

The Quest of Spatial Presence by Puzzle-Solving Games in VR

Merve Tasdelen¹, Derya Gulec Ozer², Aysegul Akcay Kavakoglu³

^{1,2,3}Istanbul Technical University

¹tasdelenm20@itu.edu.tr ²dgulec@itu.edu.tr ³akcaykavakoglu@itu.edu.tr

The experience of artificial objects in the virtual environment and the illusion of being there is a primary affordance of the virtual reality (VR) environment. The conviction of being located in a mediated environment is referred to as spatial presence. Although some studies investigate the relationship between VR and spatial intelligence, how users build a spatial presence in VR game environments remains ambiguous. Regarding that, this study tries to elaborate on the spatial presence experience construction and its characteristics in virtual reality (VR) puzzle-solving games by revealing the relationships between game mechanics and spatial presence notion. In this study, the presence-spatial performance relations are initially investigated based on previous works and analyzed in terms of spatial definition. Suppose the VR task performance depends on spatial abilities, people with higher spatial ability finish tasks faster, and their spatial presence score will be higher than people with lower spatial ability. A VR game called Golden Gate VR will be used as a case study to test and elaborate on the hypothesis above. This ongoing study has five steps: (1) Development of the game environment, (2) pre-psychometric assessment for visuo-spatial ability (Pre-Test), (3) Experience of the VR Game, (4) Evaluation of the experiences, (5) Re-development of the game environment. Experiences of the players' will be evaluated in terms of Mental Imagery, Mental Rotation and Spatial Orientation regarding Spatial Presence Experience Scale (SPES). The first four steps will be elaborated on in this paper.

Keywords: Immersive Virtual Reality, Spatial Presence, Spatial Ability, Puzzle-solving Game.

INTRODUCTION

The incorporation of virtual reality (VR) technologies into everyday life has accelerated due to technological advances, particularly in marketing methods in the gaming industry. For two decades, VR headsets used in research facilities in the 1990s have become one of the technologies available to society. Hence, the virtual environment (VE), which was questioned in terms of simulation, representation, and realism, began to be questioned

regarding the feeling of existence as virtual world experiences increased.

In the past, behavioral science has been researched in the context of design cognition concerning the design process, design thinking, and design education. But, in recent years, it has gained prominence in relation to spatial cognition in game design research. Virtual environment game design is an interdisciplinary area. In game design, the creation of virtual places is intimately tied to architectural design. The development of this set

incorporates a variety of architectural manufacturing processes. Architectural areas are developed according to the game's qualification, essence and requirements. Due to the interdisciplinary nature of the study of innovations in VR games, it has the potential to disclose unknown spatial links from both cognitive and architectural perspectives.

Even though the experience of the "being in there" notion is investigated via the concept of reality in terms of cognition, perception, and ability/skill differences have started to gain importance, especially in design-oriented research disciplines.

VR delivers more precise and extensive spatial information than any other VEs. Moreover, it exhibits accurate depth perception using a 3D cartesian system, while desktop and mobile systems only depict the world in 2D. This technical advancement may enhance viewers' spatial awareness, creating more precise mental models employing spatial information. Moreover, researchers report that the educational implementation of virtual reality has a positive impact on learning performance (Ott & Freina, 2015). Virtual reality has been extensively utilized in education. Individual differences primarily mediate these effects (Lin & Suh, 2021). Uz-Bilgin and Thomson published an article that connect the three topics together in 2022. They look into how users' prior knowledge, game experience, and VR experience affect the development of spatial presence in a VR educational game.

In addition to this spatial awareness, VR games mostly include various spatial tasks, depending on the game genre and the specific gameplay elements. Some common types of spatial tasks that may be included in VR games are navigation, object manipulation, and object recognition. VR games can provide players with a sense of presence and immersion by allowing them to interact with VE and object more naturally and intuitively. This immersion can be achieved through motion controllers, haptic feedback, and other technologies that simulate real-world interactions. High-quality computer-generated visual data and accurate head and body

tracking, as indicated by Slater in 2009, would greatly improve immersion and offer a sense of place illusion. As a result, VR games can provide a more engaging and memorable experience than traditional video games.

