ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

DEVELOPING THE SPATIAL PERFORMANCE OF PUZZLE GAMES IN VIRTUAL REALITY ENVIRONMENTS WITH SPATIAL PRESENCE

M.Sc. THESIS

Merve TAŞDELEN

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Merve TAŞDELEN
(523201008)

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Thesis Advisor: Assoc. Prof. Dr. Derya GÜLEÇ ÖZER
Thesis Co-Advisor: Asst. Prof. Dr. Ayşegül AKÇAY KAVAKOĞLU

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

SANAL GERÇEKLİK ORTAMINDAKİ BULMACA ÇÖZME OYUNLARININ MEKANSAL MEVCUDİYET İLE MEKANSAL PERFORMANSININ GELİŞTİRİLMESİ

YÜKSEK LİSANS TEZİ

Merve TAŞDELEN
(523201008)

Bilişim Anabilim Dalı

Mimari Tasarımda Bilişim Programı

Tez Danışmanı: Doç. Dr. Derya GÜLEÇ ÖZER
Eş Danışman: Dr. Öğr. Üyesi Ayşegül AKÇAY KAVAKOĞLU

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Merve Taşdelen, a M.Sc. student of ITU Graduate School student ID 523201008, successfully defended the thesis/dissertation entitled "DEVELOPING THE SPATIAL PERFORMANCE OF PUZZLE GAMES IN VIRTUAL REALITY ENVIRONMENTS WITH SPATIAL PRESENCE", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Assoc. Prof. Dr. Derya Güleç Özer** Istanbul Technical University	.....
Co-advisor:	**Assist. Prof. Dr. Ayşegül Akçay Kavakoğlu** Istanbul Technical University	.....
Jury Members :	**Prof. Dr. Leman Figen Gül** Istanbul Technical University	.....
	Assist. Prof. Dr. Betül Orbey Istanbul University	.....
	Assist. Prof. Dr. Çağda Özbaki Altınbaş University	.....

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To my mother and Humus,

FOREWORD

I would like to express my sincere gratitude to my invaluable advisor Assoc. Prof. Dr. Derya Güleç Özer, for her guidance and support throughout my research journey. I am also grateful to my co-advisor, Assist. Dr. Ayşegül Akçay Kavakoğlu, for her valuable insights and unwavering encouragement. I owe a debt of thanks to Elif Sezen Yagmur Kilimci for introducing me to visuospatial and design cognition in the correct way and for her endless support and confidence.

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September 2023

Merve TAŞDELEN
(Architect)

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ABBREVIATIONS

AR **:** Augmented Reality
App **:** Appendix
VE **:** Virtual Environment
VR **:** Virtual Reality
SG **:** Sanal Gerçeklik
ITU : Istanbul Technical University
SPES **:** Spatial Presence Experience Scale
MRT **:** Mental Rotation Test
PT-SOT **:** Perspective Taking – Spatial Orientation Test
SBSOD **:** Santa Barbara Sense of Direction Test
HMD **:** Head-Mounted-Display
iVR **:** Immersive Virtual Reality
SSM **:** Spatial Situation Model

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DEVELOPING THE SPATIAL PERFORMANCE OF PUZZLE GAMES IN VIRTUAL REALITY ENVIRONMENTS WITH SPATIAL PRESENCE SUMMARY

The experience of artificial objects in the virtual environment and the illusion of being there are primary affordances of the Virtual Reality environment. The conviction of being located in a mediated environment is called spatial presence. Spatial abilities play a crucial role in the proficient execution of cognitive activities, particularly in tasks involving the visualization and logical analysis of spatial transformations. Immersive settings, such as Augmented Reality (AR) and Virtual Reality (VR), facilitate activities that necessitate physical mobility and the utilization of environmental spatial abilities. In contrast, two-dimensional (2D) games predominantly rely on figural spatial skills. Although some studies investigate the relationship between VR and spatial intelligence, how users build a spatial presence in VR game environments still needs to be clarified. This study tries to elaborate on the construction of spatial presence experience and its characteristics in VR puzzle-solving games by revealing the relationships between game mechanics and the notion of spatial presence. VR puzzle-solving games can offer a more immersive and engaging experience that enhances the feeling of presence by enabling players to interact with their environment and manipulate objects within it. In this study, the presence-spatial performance relations are initially investigated based on previous works and analyzed in terms of spatial definition. The Spatial Situation Model (SSM) is adapted to test the study's hypotheses, which are constructed based on people's mental models and spatial abilities. Suppose the VR task performance depends on spatial abilities; people with higher spatial abilities finish tasks faster, and their spatial presence score will be higher than those with lower spatial abilities. A VR game titled Golden Gate will be designed and developed 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 visuospatial ability (Pre-Test), (3) Experience of the VR Game, (4) Evaluation of the experiences, (5) Re-development of the game environment. The players' experiences are evaluated in terms of Mental Imagery, Mental Rotation, and Spatial Orientation regarding the Spatial Presence Experience Scale (SPES). Initially, a matrix was constructed for the experiment, and the initial experiments were evaluated based on the impact of the matrix's defining characteristics.

Being a player seems to be more potent than the effects of gender and being a designer, according to the initial experiment results. The player-designer group accomplished the experiments in the shortest amount of time. In the evaluation of the first group's SPES results, it was discovered that while the participants had no trouble conveying their spatial belonging to the virtual environment, they felt less engaged while undertaking actions in the virtual environment. After calculating the average score for each question, the items that scored below the mean for spatial (Self Location) and interactive (Possible Action) items were divided in the fifth evaluation stage. Environmental modeling, in-game interactions, and sounds were re-created for the game's development, and their deficiencies were identified at the end.

On the spatial ability side, the ensemble outperformed the non-players on all other spatial ability and presence assessments, except Mental Rotation, although the sample size was small. In contrast, designers consistently generated better results than non-designers, except for scores for spatial orientation.

The present study aims to fill this research gap by examining the process of constructing a spatial presence experience in a VR puzzle game. Additionally, it investigates the potential influence of users' spatial ability, game experience, and professional background on developing spatial presence. The relationship between spatial ability and presence significantly impacts game design research and other virtual-available applications. The expansion of the video game industry involves numerous architectural production techniques. It is necessary to elucidate the disciplines and methodologies of relationship research to identify voids and potential future research topics. This study's findings could be a foundation for future architecture, virtual reality, gaming, and spatial cognition interface studies.

SANAL GERÇEKLİK ORTAMINDAKİ BULMACA ÇÖZME OYUNLARININ MEKANSAL MEVCUDİYET İLE MEKANSAL PERFORMANSININ GELİŞTİRİLMESİ
ÖZET

En iyi oyun tasarımcılarına göre "oyunun" özü, yetkinliğin; keşif, deneme-yanılma öğrenme dinamiği yoluyla inşa edildiği bulmaca veya problem çözmedir (Koster, 2005; Schnell, 2008). Meydan okuma, öğrenme ve ustalaşma heyecanı, oyunların benzersiz motivasyon yeteneğinin kalbinde yer alır. Schnell'e (2008) göre; bir kişi oyun tasarımı yapabilmek için; animasyon, antropoloji, mimari, beyin fırtınası, işletme, sinematografi, iletişim, yaratıcı yazarlık, ekonomi, mühendislik, tarih, yönetim, matematik, müzik, psikoloji, topluluk önünde konuşma, ses tasarımı, teknik yazarlık ve görsel sanatlar alanlarında bilgi sahibi olmalıdır. Bu becerilerin bir çoğu, mimarların üniversitede en az 4 yıl okudukları tasarım eğitimi ile de ilişkilidir. Mekan tasarımına hem okulda, hem de profesyonel hayatlarında devam eden mimarlar, son yıllarda giderek oyun sektöründe de ilerleme kaydetmişlerdir. Tasarımcılar, özellikle mimarlar, mekansal ilişki kurmayı eğitimlerinin en başından beri öğrenmekte ve uygulamaktadır. Aynı şekilde bölüm tasarımını ve zorluğunu planlayan oyun geliştiriciler ise bölüm içerisindeki mekansal kurguyu düzenlerler. Bu açıdan bakınca amaçlar aynı, araçlar farklıdır.

Gün geçtikçe sanal dünyaların önem kazandığı düşünülürse tasarımcıların yeni teknolojileri benimsemesi de kaçınılmazdır. Oyun motoru olarak geliştirilmiş Unreal Engine, Unity gibi programların mimari görselleştirmede kullanılması, Rhinoceros ve Blender gibi 3 boyutlu modelleme programlarının mimari model yapımında kullanılması, Cinema 4D ve Houdini programlarının animasyon için kullanılması gibi örnekler mevcuttur. Oyun tasarımcılarının kullandıkları programlara, tasarımcılar da hakim olmaya başlamış, kendileri için yeni bir yol haritası çizmişlerdir.

Mekan algısı, mekan bilişi gibi konularda da bilgisi ve ilgisi olan tasarımcıların, bu bilgi aktarımını oyun tasarımda nasıl kullanacakları önemli bir araştırma sorusudur. Tasarımcılar; mekan, katılımcı, etkileşime geçilen veya geçilmeyen objelere odaklanarak, araştırma alanını genişletmektedirler. Mekansal kurgu alanında işinin ehli olan mimarlar, iç mimarların bu alanda da söyleyecek sözleri bulunmaktadır. Oyun sektöründe giderek artan mimarların sayısı da bu durumu desteklemektedir.

Son yirmi yılda video oyun endüstrisi, dünya çapındaki eğlence ekonomisinin önemli bir katılımcısı olarak ortaya çıkmıştır. Gelişen teknoloji ile birlikte oyun bilgisayarlardan çıkmış, çeşitli konsollarda, tabletlerde ve telefonlarda oynanabilir hale gelmiştir. Kinect sensörleri, hareket algılayan balans tahtaları ve hatta elin hareketini takip eden sensörleri olan kumanda Nintendo Wii, Xbox 360, HTC Vive, Oculus Quest gibi cihazlar hayatımıza girmiştir. Bir gözlük ve kontrolcü ile sanal ortama bağlanılan, hareketi algılayan bu son nesil sanal gerçeklik gözlükleri ile gerçek dünyadan koparak size sunulan sanal dünyada var olunmaktadır. Video oyunları oynayanların aksine, VR oyuncuları bu gerçekliği deneyimlerken tehlike ve oluşumlarla doğrudan karşı karşıya kalırlar, bu da daha fazla eylemlilik ve mevcudiyetle sonuçlanır. Yapay nesnelerin sanal ortamdaki deneyimi ve orada olma yanılsaması, sanal gerçeklik (SG) ortamının birincil bir sağlayıcısıdır. Sarmalanmış bir ortamda konumlanmış olma inancı, mekansal mevcudiyet olarak adlandırılır.

Uzamsal zekâ insanlar için günlük yaşamlarında önemli olduğu kadar, sanal ortamda yön bulma, kısa süreli hafızayı kullanarak muhakeme etme gibi aşamalarda önemlidir.

Uzamsal bilgi toplama, uzamsal görevleri yerine getirme ve uzamsal oryantasyon süreçlerinin tümü uzamsal davranış örnekleridir. Uzamsal yetiler mekânsal konumlarındaki değişiklikleri öngörme ve muhakeme etme gibi bilişsel görevlerin başarılı bir şekilde yönetilmesi için katalizör olarak kabul edilir. Araştırmacılar, 20. yüzyılın başından itibaren bu uzamsal yetileri ölçmek için testler ve yöntemler geliştirmiştir. Uzamsal test kavramı, öncelikle teknik mesleklerde yeterliliği tahmin etmek amacıyla mekanik becerileri ölçmeye yönelik ilk çabalardan kaynaklanmıştır. Bu yeteneklerin fiziksel manipülasyon gerektirdiği düşünüldüğünden, bu değerlendirmelerin çoğu gerçek nesnelerin montajını veya manipülasyonunu içeren faaliyetlerdeki performansa dayanmaktadır.

VR oyunlarına dahil edilebilecek yaygın uzamsal görev örnekleri navigasyon, nesne manipülasyonu ve nesne tanımadır. Sanal gerçeklik oyunları, sanal ortamlar ve nesnelerle daha doğal ve sezgisel etkileşimleri kolaylaştırarak oyunculara bir varlık ve sarmalanma hissi sağlayabilir. Hareket kontrolörleri, dokunsal geri bildirim ve gerçek dünya etkileşimlerini simüle eden diğer teknolojiler kullanılarak mevcudiyet ve gerçekçilik duygusu artırılabilir. Böylece, VR oyunları geleneksel video oyunlarından daha ilgi çekici ve akılda kalıcı bir deneyim sağlayabilir.

