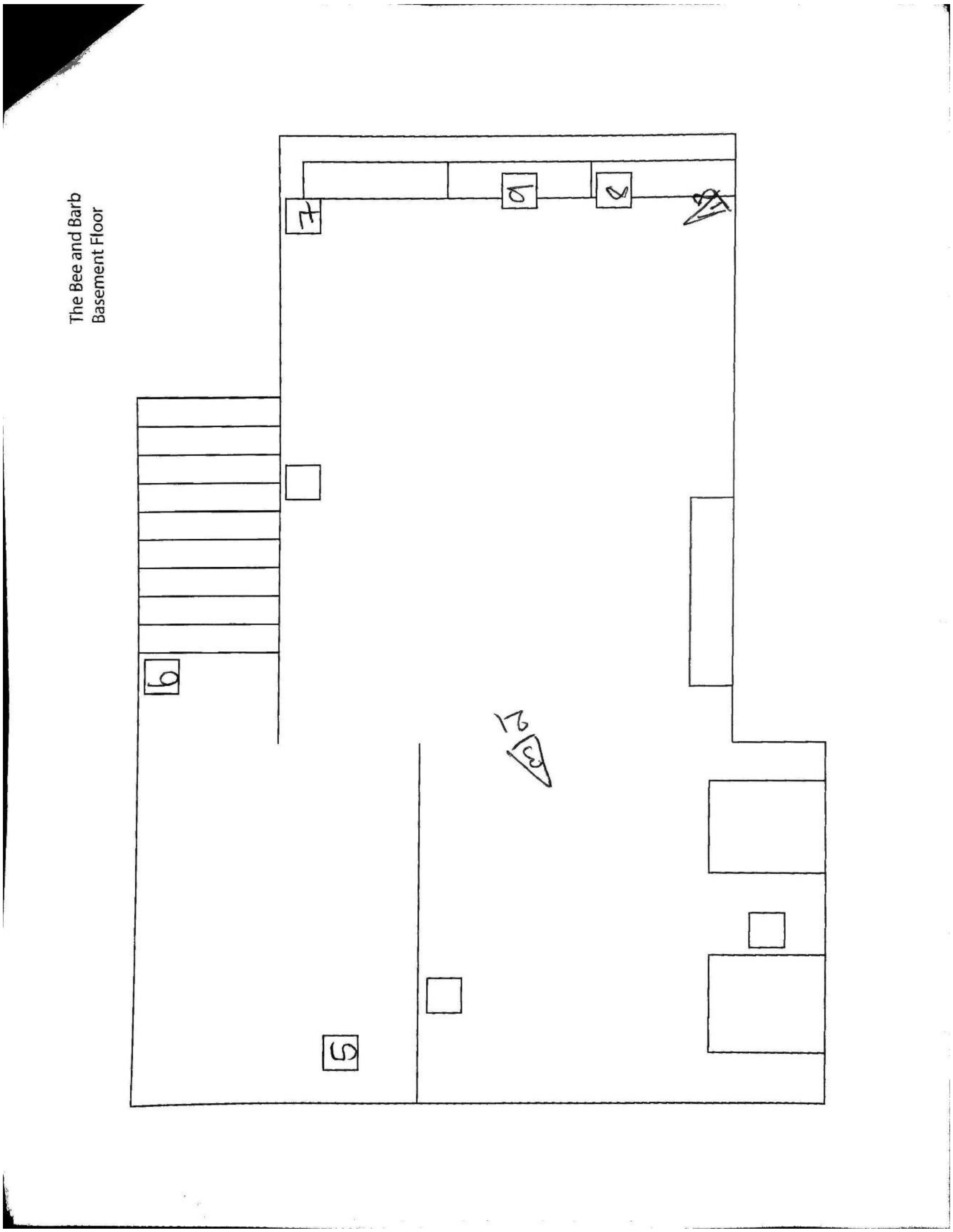

The Winking Skeever
Ground Floor
Starting Area


The Winking Skeever
Basement Floor
13
14
15
16
17
18



The Bee and Barb
Upper Floor
Participant Number
1
VR 2nd Cond.
12
13
14
15
16
17
18
19
20
21


The Bee and Barb
Ground Floor
Starting Area


The Bee and Barb
Basement Floor