The feeling of being situated with virtual objects in the simulation can be described as a telepresence or spatial presence (Lee, 2004). Spatial presence refers to an experience in a platform that is created by human-made technology, specifically media systems (Hartmann et al., 2015). This subjective feeling can vary depending on the VE's immersion level and interactivity. Computer technology can represent the body with sensors in virtual worlds, referred to as "virtual bodies." This representation enables an immersive environment, and this immersion can lead to presence, which can be described as a sense of "being there" (Slater et al., 1994). Slater mentioned two illusions of VR which are "Place Illusion" and "Plausibility" (2009). Later, he and his colleagues added a new notion that represent "body ownership" as a third illusion that VR provide (2022). An immersive VR experience that incorporates high-quality visual and auditory cues and haptic feedback is more likely to create a strong sense of spatial presence than a less immersive experience. Additionally, the level of interaction and control the user has within the VE can impact the sense of spatial presence.

In this study, the presence-spatial performance relations are investigated based on previous works and analyzed in terms of spatial definitions. Previous research has discovered that presence increases with interactions (Rooij, 2022). However, these interactions were not evaluated from a spatial cognitional framework. As a result of the literature research, it has been marked that VR game performance depends on spatial performance in some cases (Maneuvrier & Westermann, 2020; Maneuvrier et al., 2022). If this is the case, individuals with higher spatial ability should finish the tasks more quickly than those with lower spatial scores. The spatial presence score should correlate favorably with spatial ability scores, particularly

Spatial Orientation Test results. As the quality of interactions improves, spatial presence will grow if the theories above are confirmed, which is planned to measure after the first phase of the study.

Golden Gate VR, a puzzle-solving game, will be presented as a case study to evaluate and expand on the concept mentioned above. According to the results, the discussion will elaborate on whether enhancing the users' spatial performance to help them figure out interactions better and feel present could lead to a design guidebook for interactions-based VR games such as puzzle-solving games.

The study aims to investigate the presence-spatial performance relations in VR experiences regarding mental rotation test (MRT), spatial orientation (PT-SOT), and navigation (SBSOD) regarding the Spatial Presence Experience Scale (SPES) (Hartmann et al., 2016) will be evaluated. This paper will concentrate on the experiment and discussion part as the first phase of the study.

THEORETICAL BACKGROUND

VR environments are defined mainly by these elements: presence, spatial perception, immersion, and interaction. These elements primarily provide distinctions between real and VEs (Azar & Rice, 2022). With the implementation of VR tools, the gaming environment disposes of presentation into the surface and provides the best performance for 3D perception. Since VR provides visuomotor skills during gameplay, the player does not only sit with restricted body movements while using a controller, keyboards, and mice (Chang et al., 2017). The VR tools, such as Head-Mounted-Display (HMD) sets, encourage the player to move in a limited action enhancing spatial perception. This development sparks off real-like interactions with the game, unlike computer-based games.

Studies have shown that interactions within VR increase spatial presence (Roosij, 2022) and positively correlate with mental imagery (Weibel et al., 2011). Although spatial presence differs between individuals, it may be explained by differences in more general spatial abilities (Coxon et al., 2016). The

perspective-taking ability has been linked to physical motions (Chang et al., 2017) and proven that this ability to be enhanced with tangible VR games (Harley et al., 2017).

Our primary objective is to analyze the game's mechanics within the context of spatial skills, enhance them, and reveal through interactions the association between spatial ability and spatial presence. Previous research has only proven a positive correlation with mental imagery (Weibel et al., 2011) and not with other spatial abilities such as mental rotation which measure the ability of spatial visualization of 3D object drawn in 2D, perspective-taking ability to test whether participants are able to update their location to answer navigational task, and navigation.

According to Mintz et al., individuals deliver egocentric orders when given depth indications to speak in a dynamic context (2004). In a VR gaming setting, the participant's decision-making process should rely on his or her egocentric perspective-taking ability.