VR oyunlarının kullanıcısını sarmalayarak içine çekmesi ve gerçek dünya ile sanal ortam arasındaki çizgiyi silikleştirmesi mevcudiyet olarak adlandırılabilir. Mekânsal mevcudiyet, insan yapımı teknoloji, özellikle de medya sistemleri tarafından yaratılan bir platformda olma hissidir. Sanal ortamların daldırma ve etkileşim düzeyine bağlı olarak, bu öznel deneyim değişebilir. Yüksek kaliteli görsel ve işitsel sinyallerin yanı sıra dokunsal geri bildirime sahip bir VR deneyiminin, daha az sürükleyici bir deneyime kıyasla güçlü bir mekânsal mevcudiyet hissi uyandırması daha olasıdır.

Bazı çalışmalar sanal gerçeklik ile uzamsal zeka arasındaki ilişkiyi araştırsa da kullanıcıların sanal gerçeklik oyun ortamlarında nasıl bir uzamsal varlık oluşturdukları belirsizliğini korumaktadır. Bu çalışma, oyun mekaniği ile mekansal mevcudiyet kavramı arasındaki ilişkileri ortaya koyarak, sanal gerçeklik (SG) bulmaca çözme oyunlarındaki uzamsal varlık deneyimi inşasını ve özelliklerini detaylandırmaya çalışmaktadır. SG bulmaca çözme oyunları, oyuncuların çevreleriyle etkileşime girmesini ve içindeki nesneleri manipüle etmesini sağlayarak varlık hissini geliştiren daha sürükleyici ve ilgi çekici bir deneyim sunabilir. Bu çalışmada mevcudiyet-mekansal performans ilişkileri öncelikle önceki çalışmalar temel alınarak incelenmekte ve Mekansal Durum Modeli ile analiz edilmektedir.

Mekansal Durum Modeli, insanların zihinsel modeli ve mekansal yetenekleri üzerine inşa edilen çalışmanın hipotezlerini test etmek için iki basamaklı bir model oluşturur. Bu model ilk aşamada mekan içerisinde sanal dünya ile gerçek dünya arasındaki çizginin tamamen yok olmasını, sonrasında ise sunulan sanal dünyadaki olası hareketleri yapma konusunda kullanıcının ne kadar ikna olduğunu sorgular. Bu modeli kullanarak, bir SG oyununda görev performansının uzamsal yeteneklere bağlı olduğunu, daha yüksek uzamsal yeteneğe sahip kişilerin görevleri daha hızlı bitirdiğini ve uzamsal varlık sonuçlarının daha düşük uzamsal yeteneğe sahip insanlardan daha yüksek olacağını öngörülmüştür. İTÜ Mimari Tasarımda Bilişim Programı'ndaki MBL538 Sanal Mimari Tasarım Stüdyosu dersi kapsamında geliştirdiğimiz Golden Gate isimli SG oyunu, yukarıdaki hipotezi test etmek ve detaylandırmak için bir vaka çalışması olarak kullanılacaktır. Bu çalışmanın beş adımı vardır: (1) Oyun ortamının geliştirilmesi, (2) Görsel-uzamsal yetenek için ön psikometrik değerlendirme; (i) Zihinsel İmgeleme ve zihinsel Rotasyon, (ii) Mekansal oryantasyon, (iii) Navigasyon

becerisi testleri, (3) SG Oyunu Deneyimi, (4) Deneyimlerinin mekansal varlık deneyimi ölçeği ile, değerlendirilmesi (5) Oyun ortamının yeniden geliştirilmesi.

Deney için başlangıç olarak bir matris oluşturulmuş, ilk deneyler bu matristeki karakteristik özelliklerin etkisi de göz önüne alınarak değerlendirilmiştir. Deney 20-35 yaş aralığında, farklı meslek mensuplarından 30 kişiye uygulanmıştır. Oyuna başlamadan önce katılımcılara oyun hakkında kısa bilgiler verilmiştir. Katılımcılara oyun süresinin önemine ilişkin bir hatırlatma yapılmıştır. İki ile on beş dakika süren deney süresi sonucunda veriler toplanmış ve analiz için düzenlenmiştir. Rapidminer uygulaması, bulgulardaki korelasyonları belirlemek amacıyla veri madenciliği yapmak için kullanılmıştır. Bu analiz, söz konusu testler ve kriterler arasında pozitif veya negatif korelasyonların varlığını belirlemeyi amaçlamıştır. Bu çalışmada, tasarımcı olmanın test veya oyun oturumları sırasında performans üzerindeki potansiyel etkisi aydınlatılmaya çalışılmıştır.

Buna göre ilk deneylerde oyuncu olmanın etkisi, tasarımcı olmanın etkisinden daha çok etkili olmuştur. Grubun SPES sonuçları üzerinden yapılan değerlendirmede, katılımcıların mekansal aidiyetlerini sanal ortama taşımakta zorlanmazken, sanal ortam içerisinde eylemleri gerçekleştirirken kendilerini daha az dahil hissettikleri ortaya çıkmıştır. Uzamsal yetenek kısmında ise, her ne kadar örneklem kümesi kısıtlı olsa da, zihinsel rotasyon haricinde, oyuncu grubu diğer tüm uzamsal yetenek ve mevcudiyet değerlendirmelerinde oyuncu olmayanlardan daha iyi performans gösterdiği görülmüştür. Öte yandan, mekansal oryantasyon puanları dışında, tasarımcılar sürekli olarak tasarımcı olmayanlardan daha yüksek sonuçlar üretmişlerdir.

Son olarak, uzamsal yetenekler ve uzamsal mevcudiyet arasındaki ilişkinin, oyun tasarımı araştırmaları için büyük bir potansiyel içerdiği görülmüştür. Literatürdeki boşluklara değinerek, hangi noktalarda önceki çalışmaları desteklediği, hangi noktaları ortaya çıkarmakta zorlandığı analiz edilmiştir. Gelecekteki olası araştırma konularını ortaya çıkarmak için, disiplinler arası araştırma konuları ve potansiyeller incelenmiştir. Bu çalışmanın sonuçları, mimarlık, sanal gerçeklik, oyun ve mekansal biliş arayüzünde gelecekteki araştırmalar için temel oluşturabilir.

1. INTRODUCTION

The emergence of Virtual Reality (VR) technologies in everyday life has accelerated due to technological advancements, especially in the marketing strategies of the gaming industry (Zhang, 2023). In the past two decades, VR headgear used in research facilities in the 1990s has been among the newest technologies available to the public. Based on data provided by Steam, a renowned digital distribution platform for video games, the user base of VR headsets on Steam had a notable growth trajectory, with a recorded figure of 3.4 million users as of January 2021 (URL 1).

As the number of virtual world experiences grew, the Virtual Environment (VE), questioned in terms of simulation (Jain et al., 2016; Neo et al., 2021), representation, and realism, began to be questioned regarding the sensation of immersion. Behavioral science has been studied about design cognition, design process, design thinking, and design education (Faas et al., 2014). However, it has gained prominence in spatial cognition-related game design research in recent years. Virtual environments in game design are an interdisciplinary discipline. Creating virtual environments in game development is inextricably linked to architectural design. This collection was manufactured using a variety of architectural techniques. The game's specifications and requirements create architectural spaces. Due to the interdisciplinarity of the study of VR game innovations, it can potentially disclose previously unknown spatial connections from cognitive and architectural perspectives. Even though the experience of "being there" is investigated through the concept of reality regarding cognition, perception, and ability/skill differences, it has begun to gain significance, especially in design-oriented research disciplines.

VR offers more precise and exhaustive spatial information than other VEs. In addition, it displays precise depth perception through a 3D cartesian system, whereas desktop and mobile systems only depict the world in 2D. This technological advancement may improve the spatial awareness of observers, resulting in more accurate mental models that incorporate spatial data. In addition to this spatial awareness, most VR games feature a variety of spatial objectives, depending on the genre and particular gameplay

elements. Common examples of spatial tasks that may be included in VR games are navigation, object manipulation, and object recognition. By facilitating more natural and intuitive interactions with virtual environments and objects, VR games can give players a feeling of presence and immersion. Immersion can be enhanced by utilizing motion controllers, haptic feedback, and other technologies that simulate real-world interactions. Thus, VR games can provide a more engaging and memorable experience than traditional video games.

Telepresence, or spatial presence, is the sensation of being physically present with virtual objects in a simulation (Lee, 2004). According to Hartmann et al. (2015), spatial presence is the sensation of being in a platform created by human-made technology, specifically media systems. Depending on the level of immersion and interactivity of the virtual environments, this subjective experience can vary. A VR experience with high-quality visual and auditory signals and haptic feedback is more likely to induce a strong sense of spatial presence than a less immersive experience. In addition, the extent of user interaction and control within the VE can affect the perception of spatial presence.

While researchers have different definitions for spatial presence, several tests also measure the presence in a meditated environment. Presence surveys are the most often used approach for determining presence since they are sensitive enough to detect disparities in presence (Insko, 2003). They also implement a psychological model to reveal the hidden construction process, which can be defined as a situation model. Before being retained in episodic long-term memory, a situation model is initially held in working memory as it is constructed during engagement with a visual story (Cohn,2019). A theoretical model of the formation of the Spatial Presence Situation Model is a bridge for interdisciplinary differences in presence research and to establish connections between presence and "older" concepts of psychology and communication (Wirth et al.,2007). Spatial presence refers to being present in a particular location and understanding the available actions and possibilities. It combines an individual's perceived self-location and awareness of the surrounding space and its potential interactions. According to this model, enhancing the mediated environment can improve the initial phase of model creation. Attention can be directed through external media-related features or the player's attention. The user's spatial abilities can also

impact their mental model of the environment (Uz-Bilgin & Thomson, 2021; Wirth et al., 2007; Wirth et al., 2003).

The research domain of this study emerges from the intersection of VR, behavioral sciences, and architecture. There is research to understand the effects of spatial abilities in VR and the contribution of presence in VR. Binary intersections revealed these connections (Uz-Bilgin and Thomson; Maneuvrier et al., 2020; 2022; Coxon et al., 2016), but the triple intersection remains unrevealed. Figure 1.1 shows the relevant domain and sub-domains of the thesis. The thesis uses the Spatial Situation Model to examine the spatial presence experience and its characteristics in VR puzzle-solving games by elucidating the relationships between game mechanics and the spatial presence concept.

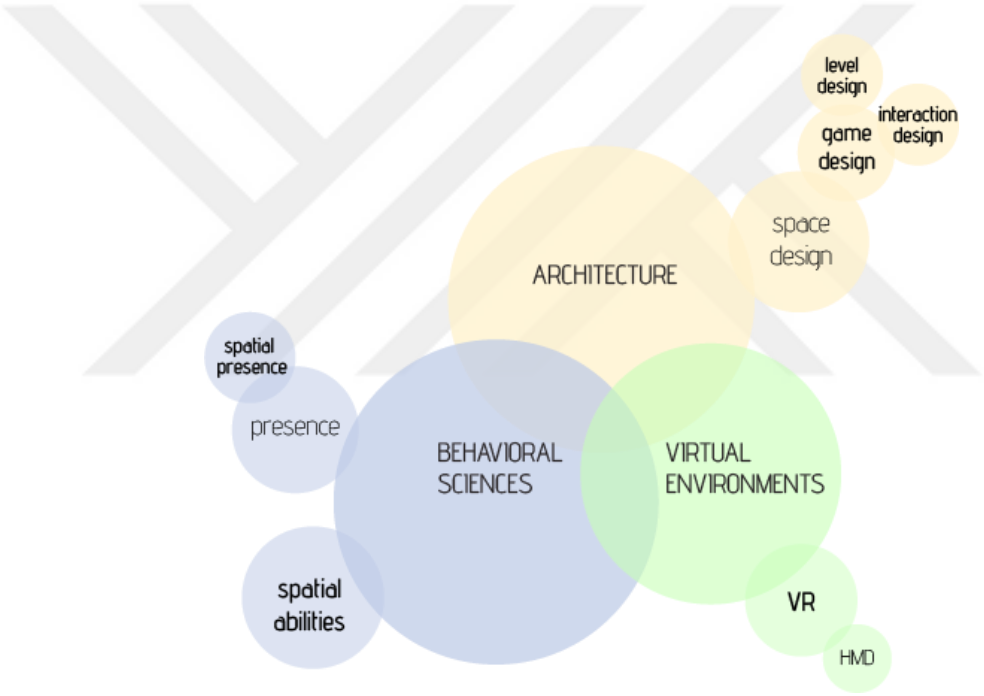


Figure 1.1: The intersections of research domains.

A review of the pertinent literature revealed that, in some cases, spatial performance affects VR game performance. (Maneuvrier et al., 2020; 2022). Coxon et al. (2016) discovered a link between spatial presence and visual-spatial imagery but not between spatial presence and other spatial skills. Uz-Bilgin and Thomson (2020; 2021) investigated spatial presence in a VR learning environment to understand better how learners perceive and experience spatial presence within the context of a VR game. Past et al. (2023) findings indicate that using advanced depth representation and visualization techniques in applications may not be necessary for applications to

provide highly immersive experiences. According to Larkin's (2015) research, players with good spatial skills can create strong spatial mental models (SSMs) and perform better in stereo 3D games by having higher levels of self-location and the ability to take more actions. Meanwhile, Weibel and Wissmath's (2011) study discovered that a person's inclination towards immersion and motivation to play the game significantly influences their perception of spatial presence in games. In summary, spatial abilities may affect performance in VR environments; those with more remarkable spatial presence perform better tasks than those with lower spatial scores, and spatial abilities impact spatial presence in VR. The related studies measure these scores using different psychometric tests. It can be assumed that the spatial presence score should positively correlate with spatial aptitude scores accordingly.