VR: in the context of Spatial Behavior

People process the spatial information in and about the environment to know where they are, collect spatial information in wayfinding, and execute spatial tasks and spatial orientation, which all can be defined as spatial behavior (Golledge & Stimson, 1997). These behaviors hinge on spatial skills to be performed in the surrounding environment.

Spatial skills are a collection of human intelligence's cognitive functions, which can be regarded as the capacity to understand, recall, and manipulate spatial information and relations in space (Lee-Cultura & Giannakos, 2020). Spatial skills are considered catalysts for successfully managing cognitive tasks such as imagining and reasoning about changes in their spatial positions (Zacks et al., 2000; Lee-Cultura & Giannakos, 2020).

In Hegarty's (2005) study, she distinguished spatial skills by necessary scale: figural and environmental. Figural spatial skills occur in a small-

scale setting, but environmental spatial abilities arise in a big area. Individuals sense horizontal and vertical rotations, mentally rotate objects, and recall the placement of basic figures in small-scale environments (Voyer et al., 1995). On the other hand, environmental spatial skills are based on physical body movement, such as navigating in available spaces and learning the layout of the spaces (Hegarty, 2006). While 2D games mostly need figural spatial skills, activities requiring physical movement and environmental spatial skills can occur in immersive environments such as AR and VR. Zacks and his colleagues also articulated classifying mental spatial transformations into object-based and egocentric perspective transformations related to psychometric spatial ability tests (2000).

Presence and Immersion in VR Game Environment

Presence is a byproduct of immersion's emergency. The results of a person's experience of occupying a virtual space while psychologically being a part of the virtual world can be expressed as "presence" (Cummings & Bailenson, 2015). A cognitive representation of the spatial environment can also be described as spatial presence (Wirth et al., 2007).

Presence can be investigated in three subcategories: physical presence (spatial presence), self-presence, and social presence (Lee, 2004). These

subcategories are represented by different factors, such as external, technological, and internal, mostly psychological. External factors based on the systemic factors related to the HMD sets, auditory externalization, and models in the VEs mainly consist of the diversity of people's responses. On the other hand, internal factors are related to the individual user's perceptual and cognitive processes. For example, a user's previous experiences with virtual environments or real-world experiences and his spatial ability capacity can influence their sense of spatial presence.

The players should complete the tasks by questioning themselves in the gaming environment. As seen in **Figure 1**, the player must first immerse himself in the game by adjusting to the gaming environment. The first level involves the development of a mental model known as the Spatial Situation Model (Wirth et al., 2007). By activating this level, the second level provides Spatial Presence construction.

Spatial ability and spatial presence measurements

Beyond the theoretical arguments on the nature of the spatial presence, there are significant discrepancies in the instruments employed to assess the phenomena across different methods (Maneuvrier & Westermann, 2020). Since the 1980s,

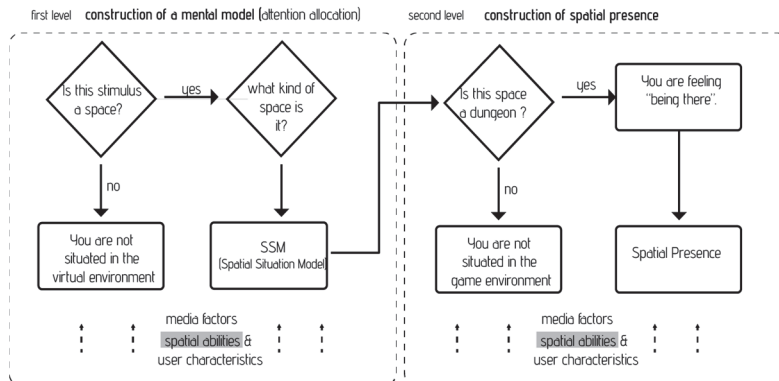


Figure 1: The implementation of Spatial Scale Model from Wirth et al. (2007).

researchers have invented methods to detect spatial presence. Researchers in the field of spatial presence use the Presence Questionnaire (PQ; Witmer & Singer, 1998), the Independent Television Commission-Sense of Presence Inventory (ITC-SOPI; Lessiter et al., 2001), the Igroup Presence Questionnaire (IPQ; Schubert, et al., 2001), and the Temple Presence Inventory (TPI; Lombard et al., 2009).