Regarding this assumption, in this thesis, examining the presence-spatial performance relationships in VR experiences involves Mental Imagery, Mental Rotation, Spatial Orientation, and Perspective-taking features, which will be measured by the Spatial Presence Experience Scale (SPES).

1.1 Purpose of Thesis

As people's exposure to virtual worlds increased, the medium's potential was questioned, initially in terms of simulation, representation, and actuality. The experience of presence in these contexts is examined by defining reality in terms of cognition and perception. The ability/skill difficulties have become prominent, particularly in design-oriented study domains.

Due to the correlation between spatial abilities and spatial presence, there are profound implications for future research and implementation in game design and virtual environments in general. The video game industry is undergoing accelerated change, bringing a vast array of architectural manufacturing techniques. Disclosing the research disciplines and methodology is essential to identify gaps and potential future research topics. Future research bridging the fields of architecture, virtual reality, gaming, and spatial cognition can significantly benefit from the findings of this study. This study takes part in the intersection of Virtual Environments, Behavioral Sciences, and Architecture domains. It is positioned in Spatial Abilities, Spatial Presence, and Game Design subdomains.

According to information garnered through data mining (Taşdelen et al., 2023a), the 2010s were the prominent research time in this field. This outcome may necessitate enhancements to headgear technology and other technological advances to materialize. After the companies published headsets with high render quality, most researchers relied on Meta and HTC headsets due to their outstanding performance and reasonable prices.

This research aims to position these concepts in the intersection and provide a novel perspective for VR game development. This thesis aims to explore how differences in spatial abilities affect game performance, examine the reliability of spatial presence as a quality assurance test in game development, and investigate whether being a player or a designer impacts game performance or other psychometric tests.

1.2 Motivation

The field of study known as "presence research" investigates the human experience of immersing oneself in a simulated virtual world. According to Sanchez-Vives & Slater (2005) and Pillai et al. (2013), neuroscientists should investigate the experience of presence because it can be interpreted as a form of bounded consciousness that could shed light on the nature of consciousness. As an architect, they should collaborate with other domain-specific professionals during the development of the game's environment. A game's environment, characters, and mechanics can be designed with the player's emotional experience. Those who create games should know how to design the environment, characters, and game mechanics for the player.

Some researchers investigated the relationship between these concepts, such as discussing virtual environments as a learning platform (Chang et al., 2017; Breves & Stein, 2022), enhancing spatial abilities with mediated environments (Giakis et al., 2018), and as a sportive training platform (Alce et al., 2019) mainly after the COVID-19 pandemic; mockups and simulations which is hard to observe (Alves et al., 2019).

Some studies investigate spatial ability, presence, and virtual reality/environments. The motivation of the study is to support the previous literature, as mentioned above, and investigate the unrevealed connections, such as the connection between presence and spatial performance in VR. Secondly, based on the outcomes of the SPES tests, it is possible to construct a novel assessment approach for examining spatial

performance within the game development domain. Finally, the investigation might help the researchers to understand the potential influence of users' spatial ability, game experience, and professional background on developing spatial presence.

1.3 Hypothesis

There are three hypotheses in the virtue of the literature search:
People with higher spatial ability scores build mental models faster, and mental imagery is correlated with the Spatial Presence Experience Scale (SPES). They could engage in a game more than others and finish the tasks faster. Playtime and the Mental Rotation Test (MRT) should be correlated, while other psychometric tests may also show some correlation.

Suppose a user's spatial abilities can affect their mental model of the environment. In that case, their spatial presence score should negatively correlate with their spatial ability scores, specifically with the Spatial Orientation Test (SOT) results.

Designers' psychometric test and spatial presence scores will be higher than those of the non-designer group. While diving into the designer group, participants who are a designer and have gaming habits will have higher SPES, MRT, and SOT scores.

1.4 Methodology

Regarding these hypotheses, this research aims to examine the relationship between spatial abilities and the roles of designer and participant in video games, as well as the effect of these two roles on the game's performance with different spatial abilities and presence scales.

Players will require solid spatial reasoning skills to complete the game. The most measured spatial skills that affect game performance are mental images, spatial perception, spatial visualization, navigation, and spatial orientation.

Spatial skills should be essential to the task's success. The figural operations can be explained as remembering and identifying which object emerges. On the other hand, the response to the experimenter’s opening statement that "the objects with which you will interact will appear one by one" can be distinguished from the environmental operations because they involve the physical movement of the body and hands. Scores for both presence measurement subscales, which are possible actions and self-location,

should go hand in hand if the game mechanics are enough to provide a proper game environment for both physical movement and feeling present.

The study uses qualitative and quantitative methods and is methodologically based on a VR game experiment and self-reports psychometric tests. A VR game called “Golden Gate” [1]is used as an experiment content. The research consists of seven phases: literature review, experiment preparation, pre-experiment, VR experiment, post-experiment, data analysis, and game development.

During the design phase of the experiment, the researchers determined the specific assessments that would be used to assess the participant's skills in the game. The data provided includes the weekly gaming hours played and the professional background of the individuals., A sample size of 30 individuals was chosen, with an attempt to ensure equal representation of both designers and non-designers, individuals of all genders, and experience of VR, thereby aiming for homogeneity to establish a coherent cohort for the experiment's outcomes.

There were psychological tests to measure their spatial ability scores before the experiment. The experimenter gave oral instructions before each test, along with written instructions and examples in the test papers. Standardized protocols for the administration of the Mental Rotation Test (MRT), the Perspective Taking-Spatial Orientation Test (PT-SOT), and the Santa Barbara Sense of Direction (SBSOD) were followed. Each participant's total time for the experiment was approximately 1 hour 15 minutes, including breaks. These steps were evaluated in the pre-experiment stage.

To maintain the experiment's viability, a participant from the study group was chosen to undergo the procedures. Based on their feedback, the experimental design was revised. The participant played two VR games to determine which would better test the hypotheses. It should be noted that the results of this player were not included in the evaluation of the experiment group. A preliminary session was conducted to familiarize the participants with the virtual reality environment, given their minor or nonexistent prior experience with VR or with a maximum duration of two hours. The Introduction to the Oculus Quest 2 game inside the headset was initiated in this instance. The participants acclimated to the glasses and acquired proficiency in using

[1] Golden Gate VR game is designed by Sena Ayça Metin, Fatih Erdil and Merve Taşdelen, at the “MBL538 - Virtual Environments Studio” course in ITU Architectural Design Computing Program.

the controls. Simultaneously, it was observed that the glasses' cameras may be activated under hazardous circumstances, enabling individuals to see their environment visually. Hence, the inquiries about the individuals were addressed, and efforts were made to mitigate the potential occurrence of difficulties throughout the experiment.

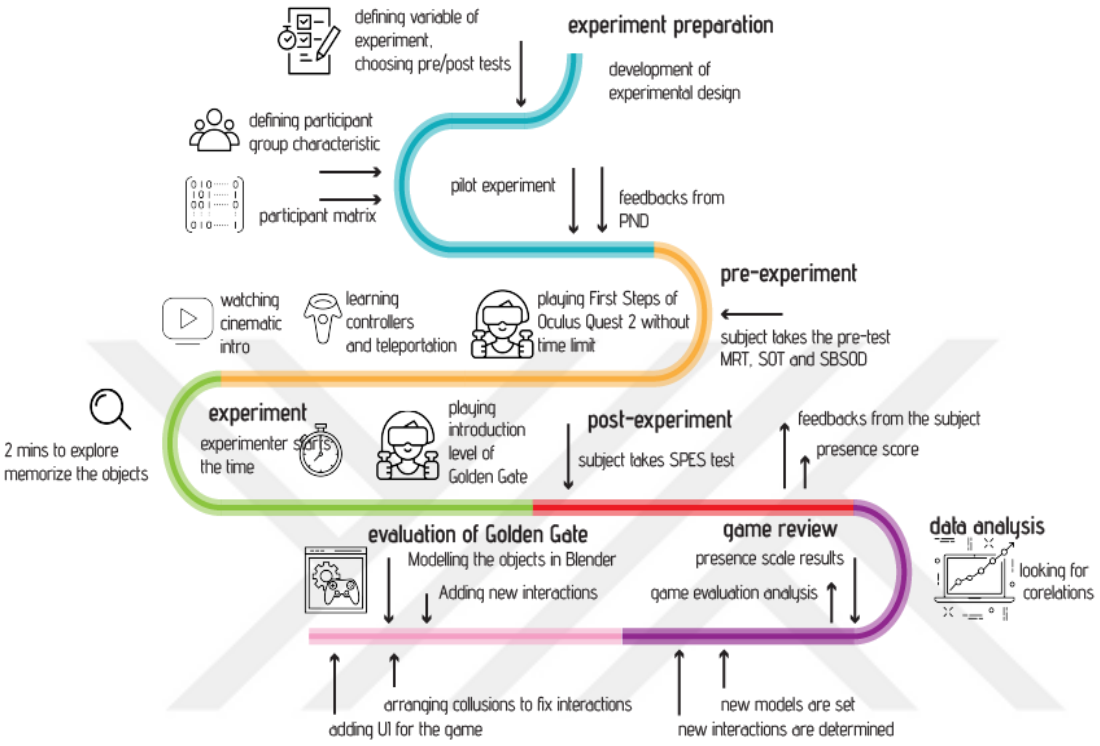


Figure 1.2: Flowchart of the experiment (Earlier version of this table is published in Tasdelen et al. 2023b)

Subsequently, the participants were exposed to the VR environment, where they saw the game's trailer video. Additionally, they were provided concise details on the game before commencing gameplay. The participants were provided with a reminder of the significance of playing time. Following this, they were given two minutes to acclimate to their surroundings and recall any preexisting things. During the first phase, mental imagery and short-term memory (working memory) were desired to be active. During this period, individuals were instructed to engage in the exercise of teleportation.

The game requires four interactions to be found. The objects are shown sequentially, accompanied by an auditory cue signaling the presence of each item. Initially, there was a prevailing belief that players needed to carefully observe and mentally retain the surrounding items within the designated timeframe, with the expectation that this practice would expedite the subsequent search for these things. The last interaction

opened the dungeon door, and the participant finished the game. After the game experience, participants take the post-test and conclude the experiment.

The data was gathered and organized in preparation for analysis. The Rapidminer program was used for data mining and identifying correlations within the obtained findings. The objective was to ascertain if there were positive or negative correlations between the administered tests and the criteria under investigation. This study aimed to examine the impact of individuals identifying as designers on their performance in exams or gaming sessions. To validate the three previously mentioned hypotheses, an investigation was conducted to identify the factors influencing in-game performance and the concept of presence. This examination included analyzing the average values of the groups and assessing the association between psychometric test results.

2. THEORETICAL BACKGROUND

The literature review is comprehensively beginning with broad topics and progressing to detailed sub-categories. Initially, the virtual reality environment's purpose, tools, and programs are described. Then, based on previous research, it describes how a sense of presence can be achieved in these environments and which effects will contribute to this sense. The relationship between spatial abilities and spatial presence is then emphasized. To examine this relationship, the experiments were conducted by playing games in VR.

As a literature review part, the databases were scanned through keywords. To reveal all the trajectories of the research topic, we searched using keyword combinations representing the study's focus and pillar concepts to generate a list of relevant research publications. The Rapidminer software was used to generate word association rules by scanning abstracts. These findings are presented under the “2.7 The Literature about these Trajectories” section.

Virtual reality environments are primarily defined by presence, spatial perception, immersion, and interaction. These characteristics distinguish between real and virtual environments (Azar & Rice, 2022). With the incorporation of VR tools, the gaming environment dispenses with a presentation on the surface and provides the optimal performance for 3D perception. Since VR provides visuomotor skills during gameplay, the player is not confined to a seated position while using a controller, keyboard, and mouse (Chang et al., 2017). The VR equipment, such as Head-Mounted Display (HMD) displays, encourages the participant to move in a limited manner, enhancing spatial perception. Unlike computer-based games, this innovation inspires interactions with the game similar to real life.

Interactions within virtual reality have enhanced spatial presence (Rooij, 2022) and positively correlated with mental imagery (Weibel et al., 2011). According to Coxon et al. (2016), differences in general spatial abilities may cause individual differences

in spatial presence. Perspective-taking ability has been linked to physical motions (Chang et al., 2017), and tangible VR games have been shown to enhance this ability (Harley et al., 2017).

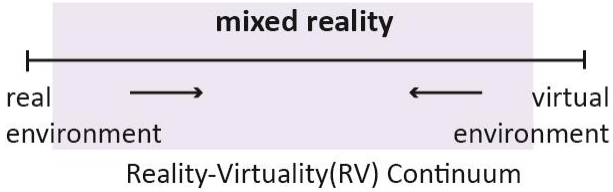


Figure 2.1: Reality-Virtuality Continuum Diagram from Paul Milgram (1995).

Our primary goal is to analyze the game's mechanics within the context of spatial skills and disclose through interaction the relationship between spatial ability and spatial presence. There needs to be more literature to reveal the trajectories between spatial presence in VR environments regarding spatial ability basics. Previous research has only demonstrated a positive correlation between mental imagery and mental rotation, perspective-taking ability, and spatial visualization (Weibel et al., 2011).

Individuals deliver egocentric orders when given depth cues to speak in a dynamic context, according to Mintz et al. (2004). In a virtual reality gaming environment, the participant's decision-making should depend on their capacity for egocentric perspective-taking. Those with a high capacity for egocentric perspective-taking should finish the game more quickly, as their action and decision phases will be shorter, and they will have higher SPES scores.

2.1 The Brief History of Virtual Reality

In dictionaries, virtual is defined as " *objects and activities generated by a computer to simulate real objects and activities*" (URL 2). A computer generates virtual objects that mimic the behavior of real-world objects. Computer-generated environments that serve as virtual environments can represent real or imaginary worlds. In his science fiction novel, American author Ray Kurzweil characterized the twenty-first century regarding the development of technology and artificial intelligence. In addition, he asserts that by 2019, people will wear spectacles or devices that transmit images to their retinas and allow for audio-based communication. According to him, the actual

world will be visualized using three distinct systems: Augmented reality, virtual reality, and mixed reality (Steinicke, 2016). This is described as Mixed Reality by Paul Milgram's reality-virtuality continuum paradigm, as shown in Figure 2.1. In this theory, substeps provide continuity between the real and virtual realms. (Milgram et al., 1995) These substeps are a hybrid of actual and virtual elements.

2.1.1 Early virtual reality attempts

The 3D effect on our screens helps us perceive depth, which is crucial in creating virtual reality. Charles Wheatstone's 1838 demonstration that our brain combines the two-dimensional images from our eyes to form a 3D object was the first step towards VR development. Using a stereoscope to view two stereoscopic images or photographs side by side gave the viewer a sense of depth and immersion. The stereoscopic images are the critical component of HMDs. The first glass-like device can be seen in Figure 2.2. In the story by American science fiction author Stanley G. Weinbaum, the protagonist, Dan Burke, encounters an elfin professor named Albert Ludwig, who invented a pair of spectacles enabled in 1935. This was the initial concept for the VR spectacles. The second image in Figure 2.2 demonstrates the spectacles described in the story as “Pygmalion’s Spectacles” (Weinbaum, 1920).

In a 1955 paper titled "The Cinema of the Future," American cinematographer and inventor Morton Heilig described his vision of a multisensory theater. In 1962, Heilig constructed the Sensorama, a prototype of his immersive, multisensory, mechanical, and multimodal theater, and created five short films. Heilig was granted a U.S. patent on August 28, 1962, for a "Sensorama Simulator." This innovation is regarded as one of the earliest successful virtual reality endeavors (URL 3).

Sketchpad, created by Ivan Sutherland in 1963, was the first interactive computer interface to use a Graphical User Interface. The user could draw directly onto the screen using a light pen, a pen-like device Ivan Sutherland and his student, Bob Sproull, showcased in The Sword of Damocles in 1968. It is considered the first-ever head-mounted display system with 3D tracking capabilities. The setup included a stereoscopic display system that showed the computer program's output, which changed in real-time based on the user's movements. (URL 4; van Krevelen, 2007).

Founder of the Visual Programming Lab (VPL), Jaron Lanier, coined or popularized "virtual reality" in 1987 after years of human-computer interaction development. The field of research was named “virtual reality.” (URL 5).

Since the late 1990s, NASA and the U.S. Air Force have also developed these systems for training, simulation, and research (Bostrom, 2003). These simulation systems are now utilized for entertainment, education, training, medical, and therapeutic purposes.

The Nintendo Virtual Boy (VR-32) was the first portable 3D game console. However, it had limited games in red and black, lacked software support, and was uncomfortable to use. All these developments can be seen in Figure 2.2.

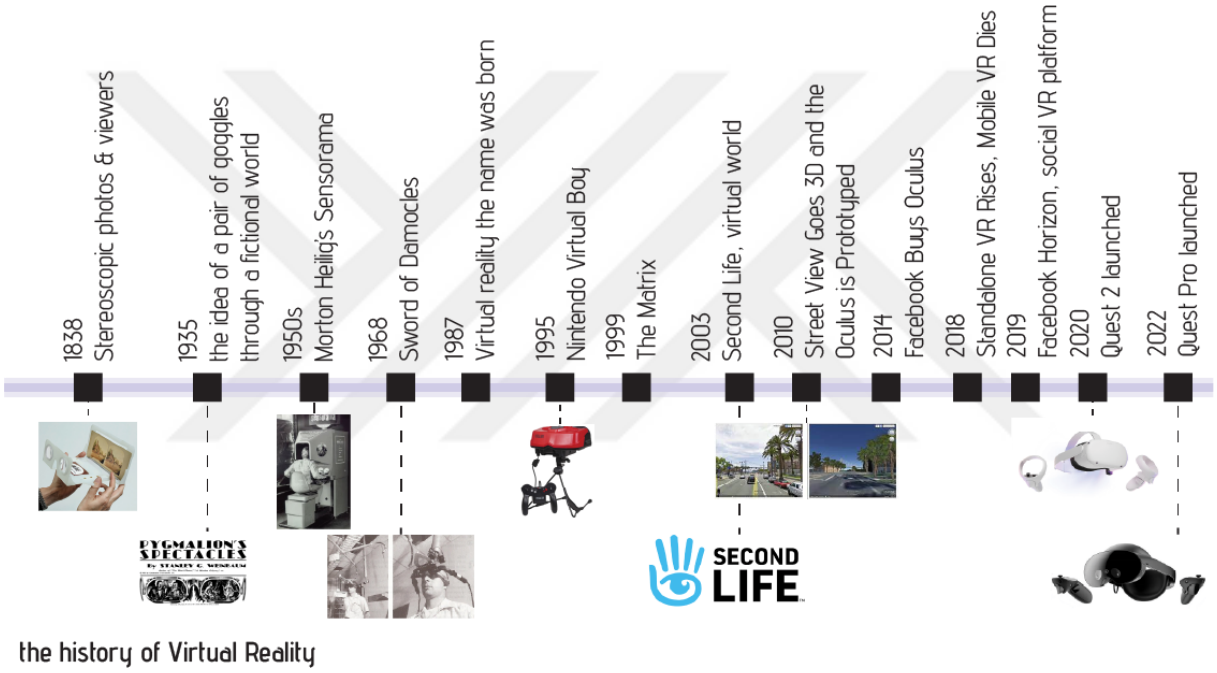


Figure 2.2: The timeline of the history of Virtual Reality.

2.1.2 The developments of the virtual environments since the 2000s

The community has dealt with many technological advancements when the new millennium begins; these advancements continue in Figure 2.2. Due to improvements in the film industry, such as animation, disasters, and technological takeovers have been portrayed in movies. World on a Wire (1973), a German film, was the first to deal explicitly with Virtual Reality, but the movie Matrix (1999) was more famous. A government computer institute runs an elaborate and unique virtual reality simulation

in this two-part TV movie by Rainer Werner Fassbinder (URL 6). This Wachowskis-directed matrix left a lasting mark on Hollywood action cinema. Neo, a programmer, believes that reality is faulty. Neo and his fellows are inside the Matrix, a sentient machine-run virtual reality simulation. Neo faces off against the artificial intelligence that has enslaved humanity.

The 3D virtual environment platform Second Life is a free world for its users to interact with other users and create events, see Figure 2.3. There is a thriving business community there as well. The public release of the platform occurred on June 23, 2003. However, its development can be traced back to the late 1990s, according to Linden Lab (URL 7). Second Life has no specific goals. A real person controls another user's avatar who created the vast landscape you are viewing.

Figure 2.3: The one sequence of Second Life and User Interface (URL 8).

Facebook acquired Oculus VR, a prominent provider of virtual reality games. This marked a significant turning point for virtual reality. Established in 2012, Oculus VR, Inc. is working to develop a cutting-edge home-based VR system. The Oculus Rift, the company's first product, is a virtual reality headset that gives users the impression that they are immersed in a computer-generated world.

Facebook, called Meta, is constructing its own Ready Player One Oasis. Facebook Horizon is a virtual reality universe where users can create their environments and games, interact with friends, or explore user-generated landscapes. This is Facebook's

interpretation of Second Life (URL 9). Following these developments from Facebook, Meta has released Oculus Quest in 2020 and Oculus Pro in 2022. The pro version of Quest features full-color mixed reality enabled higher resolution (URL 10) and more professional and natural tracking of the hands and body. In their place are more sophisticated sensors able to read the user's hand movements, eliminating the need for traditional controllers.

The development of VR devices has not advanced in the past decade; see Figure 2.4. Their technological handling capacity and burden have increased. Oculus and HTC increased their devices and released them at more affordable prices, bringing these devices into our households. The Quest 2's screen resolution is significantly higher than that of The Quest 1, resulting in an enhanced and more immersive visual experience (URL 11). The Rift has a lower resolution than the other two devices. The most significant advantage of the Oculus Quest 2 is its wire-free

experience. The headset and controllers operate without cables. It was determined that these Oculus Quest 2 HMDs were accessible, affordable, and work-friendly, so they were used in the study.

Figure 2.4: The history of VR Headsets in the last decade.

2.2 The Domain and Mediums of VR Research

Virtual reality environments are primarily defined by presence, spatial perception, immersion, and interaction. These characteristics distinguish between real and virtual environments (Azarby & Rice, 2021). Other virtual environments, such as computer displays and AR environments, provide spatial data with greater precision and quantity

than VR environments. This may increase the spatial awareness of observers, leading to more accurate mental models.

VR and AR environments differ from desktop and mobile environments in that they provide consistent depth perception by permitting a 2D representation of the world in a 3D Cartesian system. Cognitive processes allow identifying, recognizing, and interpreting objects, incidents, and people. If the level of abstraction is more significant than anticipated, it may be difficult for individuals to complete this visual task. In virtual environments, conception is more prevalent than in actual ones. The greater the level of abstraction, the greater the difficulty in estimating, identifying, recognizing, and assigning meaning to objects.

Moreover, maintaining good health and preventing chronic diseases requires physical activity, but many people face obstacles in incorporating it into their daily routines. These barriers include lack of time, motivation, or access to facilities. VR technology offers a solution by providing an immersive and engaging experience that can inspire individuals to be more physically active.

Due to the complexity of producing compelling results, haptic sensations play a minor role in virtual reality design. Most virtual reality applications that emphasize haptic sensation are medical surgery applications. These applications attempt to simulate actual surgery for medical education. They simulate real surgery to overcome the problems that novice endoscopic surgeons may face (Gallagher, 1999) and discuss the results of surgical education (Satava, 2001).

Upon examination of the retrospective research, Table 2.1 presents the predominant domains in which VR has been extensively utilized. Based on the information presented, VR is primarily employed in cognitive research, with subsequent applications in education, gaming, and architecture. The total count of scholarly articles that investigated the relationship between spatial ability and presence concurrently amounted to three.

		Domain					Medium			
Year	Author	Architecture	Cognition	Gaming	Education	Learning with Gamification	VR	AR	Spatial Ability	Spatial Presence
2011	Weibel et al.		■						■	
2014	Busch et al.		■				■		■	
2016	Coxon et al.		■						■	■
2016	Hartmann et al.		■							■
2016	Torner et al.		■				■		■	
2017	Chang et al.		■		■	■	■		■	
2017	Gorisse et al.									
2017	Seibert & Shafer		■	■			■			■
2019	Yildirim et al.		■				■			■
2019	Giakis et al.									
2019	Khenak et al.		■				■			
2019	Shafer et al.			■			■			■
2019	Uz-Bilgin et al.		■			■	■			
2020	Tóth et al.		■			■		■	■	
2020	Maneuvrier et al.									
2021	Uz-Bilgin & Thompson		■	■			■			■
2022	Breves & Stein		■		■		■			
2022	Guzsvinecz et al.		■				■		■	
2019	Narciso et al.		■				■		■	■

Table 2.1: The domains and mediums of studies about VR in the 2010s.

2.2.1 Virtual environments for experiments, mockups, and simulations

Researchers may find evidence-based design techniques by comprehending the impact of the surrounding environment on inhabitants. Nevertheless, conducting empirical investigations to assess the impact of the surrounding environment on behavior poses significant challenges. Implementing environmental changes in real-world settings may be expensive and pose political challenges (Schwebel et al., 2008).