This paper will focus on the SPES (Spatial Presence Experience Scale), based on Wirth et al.'s model of generating spatial presence experiences (2007). The SPES, a novel self-report measure, examined media consumers' perceptions of spatial presence. The ten-item scale reliably and robustly represents two aspects of spatial presence self-location and feasible actions (Wirth et al., 2007). Their cognitive participation in the mediated environment is the sensation of spatial presence - SPES scores (Hartmann et al., 2016).

One of the reasons for choosing this spatial presence test is not only the shift in self-location but also the shift in perceived action possibilities. Hartmann and colleagues have suggested that if users feel spatially present in a VR environment, their actions will be transferred to the media environment just like in the real environment (Hartmann et al., 2016). Because if task performance in VR is related to spatial abilities, the correlation between these abilities and spatial presence will be proven.

METHODOLOGY

People need spatial abilities to sort out riddles in the game. The primary spatial abilities which play an essential role in in-game performance are mental imagery, spatial perception, spatial visualization, navigation, and spatial orientation. People's game performance (play-time) should be correlated with spatial ability scores. The higher spatial ability scores indicate faster tasks and a more present game environment.

As Zacks (2000) et al. and Hegarty et al. (2005) proved for both small and large-scale

transformations for navigational tasks, our VR game should be contained both scaled tasks. Moreover, the performance of the task should depend on these spatial skills. While the author gave oral information at the beginning of the experiment about "the objects you interact with will appear one by one," can be seen as figural operations to keep the objects in mind and realize which object emerges, the other interactions which are needed to be done with the movement of the body and the hand are environmental operations. If the game mechanics are adequately developed, possible action scores correlate with self-location scores.

The tests were conducted as groups in a computerized version. Before beginning each test, written instructions and examples were provided, and an author gave general oral instructions.

The sample group was divided into two primary groups: designers and players, as seen in Figure 4. The purpose of this study is to determine whether being a designer or a player has an influence on spatial skills or the effect of these two characteristics on the game performance of people with similar spatial abilities

To answer research questions and reveal the relations above, experiments were conducted in an isolated environment. 24 adults aged 20-35 who follow technological developments. There were no significant differences in mean age or gender distribution, but there are differences in gaming habits and professional background. They are represented as (P)layer-(D)esigner and gender, while NP indicates non-player, N indicates non-designer. As stated by Maneuvrier and Westermann (2020), spatial presence might rely on interindividual variations in in-virtual experience (cybersickness, interface awareness) and the cognitive profile of the user (video-game experience, field of dependence). The in-virtual experience is not explored since all subjects have never experienced virtual reality, and cybersickness is not in the scope of this research. Nevertheless, the cognitive profile included gaming behavior and spatial aptitude scores.