A potential avenue for gaining a deeper understanding of the impact of the surrounding environment on human behaviors is in the use of immersive settings that include intricate physical and social elements, hence ensuring ecological validity and stringent control over experimental conditions (Veling et al., 2016). Potential simulations in academic research include a variety of visual representations, including mockups, drawings, pictures, models, and immersive virtual environments (IVEs) (Neo et al., 2021). VR can investigate human behavior in real-life scenarios while mitigating the possible hazards and variability associated with actual surroundings (Blascovich et al., 2002). Participants can securely engage in immersion inside the virtual environment

when the actual world poses a risk. VR is generally considered a high-presence medium (Neo et al., 2021).

Previous studies have indicated that VR can be a valuable research instrument for replicating real-world environmental characteristics. By immersing participants in hypothetical scenarios, VR enables researchers to investigate their reactions to controlled environmental alterations that would otherwise be challenging to observe in actual settings (Schwebel et al., 2008).

Figure 2.5: VR market and experimental setup from the research of Lombart et al. (2019).

These mock-ups can vary with the different functions such as fall risk (Shi, 2019), road crossing (Kooijman, 2019), food selection see in Figure 2.5 (Lombart et al., 2019), emergency (Tucker, 2018) with different aged participants (Neo et al., 2021). Interactive virtual prototypes differ from traditional ones, allowing users to interact only passively through their vision. A virtual prototype is mainly suitable for evaluating product aspects by relying only on vision, such as color and affordances, and for evaluating product aspects, such as usability and comfort (Lombart et al., 2019).

The researchers conducted empirical investigations using domain, dependent, and independent variables to explore this domain further. The variables investigated and the interventions implemented are presented in Table 2.1. For instance, the researchers conducted a comparative analysis of different media platforms to assess the optimal level of presence (Weibel et al., 2011). Additionally, they examined the impact of

being a player on presence (Uz-Bilgin & Thompson, 2021). Furthermore, they explored the influence of video and audio quality on the perception of presence (Narciso et al., 2019;). During these investigations, researchers occasionally focused on certain sub-dimensions of spatial aptitude, such as mental cutting (Chang et al., 2017), spatial visualization, and mental rotation (Guzsvinecz et al., 2022). To investigate further it is detailed in the Table 2.1.

domain	independent variable	dependent variable	intervention	targered subskills
design	diff. media types	presence	game development	spatial visualization
cognition	dif. mediated environment	immersion	SP test development	spatial orientation
education	gender	cybersickness	HMD vs. Desktop	spatial relation
gaming	game experience	enjoyment	diff. SP Tests	perspective taking
	sound & video quality	interaction time	diff. media types	navigation
				mental imagery

Table 2.2: Virtual Environment literature in a manner of domains and variables.

2.2.2 Virtual environments as a learning medium

Information and communication technology advancements have opened up new possibilities for integrating 3D virtual worlds into design education. These virtual environments have significant promise as constructivist learning spaces (Gül et al., 2008). Researchers report that the educational implementation of virtual reality positively impacts learning performance (Ott & Freina, 2015). Virtual reality has been extensively utilized in education. Individual differences primarily mediate these effects (Lin & Suh, 2021).

The primary uses of low-immersive virtual reality (iVR) in higher education contexts encompass various applications. These include virtual lecturing, which involves creating a virtual replica of a classroom environment. Additionally, low-immersive

VR can facilitate individual learning experiences through virtual field trips to locations such as museums or hotels. Simulations are another valuable application, particularly for learning activities that are challenging to replicate in real-world settings, such as navigating through the solar system. Lastly, game-based experiences have also been explored to enhance educational processes (Choi et al., 2016; Dubovi et al., 2017).

2.3 Designing Immersive Virtual Environments for Human Behavior Research

Our physical environment's social, political, and cultural characteristics can influence how we act (Waterlander et al., 2015; Neo et al., 2021). Sometimes, seeking the same environment for a specific research question is complex. Researchers may need standardized environments in identical settings to comprehend how our environment affects human behavior. Moreover, real-time environmental settings may need to be more affordable and unpolitical to implement (Shwebel et al., 2008). Due to these factors, simulations are occasionally utilized to investigate the relationship between environment and behavior. Simulations may include prototypes, sketching, photographs, models, and immersive virtual environments (IVEs) (Neo et al., 2021).

IVR products have become increasingly popular among consumers, providing highly engaging experiences and opening doors for academic research. With the development of affordable and readily available commercial devices such as the HTC Vive, Oculus Quest, and Playstation VR, interest in this area has grown tremendously.

Presence is studied in different domains to connect cognitional operations, technological developments, and user psychological characteristics. The research area's interventions for investigating presence differ, such as the effects of rendering quality (Zimmons & Panter, 2003), interaction quality, and absence of interaction (Roij, 2022; Maneuvrier, 2022) on task performance.

With the incorporation of VR tools, the gaming environment dispenses with presentation on the surface and provides optimal performance for 3D perception. Since VR provides visuomotor skills during gameplay, the player is not confined to a seated position while using a controller, keyboard, and mouse (Chang et al., 2017). Virtual

Reality tools, such as HMD devices, encourage the participant to move in a limited manner to improve spatial perception. Unlike computer-based games, this innovation inspires interactions with the game that are similar to real life. While wearing virtual reality equipment that conceals their eyes and sometimes ears, players interact with the virtual environment using controllers or hand gestures. HTC Vive is a device that hides the ears, while the Oculus Rift and Quest use speakers.

authors	types of presence	definition
Sheridan, 1992	1.telepresence 2.virtual presence	"telepresence" in the case of teleoperation (feeling like you are actually "there" at the remote site of operation) and "virtual presence" (feeling like you are present in the environment generated by the computer)
Steuer, 1992	1.telepresence 2.virtual presence	"presence" refers to the natural perception of an environment, and "telepresence" refers to the mediated perception of an environment.
Zahorik, 1998	Teleoperation, and presence in virtual reality systems	Presence is subjective feeling of existence within a given environment
Lee, 2004	1.physical presence 2.self-presence 3.social presence	Presence is subjective feeling of existence within a given environment

Table 2.3: The notion of presence according to authors' definitions.

2.3.1 Presence, immersion, and embodiment in VEs

The result of immersion's emergency is presence (Cummings & Bailenson, 2015). "Presence" refers to the consequences of a person's experience of occupying a virtual space while psychologically being a part of the virtual world, as seen in Slater'. In virtual worlds, computer technology can represent the body with sensors, referred to as "virtual bodies.

> *"This representation enables an immersive environment, and this immersion can contribute to presence, which is a feeling of "being there" (Slater et al., 1994).*

As seen in the quote of Slater et al. (1994) and others in Table 2.3, the researchers defined their presence notion according to their findings in their experiments. The authors defined presence and established distinct subcategories within this construct.

During the separation process, they also explained the specific manifestations of each presence in different situations. Telepresence indicates a mediated device or environment (Steuer, 1992), self-presence indicates the feeling of being present with your body, and social presence indicates feeling present with others in a mediated environment, which can result from a chat or interactions with other users (Lee, 2004).

On the other hand, internal and external factors contribute to auditory externalization in HMD sets and models within VEs, primarily due to individual responses (Cummings & Bailenson, 2015). Internal factors include emotions about self and others, such as anxiety, loneliness, and retrospective emotions; thoughts about self and others, such as memories, social judgments, and narrative; and physiological reactions, such as anxiety and cybersickness (Riches et al., 2018).

Field of view, tracking level, image quality, stereo vision, high vs. low overall sound, update rate, and the user's perspective are system factors or operationalizations (Oh et al., 2018); interactivity with environment, environmental characteristics, behavior of avatars (Riches et al., 2018) other factors required as external factors for immersion to enable presence in virtual environments. When the participants were measured and grouped using self-report spatial ability tests, Cumming's (2015) meta-analysis found that the effects of field of view, tracking level, and stereoscopic vision were more significant than others.

Physical presence, self-presence, and social presence can be studied as subcategories of presence (Lee, 2004). Various factors, including technological and psychological ones, these categories are further explained below. Self-presence is evoked when the virtual and actual selves experience identical feelings. This is about the connections between a virtual body, emotion, and identity (Ratan & Hasler, 2009) and not about the environmental and psychical factors. Telepresence has also been extended to include engagements inside virtual environments, see Figure 2.6. In this scenario, an individual is fully engaged inside a computer-controlled display system, allowing them

to influence modifications within such an environment. Experiencing a sense of presence results in a mental model through human operators and controls in hardware or software.

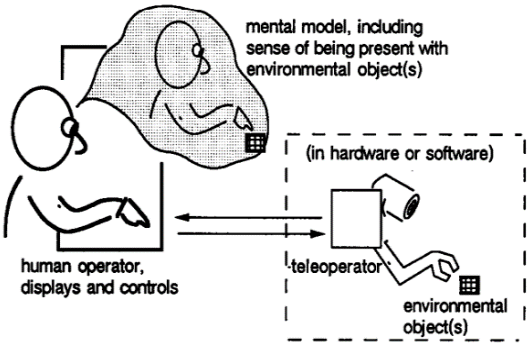


Figure 2.6: Telepresence and mediated environment relations (Sheridan, 1992).

In contrast to self-presence, which refers to the actual and virtual self of the interactant, social presence refers to the feeling of being with another (Biocca et al., 2003). Feeling the socially presented necessitates, above all, a sense of presence or "self-presence." This experience of social presence, or co-presence, alludes to being more immersed in daily life and social interactions than in artificial performance (Lee et al., 2006).

Due to the technological capacity to generate realistic experiences, immersion has emerged. This instantaneous status disconnects the interlocutor from reality (Slater & Wilbur, 1997). Immersion indicates technological capability, whereas presence is based on subjective experiences. Even though the computer-mediated environment has insufficient specialized apparatus, the participants experience a sense of "being." Different avatar circumstances, such as having a scanned avatar, an actual avatar, or no avatar (Aseeri & Interrante, 2021), have been shown to affect the amount of presence.

2.3.2 Immersive qualities

These factors are mainly technological features such as modality, visual representation, interactivity, haptic feedback, depth cues, display, and audio quality (Oh et al., 2018). There are some differences in these technological features that researchers have investigated:

- **Modality:** the difference between desktop vs. HMD, desktop vs. CAVE, text vs. audio, 2D vs. 3D, etc.
- **Visual representation:** behavioral realism (mutual gaze; high, low, and none; static vs. dynamic, etc.)
- **Interactivity:** low, medium, and high interactivity; machine vs. person interactivity, synchronicity; passive vs. interactive, etc.
- **Haptic feedback:** absent vs. present
- **Depth cues:** stereoscopy, mono vs. motion parallax vs. stereo + motion parallax, etc.
- **Display:** the image quality, screen size, etc.
- **Audio quality:** two-channel sound vs. surround sound, etc.

Embodied interaction refers to the connection between the body and the brain and how it impacts the generation, handling, and dissemination of purposeful interactions with technology. This includes handhelds, large touch screens, computers, motion tracking systems, immersive digital environments, virtual environments, and customized solutions (Lee-Cultura & Giannakos, 2020).

2.4 Virtual Reality Developments and Devices

Regarding human-machine interface, a virtual reality headset has surpassed the keyboard, mouse, and touch screen. The device uses focused lenses to deceive the viewer's visual perception, creating the illusion of being physically present in the simulated environment. According to Huang (2018), the sense of vision is the most potent sensory input available to humans. When this sense is substituted with a virtual environment, individuals may have a profound sensation of being immersed in an alternate reality. The following section will provide an in-depth overview of these advancements.

2.4.1 Developments of Devices

With the introduction of Oculus Rift headsets, the head tracker continuously analyzes the player's head movement and uses that information to control the view in-game instead of using a mouse or analog stick. This makes for a more realistic way to take in your surroundings, an essential part of the immersion process (Desai et al., 2014).

In virtual reality, there are headsets such as Google Cardboard, Google Daydream, Oculus Quest 2, and HTC Vive. High-quality computer-generated visual data and accurate head and body tracking, as indicated by Slater in 2009, would significantly improve immersion and offer a sense of place illusion. The Oculus Rift virtual reality headset was introduced in 2015 after Facebook announced it in March 2014 (URL 12.). In 2015, when the first HTC Vive headsets were released, the company and its community won several awards. On January 8, 2018, HTC introduced the HTC Vive Pro, an upgraded version of the original Vive. It features displays with a 78% improvement in resolution (URL 12). Coyne et al. (2019) note that recent developments in video card technology have enabled the development of VR headsets with high-resolution visual displays. For instance, Meta has just issued an update, Direct Touch, for its headsets that allows hand recognition even when the remote controller isn't in use. This update was published in February 2023 (Company & Meta, 2023). The company has already issued such an update in 2019, but the users still need to embrace this enhancement. These advancements pave the way for research on behavior in virtual reality settings.