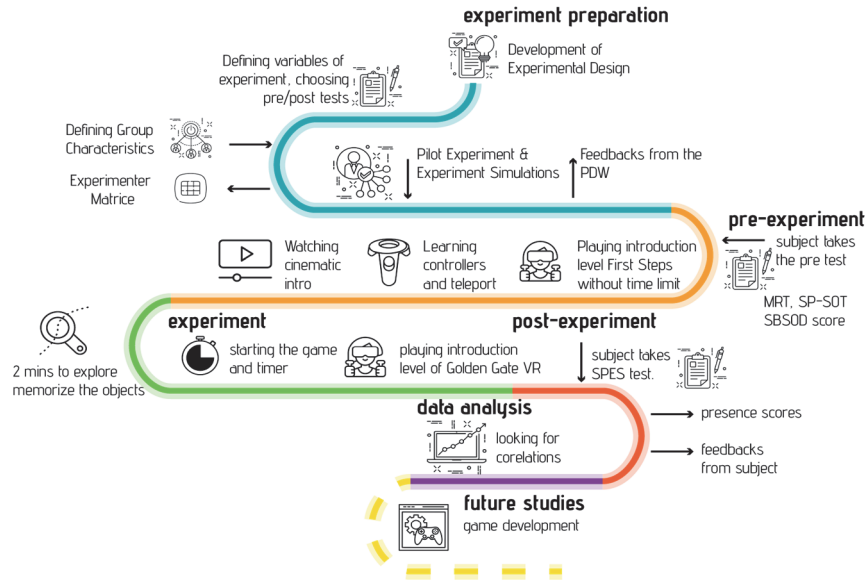


Figure 2
The flowchart of
the research.
(Source: author).

Pre/post psychometric assessment for visuospatial ability

To prove the hypotheses, we need to perform some psychometric tests on the participants before the experiment. The reason we do these tests is to prove our first hypothesis. Mental Rotation Test (MRT) (Peters et al., 1995), Perspective Taking-Spatial Orientation Test (PT/SOT) (Friedman et al., 2019), and the Santa Barbara Sense of Direction Test (SBSOD) (Hegarty et al., 2002) will be performed to the participants. Each student worked individually, and the order of the tests was the same for all participants. The total time for testing, including a break, was 1 hour and 15 minutes.

VR game experiments: Golden Gate VR

The game is used to measure the task sequence and playtime to reveal the relations in-game dynamics. As seen in **Figure 2**, the experiment has five stages. They first took the pre-psychological tests. In the orange part of the flowchart, they all played the “First Steps for Oculus Quest 2” and learned the basics of

the controller and VR environment such as guardian systems and teleport. After this step, they all watched a cinematic intro video to learn where they are and what we are expecting them. Then the experiment part, indicated with green color, started; the participant had 2 mins to explore and look at the objects and keep them in his mind to follow the other cues. Then the author reminds the stopwatch and started for each player, and kept all the interactions and their finishing time.

Our main goal is to evaluate the game’s mechanics within the scope of spatial abilities, improve them and play them to the players and reveal the correlation between spatial ability and spatial presence.

The VR Spatial Presence experience will be constructed using Unreal Engine 5 and integrated with the Oculus VR Game kit; this will be used to build the game’s 3D assets and animations. The game will have elements that will encourage players to complete spatial exercises that will become more challenging as they move through the stages. Sound

Figure 3
Correlation
between the
attributes.
(Source: author).

Attributes	Player	Designer	Gender	Age	Playtime	PT-SOT	MRT	SBSOD	SPES - SL	SPES - PA
Player	1									
Designer	0	1								
Gender	0	0	1							
Age	-0.052	0.052	-0.052	1						
Playtime	-0.434	0.050	-0.064	-0.053	1					
PT-SOT	0.206	-0.180	0.074	0.244	0.214	1				
MRT	-0.156	0.185	0.014	-0.338	0.004	-0.351	1			
SBSOD	0.210	0.416	0.263	-0.048	-0.065	0.181	0.067	1		
SPES - SL	0.035	0.268	0.087	0.063	-0.124	-0.363	0.475	0.031	1	
SPES - PA	-0.061	0.454	-0.018	-0.033	-0.144	-0.470	0.391	0.122	0.889	1

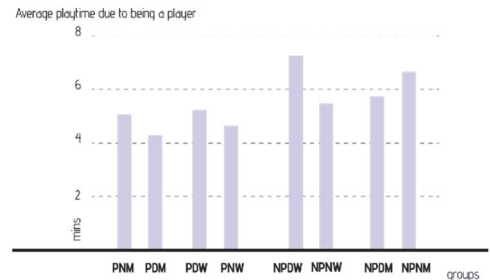
Figure 4: Average
playtime due to
being a player.
(Source: author).

effects indicate the right actions, while controller vibrations provide feedback for Boolean interactions.

RESULTS

Due to the limited sample size, acquiring the intended outcomes for the experiment was not provided. The findings indicate that individuals with a low presence score complete the game more quickly. This may be because the player has not fully shifted to the virtual environment, therefore, he remains focused on the objective of completing the game's tasks as quickly as feasible.