2.5 Spatial Ability

Having spatial intelligence is crucial for humans in their daily lives. It involves predicting locations, gathering spatial information while navigating, performing spatial tasks, and orienting oneself (Golledge & Stimson, 1997, cited in Ishikawa, 2020). Spatial intelligence is a combination of cognitive functions that make up human intelligence. Gardner (2011) defines it as the ability to understand, recall, and manipulate spatial information and relationships (Zacks et al., 2000; Lee-Cultura &

Giannakos, 2020). Spatial abilities are vital for effectively managing cognitive tasks such as visualizing and reasoning about changes in spatial positions.

The researchers developed assessments to measure these spatial abilities from the beginning of the 20th century. The concept of spatial testing originated from the first endeavors to quantify mechanical skills, primarily with the aim of forecasting proficiency in technical professions. Because it was considered that these abilities needed physical manipulation, many of these assessments were based on performance on activities that involved assembly or manipulation of actual objects (Hegarty & Waller, 2005). Paper-and-pencil tests allowed for testing in large groups, resulting in vast data sets that gradually started to define the structure of intelligence and the nature of visuospatial skills (Smith, 1964). They believed that verbal intelligence had a connection with spatial tasks until Koussy (1935), Eysenck (1939), and Thurstone (1938) all showed that spatial ability could be distinguished from linguistic ability.

After this distinction, in the mid-20th century, scholarly investigations about variations in spatial skills were primarily concerned with explaining the factor structure of those abilities. These factors can be mentioned as sub-skills or sub-scales. Several researchers, including Guilford and Lacey (1947), Zimmerman (1954), Thurstone (1950), and French (1951), have discovered that extensive sets of spatial tests provide support for several distinct sub-scales of spatial ability.

In Hegarty and Waller's (2005) research, she distinguished spatial abilities by required scale: figural and environmental. While figural spatial abilities occur in a small-scale environment, environmental spatial abilities happen in a large environment. People perceive horizontal and vertical rotations, mentally rotate objects, and retain the position of simple figures in small-scale environments (Voyer et al., 1995). Environmental spatial skills, on the other hand, are based on physical body movement, such as traversing available spaces and learning their layout (Hegarty, 2006). Immersive environments such as AR and VR allow for activities requiring physical movement and environmental spatial skills, whereas 2D games primarily require figural spatial skills. Zacks and his colleagues (2000) also discussed categorizing mental spatial transformations into object-based and egocentric perspective transformations, which have distinct relationships to psychometric spatial ability tests.

According to their evidence, our theory for VR environments is that these two spatial tasks necessitate different computations in the real world. Depending on how this process is refined, people may be more proficient at one transformation than the other.

2.5.1 Sub-scales of spatial ability

In their seminal work, Michael, Gulford, Fruchter, and Zimmerman (1957) analyzed the extant literature, concluding with a conclusive summary. They believe there are three factors: spatial visualization, spatial relations and orientation, and kinesthetic imagery. They also matched the factors with the test as cited typical markers (Hegarty & Waller, 2006). McGee (1979), Lohman (1988), and Carroll (1993) also investigated the experiments to determine their factors, in other words, sub-scales.

Unlike the factor determination, According to Hegarty (2010), one approach is that individuals can choose between flexible strategies, such as building and modifying mental pictures and engaging in more analytic thinking. The second aspect of spatial intelligence identified is known as meta-representational competence, as described by diSessa (2004). This component encompasses the capacity to select the most suitable external representation for a given task.

When examining the current body of research, it becomes evident that Carrol (1993) and Lohman (1988) have often been cited. The decision to undertake this study is predicated on our belief that the definition of the VR environment proposed by Lohman (1988) is the most appropriate. Lohman identified the sub-scales with spatial visualization, spatial relations, and spatial orientation with the tests of Paper Folding, Card Rotations, and Guilford–Zimmerman Spatial Orientation (Hegarty & Waller, 2005).

The VR environment will serve as a spatial training aid, allowing those with low spatial abilities to develop their skills more effectively than those with high spatial knowledge. Additionally, VR environments reduce the cognitive burden associated with these cognitive functions.

People utilize spatial information for navigation due to their capacity for spatial reasoning (Newcombe et al., 2019). Navigation is one of the most essential spatial activities for survival to maintain orientation and wayfinding. Cognitive mapping

entails acquiring, representing, and utilizing spatial relationships (Ishikawa, 2021). To comprehend the structure of their environments, humans must incorporate independently learned information at distinct locations, which necessitates the development of accurate cognitive maps and, consequently, flexible navigation and spatial awareness. Navigation in VR using the depicted map requires the user to orient himself and update his position with the environment. As previously stated by Zacks et al. (2000), this navigation occurs on an environmental scale. At the beginning of the 2000s, psychometric findings supported the notion that there is a distinction between mental abilities such as mental rotation and perspective taking, which entails envisioning how a scene appears from various perspective points.

2.5.1.1 Mental imagery

Mental imaging occurs when individuals retrieve perceptual information from memory, resulting in the subjective sense of seeing or auditing sensory stimuli without external sensory input (Kosslyn et al., 2001). He explained the notion before: "Imagery is a basic form of cognition and plays a central role in many human activities" (1994). People have mental images that are coded with or without their experience. Mental imagery may arise from retrieving previously experienced objects or events and innovatively synthesizing and altering stored perceptual information (Kosslyn, 2001). Imagery may facilitate cognitive processes involving mental simulations when individuals endeavor to see the potential outcomes of corresponding physical scenarios (Kosslyn, 1987).

Designers consistently use imagery as a means to produce novel combinations of forms, which they then depict via the act of sketching. However, they also engage in the opposite process by sketching to mentally see and develop pictures of various kinds (Goldschmidt, 1994). She concurs with the standpoint that visual thinking entails the generation of cognitive processes via visual images. Furthermore, it is well acknowledged that creative thinking is more prevalent in this regard. With their prior knowledge, designers should have high mental imagery ability to design, sketch, and make models. Imagery, as a component of visual cognition, is a cognitive process that drawing may enhance (Goldschmidt, 1994).

In design cognition, imagery is believed to have an essential role while sketching. The research mainly focused on the with or without blindfold designers to reveal the connection between imagery and sketching or modeling. Presence and mental imagery relations are investigated by Athavankar et al., who examine the possibilities of blindfolded architects interacting with the virtual architectural spaces they create in their mind's eye while designing (2008).

2.5.1.2 Mental rotation

Visual mental pictures can be manipulated akin to tangible things, facilitating cognitive processes that include reasoning about the potential outcomes of similar physical manipulations (Shepard & Cooper, 1982). To carry out these activities, people engage in a mental process called "mental rotation." A mental rotation is performed instead of a physical one, with the object traveling through a series of intermediate locations along a trajectory (Kosslyn et al., 1998).

2.5.1.3 Spatial orientation

Spatial visualization involves the ability to imagine the movements of objects and shapes in space, as described by Hegarty and Waller in 2004. Mental Rotation Tests and surface development tests are commonly used to measure this skill, such as the ability to visualize the folding and unfolding of paper. Various studies have explored the connection between mental imagery and spatial presence across different media formats, as seen in Weibel et al.'s work in 2011, and self-generated reality, as explored by Pillai et al. in 2013.

2.5.2 Spatial skills in the context of VR gaming

Hegarty (2005) divided spatial abilities into figural and environmental based on the scale of the process. Environmental spatial abilities are developed in a large region, unlike figural spatial skills, which are developed in a restricted space. Humans can see horizontal and vertical rotations, mentally rotate things, and remember the location of simple figures in miniature settings (Voyer et al., 1995). Physical mobility is the foundation of environmental spatial skills like understanding the architecture of a new area and figuring out how to go about it (Hegarty, 2006). Activities involving physical

mobility and environmental spatial skills may be carried out in immersive settings like AR and VR, but 2D games generally need figural spatial skills. Zacks and his colleagues (2000) identified two types of viewpoint transformations that affect psychometric spatial ability tests: object-based and egocentric.

Virtual reality games provide maximum player interaction due to their first-person, fully immersive experience. Video games provide the player with a greater sense of agency and personal investment in the story's outcome than inert media such as movies. (Lin, 2013).

Those who play VR games are exposed to more hazards than video game players, leading to a heightened sense of agency and presence (Madsen, 2016). Due to the increased realism of VR, players experience a greater sense of dread. Day's (2015) study revealed that individuals who played a horror game in VR experienced more terror than those who played the same game on a traditional screen.

While Kari (2007) started investigating, Bouvier et al. (2008) followed her investigations about VR gaming and spatial presence. The timeline of the conducted researchers in their field can be seen in Figure 2.7. The article evaluates VR game environments and presents data about the immersion and presence notion to show gameplay. 2016, the studies have started to deal with spatial and spatial ability training in VR games. Ijaz et al. (2016) developed a VR game, VR Rides for Retirement Homes, to evaluate it in a realistic setting. Freina and Bottino developed a VR game environment to enhance visual thinking for primary school children (2016). Uz-Bilgin and Thomson published the first academic articles connecting the three topics in 2022. They look into how users' prior knowledge, game experience, and VR experience affect the development of spatial presence in a virtual reality educational game.

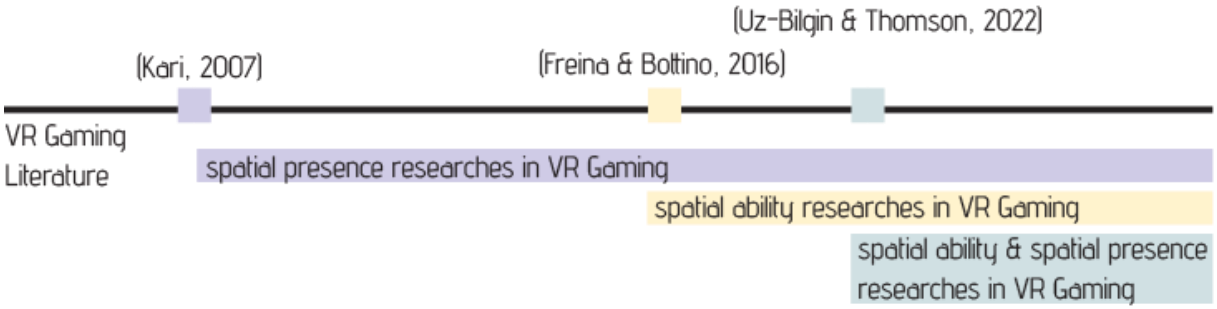


Figure 2.7: VR game literature regarding spatial ability and presence.

2.6 Spatial Presence and Task Performance in Virtual Environments

In 1992, Steuer identified three categories that determine how people experience presence in a virtual environment: vividness, interactivity, and user characteristics. Vividness refers to the level of detail and complexity in the visual elements of the virtual environment. Interactivity measures the user's ability to interact with and affect the virtual environment, which can enhance the feeling of presence. A study by Huang and Yu-Ting in 2013 found that increased interactivity led to a greater sense of flow, which is the state of focused concentration on a task and is also linked to the experience of presence. Users differ in personality traits, technological proficiency, and cognitive approaches, affecting their ability to connect with a virtual environment. This research explores these differences and their impact on people's ability to experience presence.

According to Bown et al. (2017), our minds create mental representations of virtual environments by combining signals and features, much like we do for physical reality.

year	name	authors	items	subscales
1998	PQ	Witmer & Singer	32	Involvement, Naturalness, Concentration
2001	ITC-SOPI	Lessiter et al.	44	Spatial Presence, Engagement Naturalness, Negative effects
2003	IPQ	Schubert et al.	20	Spatial Presence, Involvement, Experienced Realism, Immersion, Interaction
2016	SPES	Hartmann et al.	20	Self Location, Possible Actions

Table 2.4: Well-known presence scales in literature.

2.6.1 Spatial presence measurements

Since the 1980s, scientists have been creating spatial presence assessments. The Presence Questionnaire (PQ) (Witmer & Singer, 1998; Witmer et al., 2005), the Independent Television Commission-Sense of Presence Inventory (ITC-SOPI; Lessiter, Freeman, Keogh, & Davidoff, 2001), and the Igroup Presence Questionnaire (IPQ; Schubert, Friedmann, & Regenbrecht, 2001), are all used by researchers interested in the spatial presence, see in Table 2.4.

The SPES (Spatial Presence Experience Scale), which Hartmann et al. (2016) developed, will be the main subject of this study. Consumers' feelings of spatial presence in media will be investigated using the SPES, a brand-new self-report measure. The eight-item measure consistently and robustly represents two components of spatial presence (self-location and possible behaviors; Wirth et al., 2007). The SPES measures how actively they cognitively engage in the mediated environment (Hartmann et al., 2016). The scales and their targeted sub-scales are in Table 2.4.

2.7 VR Gaming

This section will examine the intersection between the game and the current body of literature, identify the studies that have built upon previous research and corroborated its findings, and highlight the areas that need more investigation in the subsequent phase. Subsequently, the following sections will outline the stages of development, accompanied by analytical diagrams about the components to be built. Additionally, comprehensive details will be provided on the methodologies used and the specific software utilized to address the abovementioned aspects. The Golden Gate VR game has a solitary introduction level throughout its first stage. While the production of the game used in this thesis is not the primary focus, the planned and executed procedures and the test outcomes in Section 3 are elucidated.

This approach aims to provide a scholarly contribution to the existing literature by outlining the key factors designers interested in virtual reality game creation should consider or prioritize.

2.7.1 Design Trajectories for Game Designers

Games exhibit common characteristics with other types of cultural creation, such as adventure books. However, adventure books are sometimes criticized for needing more vitality and excessive reliance on technical explanations rather than providing captivating entertainment, thematic depth, or intricate character development (Jenkins, 2002). Also, he adds that not all games possess narrative elements. Games may be seen as an abstract, dynamic, and sensory medium, sharing more similarities with music or contemporary dance rather than film.

Game designers not only narrate tales; they create complex virtual environments and precisely shape the dimensions of space inside them. It is not a coincidence that game design documents have traditionally emphasized matters about level design more than narrative planning or character motivation (Jenkins, 2002). This is where architects, industrial designers, and urban planners play a crucial role. In this context, designers draw upon their familiarity with the 3D environment, understanding of color and texture, and ability to perceive scale accurately. These elements together contribute to their knowledge of composition. By including these elements, the designer can create game levels that are more realistic and devoid of design-related disabilities.

Our game tells a story that relies on a mystic legend in Yedikule about a curse and a pagan. At the beginning of the game, a non-player character (NPC) initiates an exposition, elucidating the player's physical location and outlining the nature of the tasks that lie ahead. The narrative starts with the protagonist beginning the storytelling process, whereby the subsequent discovery of clues is contingent upon both the contextual framework and the report itself. The presence of objects inside the playground does not impede the teleportation process since these objects are well-proportioned, possess the appropriate surface characteristics, and perform as intended. Haptic feedback was implemented, and auditory cues were used to indicate the authenticity of the encounter.

2.7.2 The state of the art: VR Gaming

VR games serve several objectives beyond entertainment, including education, rehabilitation, fear reduction, and mobility restoration for those with movement impairments. There are studies which investigate the rehabilitation process with gamification after injuries and movement disability (Das, 2005; Ma & Bechkoum, 2008; Cuthbert et al., 2014; Ma et al., 2020), dealing with phobias such as dark (Xinyi & Shuo, 2023), studies with elderly in health domain (Miller et al., 2014), improving cognitive functions (Amado, 2016), reconstruction of cultural heritage (Run & Alvito, 2011; Ferdani et al., 2020).

To investigate further, the novel approaches regarding the development of VR games can be listed. Jeong et al. (2023) have developed a VR game called "Glow the Buzz"

that incorporates worn haptic devices as a central component for providing haptic feedback. To prove the viability of haptic feedback as the primary interface form in games, its use resulted in a more realistic sense of touch when grabbing or touching and offered adequate immersion. In addition, Oculus released an update to track hand movement in the menu without any controller a few months ago. In further upgrades, it is anticipated that the introduction of novel devices would replace conventional controllers with a hand-tracking system that monitors and digitally represents the movements of the user's hand.

The VR game Spatial Chef, developed by Yen et al. (2023), has been specifically designed to effectively redirect the player's focus from individual objects to the surrounding spatial environment. The primary concept revolves around providing an opportunity for three-dimensional editing, encompassing room preparation, cooking, and serving. The researchers also examined the distance between individuals and its impact on their interactions.

The studies in the immersive environments affected the spatial ability domains. The Immersive MRT was created to assess the effects of VR visuals and 3D virtual environments on mental rotation performance (Lochhead, 2022). By prior research, the findings of their preliminary investigation indicate that mental rotation tasks exhibit higher accuracy and speed when presented with stereo 3D stimuli compared to 2D representations of the same stimuli.

2.8 The Literature about these trajectories

In an earlier research publication, the 2010s were the golden research period in this discipline; see Figure 2.5 below. The development of better headset technology could determine the outcome. To reveal all the trajectories of the research topic, it was searched using keyword combinations representing the study's focus and pillar concepts to generate a list of relevant research publications. The Rapidminer program was used to generate the study abstracts and the requirements for the word association rules. There may have been fewer studies done throughout time, researchers may have elected to employ other methods, the prevalence of specific terms in the literature may have grown, and pre-and post-tests may have been completed within the realm of

study. Automated database scans can be performed instead of manually reading the results. Despite the limited number of papers included in this analysis, it is worth noting that doing more thorough literature searches using this approach will save time and lead to more reliable forecasts in the future.

rule no.	term groups	support values	1996-2017	2018 - ...
r1	presence - virtual - environment	0.727	15	10
r2	presence - virtual - spatial	0.697	12	9
r3	presence - virtual - results	0.545	8	7
r4	presence - environment - spatial	0.545	12	8
r5	presence - environment - result	0.515	9	6
r6	presence - virtual - reality	0.485	6	10
r7	presence - virtual - stud*	0.424	9	7
r8	presence - virtual - participants	0.424	10	3
r9	presence - virtual - performance	0.394	10	1
r10	presence - environment - reality	0.394	7	8
r11	presence - virtual - environment - result	0.515	8	6
r12	presence - virtual - environment - spatial	0.545	13	8
r13	presence - virtual - environment - task	0.364	10	1
r14	presence - virtual - environment - participant	0.364	8	3
r15	presence - virtual - spatial - performance	0.333	9	0

Table 2.5: Association rules comparison chart and overall support values through decades (Taşdelen et al., 2023a).

The support metric measures the frequency of an item set inside a dataset. So, the more familiar a group of items is in datasets, the higher its support value. In addition to revealing how often a group of items is seen, the lift metric also displays how distinctive that set is about others. Our primary focus will be on support and lift values as we compare the rules in the provided data sets to uncover patterns and gaps in the research on the effects of VR gaming environments on players' spatial cognition.

The Figures above 2.6 and 2.7 depict the prevailing combinations that are frequently employed. By examining the six most frequently utilized keywords in binary analysis

and the three most often used words in triple analysis, it becomes evident that we may discern the associations between different phrases.

Table 2.5 suggests interesting connections and patterns among the terms "presence," "virtual," "environment," and "spatial." "presence" and "virtual" are often used to describe virtual and augmented reality systems. Participant, outcome, performance, and research are often used in contexts where they appear together. This suggests that studies are used in this field of study and that participants make an attempt to give data.

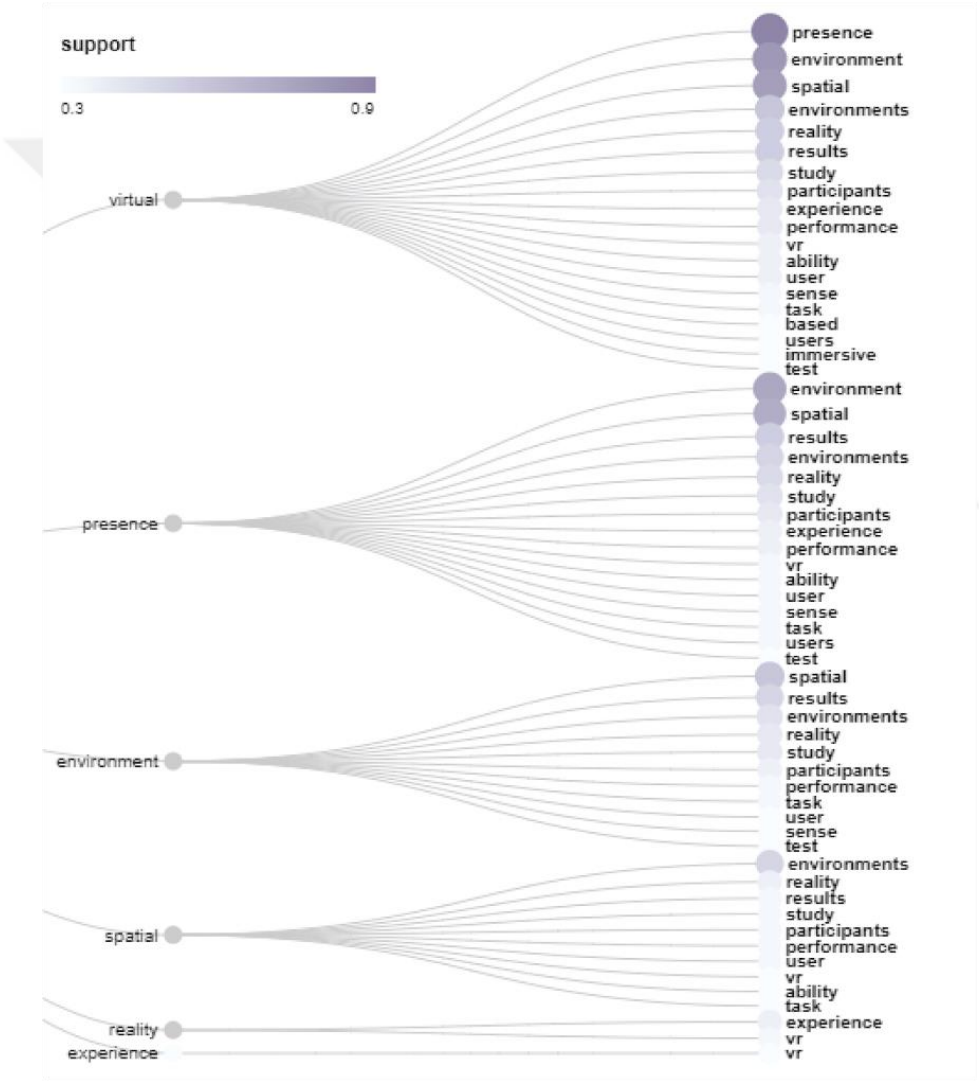


Figure 2.8: Linear binary co-word analysis (Taşdelen et al., 2023).

Table 2.5 lists the top 15 collections based on the times each concept was applied. In recent years, more papers have been written on the connection between all ideas, r6 and r10. These perspectives are more common than others. The word "result" appears often in the table, suggesting that scientists may share the outcomes of their experiments with the abstract's readers.

The terms "task" and "performance" are often used interchangeably, although Table 2.5 shows a subtle but significant difference. According to this notion, some researchers manipulated experimental results for reasons other than gauging participants' ability to complete a specific task. Words like "virtual" and "test" were used in 33% of all articles but were left out of the chart owing to space constraints. Assessments may let researchers see how an intervention is changing their subjects.

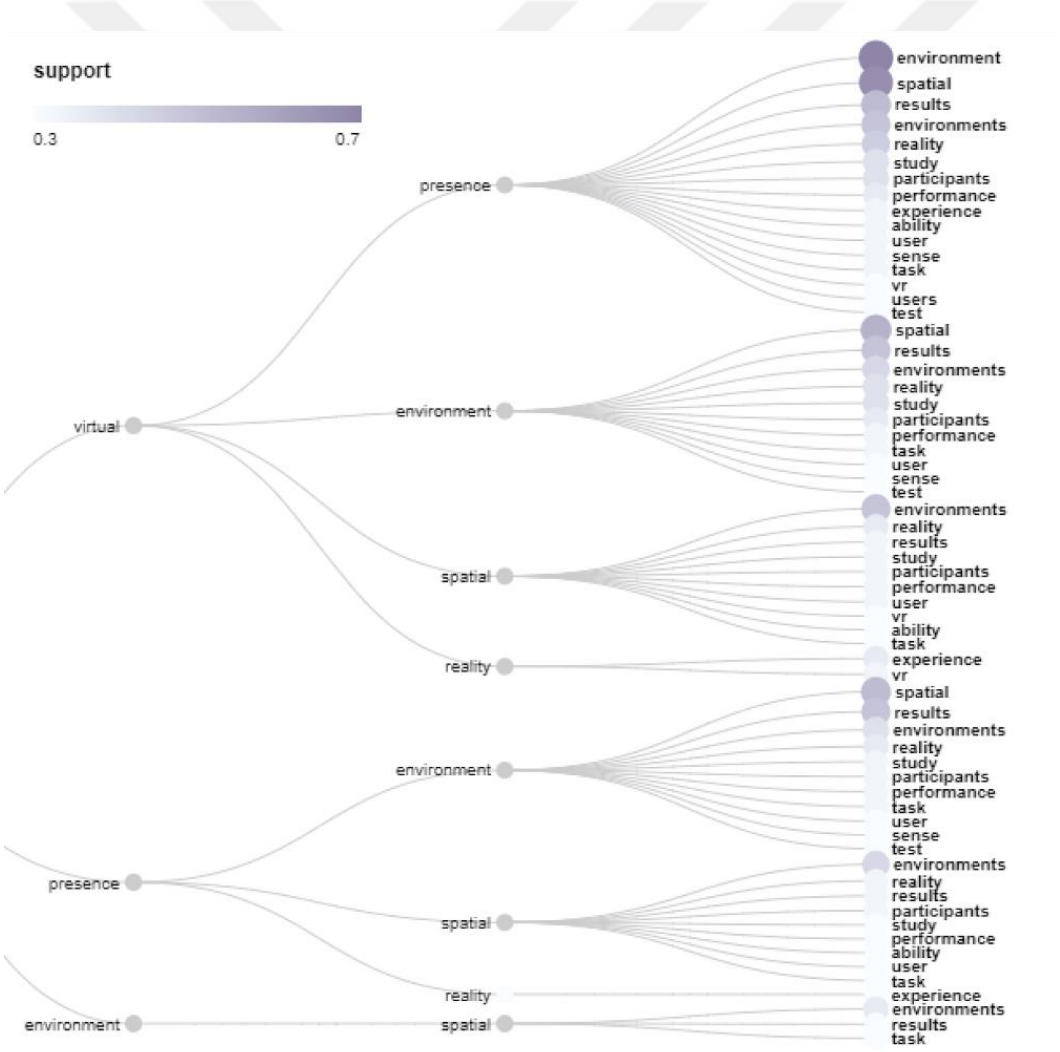


Figure 2.9: Linear triple co-word analysis (Taşdelen et al., 2023).