Our first hypothesis is unproven since individuals with greater spatial ability scores are unable to complete activities more quickly. The only factor that affected the duration was the participant's player status, and it had somewhat significant impact, as seen in **Figure 3** and **Figure 4**. The fact that there was a blend of participants enjoying mobile and computer games may have contributed to the lack of significance. In the subsequent study, it can be implemented with a group playing a computer console game. The findings also indicate that individuals with a low presence score complete the game more quickly. This may be due to the fact that the player has not fully shifted to the virtual environment, therefore he remains focused on the objective of completing the game's tasks as quickly as feasible.



The second hypothesis about the relationship between spatial abilities and presence were analyzed, negative and positive weak correlations were observed. The negative correlation should be expressed as follows: as the subjects' angle error in the spatial orientation test decreased, their active feeling in the virtual environment increased. This negative correlation shows that the correlation value of -0.47 in such a small experimental group is expected to evolve into a more significant result in a larger group.

While the spatial orientation has more impact on presence, in addition to that, positive correlation was also observed between mental rotation and self-location which is a subset of the presence as above. This indicates that shifting location is more up to mental rotation while relocating themselves is based on perspective-taking ability. While these two abilities somehow show a correlation, the ability of navigation has a very weak impact on presence.

The designer group felt more active in the virtual world in the self-questionnaire than non-designers. Designers found being active in the environment more convincing than moving their locations to the virtual world. This result may be because they have been developing their skills in designing virtual worlds since the beginning of their education.

Presence score values did not yield a significant result regarding the status of being a player; however, it is possible to add that they were more convinced about moving their locations to the virtual world, see the correlation matrix in **Figure 3**. A possible comment would be their gaming backgrounds may prevent to feel more belonged to the game enough. With the exception of the mental rotation, the group of players outperformed the non-players on all other spatial ability and presence assessments. On the other hand, except for the Spatial Orientation scores, the designers consistently produced higher outcomes than the non-designers.

The player-non-designer group had the highest spatial orientation and navigation skills. The designer achieves higher results in navigation test (SBSOD) than the non-designer group. This might be an indicator that designer's navigational ability is enhanced correlatedly with their background.

Finally, in the examined outcomes, the presence score for self-location was reported higher than the possible actions, namely 4,07 and 3,86. In other words, the participants were able to shift their locations in the game, but they were not convinced enough that they could move in a virtual environment. According to the Spatial Situation Model from Wirth et al. (2007), successful results were achieved in the first phase but were blocked in the second phase.

DISCUSSION

CONCLUSION & FUTURE STUDIES

The participants were able to relocate their perception of location into the game, but they were not persuaded that they could get in action in the game environment. Self-location and possible action scores should be comparable, and the average of

both should be increased to match the capability of the VR game. As a result, the link between possible actions and game interactions has not been developed properly, and it is anticipated that the game mechanics would be enhanced in the future stage to provide better results in possible actions scores. By using developed game mechanics, the presence-interaction impact will be compared with undeveloped scores.

We already intend to develop VR games that evoke a feeling of being there more intensely with better-qualified interactions. With this spatial cognition framework, we will evaluate the interactions and their cognitional load in the future studies.

As we mentioned earlier, the second phase will be done to evaluate the game mechanics according to the game's first version results. The mechanics will be enhanced to increase the spatial presence in the VR game environment.

As Zacks and his colleagues proved in 2000, people use different computations to succeed in figural and environmental transformations our purpose is to prove it will require the same in VR environments, too. It is also important to identify that although different spatial abilities may enhance different sub-factors of presence in VR.

Lastly, the relationship between spatial abilities and spatial presence has significant implications for both game design research and other applications using virtual environments. This gaming industry's growth comprises several architectural production procedures. It is necessary to expose the disciplines and procedures of relationship research to uncover inquiry gaps and probable future research subjects. This study's results form the basis for future research at the interface of architecture, virtual reality, gaming, and spatial cognition.

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