The examination of pairs and triplets of cognates may provide light on Table 2.5; the "virtual-participant" category accounts for 45.5% of all articles, the "virtual-experience" and "virtual-performance" categories account for 42.4%, the "virtual-user" category accounts for 39.4%, the "virtual-sense and virtual-task" categories account for 36.4%, and the "virtual-immersive" and "virtual-test" categories account for 33.3%. It is reasonable to assume that users are tested and graded based on their proficiency in experience-based activities inside virtual worlds.

Like other triple combinations, strong correlations between virtual and presence emerge in the latter stages of co-word analysis. For example, as shown in Figure 2.9, the words "virtual," "presence," "environment," and "spatial" occur together in one-half of the papers we looked at. In contrast to the spatial nature of the last word in the previous example, "virtual - presence - environment - test" only occurs jointly in 30% of the articles. The word "reality" has gained popularity recently.

Table 2.5 shows that the ideas of "presence," "virtual," "environment," and "spatial" are often employed interchangeably. Words like "participants," "performance," "task," and "orientation" have lost some of their luster over the years. This may need a shift in approach throughout the study. Researchers may find it more beneficial to conduct experiments with people and evaluate how well they do and how the intervention affects the results.

R15	R14	R13	R12	R11	R10	R9	R8	R7	R6	R5	R4	R3	R2	R1	
■			■	■		■				■	■	■	■	■	Slater et al., 1996
															Lackner & Dizio, 1998
															Johns & Blake, 2001
■	■	■	■			■					■		■	■	Zimmons & Panter, 2003
■	■	■	■	■		■		■		■	■	■	■	■	Mania et al., 2003
■	■	■	■			■					■		■	■	Parush & Berman, 2004
■		■	■	■		■		■		■	■	■	■	■	Morganti et al., 2008
■			■			■		■			■		■	■	Andrade et al., 2012
					■					■					Pillai et al., 2012
	■			■	■		■	■	■	■		■	■	■	Diyana & Rambli, 2013
■	■	■	■	■		■	■				■		■	■	Bashir & Bicker, 2013
	■		■	■			■	■		■	■	■	■	■	Yoon et al., 2015
							■		■						Locher et al., 2015
	■	■	■				■				■		■	■	Frischmann et al.,2015
			■		■				■		■		■	■	Freina & Canessa., 2016
■	■		■		■	■	■	■	■		■		■	■	Coxon et al., 2016
		■		■		■				■		■		■	McKenzie & Klippel, 2016
■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Nguyen-Vo et al., 2017
	■		■	■	■		■		■	■	■	■	■	■	Langbehn et al., 2018
															Suzer & Olguntürk., 2018
■	■	■	■	■		■	■	■		■	■		■	■	Merriman et al., 2018
				■	■			■	■	■		■		■	Iachini et al., 2019
			■	■				■	■	■	■	■	■	■	Melo et al., 2019
									■					■	Cmentoski et al., 2019
			■		■				■		■		■		Cmentoski et al., 2019
														■	Zhai et al., 2020
			■		■			■	■		■		■	■	Carbonell-Carrera et al., 2021
			■	■	■			■	■	■	■	■	■	■	Stewart & Lopez., 2021
			■	■	■			■	■	■	■	■			Uz-Bilgin & Thompson, 2022
															McLean & Barhorst, 2022
														■	Al-Ajmi et al., 2022
	■		■		■		■	■	■				■	■	Kallai et al., 2022
				■	■			■	■	■		■			Paes et al., 2023

Table 2.6: Word mapping in the abstract (Taşdelen et al., 2023).

2.9 Mapping the Literature

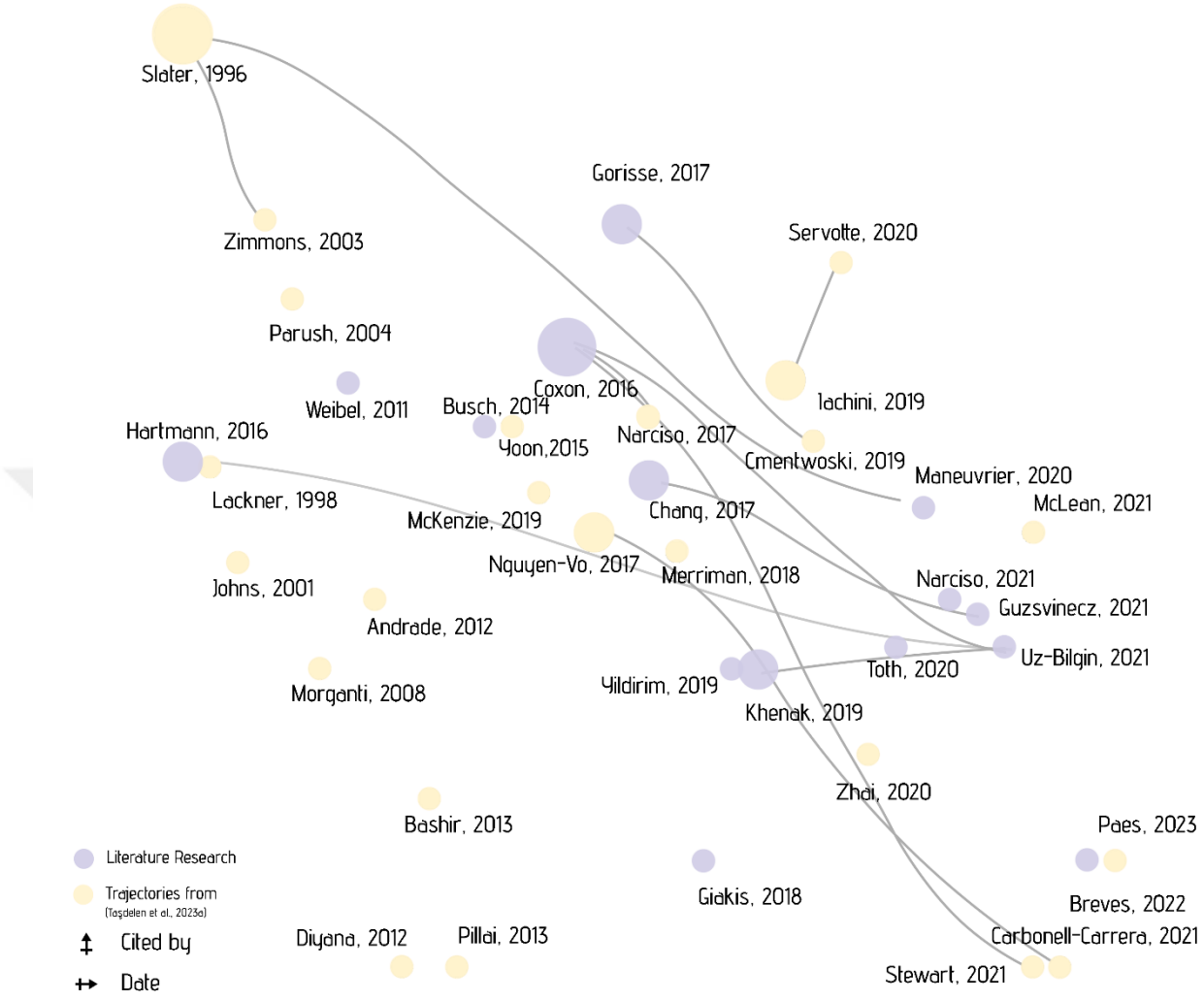


Figure 2.10: Literature mapping.

The above diagram, Figure 2.10, illustrates the combination of literature searches. The articles highlighted in yellow correspond to the articles obtained by examining abstracts in the databases about the subject matter. Conversely, the articles highlighted in purple were obtained using the methodology in section 2. In this context, the vertical axis represents the number of citations within all literature, and the horizontal axis shows the chronological progression of time. On the other hand, the radius represents citations calculated based on this map. Lines visually represent the interconnection between articles, described as two or more papers cited in the same papers. It can be

understood the papers which have a significant role in the literature and are most cited. It can even create a seed map to start a literature review. In future studies, a seed map can be useful to investigate the literature further.

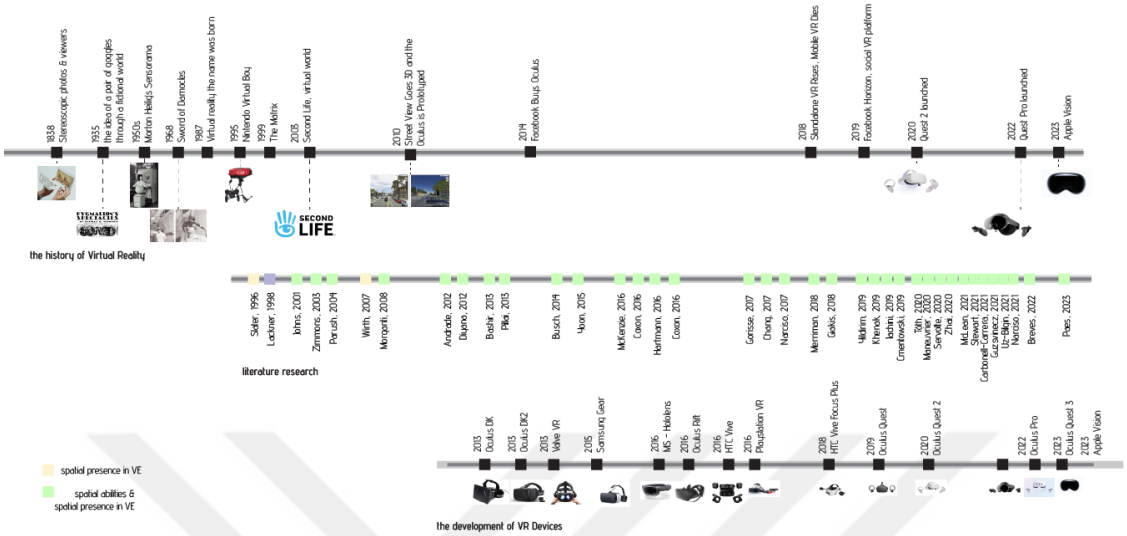


Figure 2.11: Literature mapping with VR developments and history of VR.

Through the integration of the seed map with our prior timelines, a noteworthy upswing in research activities within this specific field has been observed in Figure 2.11, more detailed in Appendix D. Moreover, there has been a simultaneous progression in the development of devices utilized since the 2010s. Before the advancements in these devices, a sequence of literary discussions predominantly examined ideas and principles. Slater(1996) discussed the factors that might affect the level of presence in iVE, Lackner (1998) did experiments to reveal the spatial orientation and presence relations. While Wirth et al. (2007) proposed visuospatial imagery is a precursor to the first stage of spatial presence with their paradigm, Morganti studied spatial cognition in virtual environments.

3. METHODOLOGY

Mental imagery, spatial perception, spatial visualization, navigation, and spatial orientation are the primary spatial skills that contribute significantly to in-game performance. There should be a correlation between game performance (playtime) and spatial aptitude scores. The quicker tasks correspond to spatial aptitude scores that are higher. Furthermore, the task performance should depend on these spatial skills. The experiment started with the experiment preparation, such as defining variables, group characteristics, and psychometric tests, see Figure 3.1. Then, the pilot experiment was conducted to determine whether the experiment's steps were proper. Feedback from the pilot participants was evaluated, and then the group was created. The participant group finished the pre-test before the experiment. When the experiment day came, they all had pre-test results and were ready to experience the VR environment and the game. The instructor's verbal instruction at the beginning of the experiment that "the objects with which you will interact will appear one by one" can be viewed as figural operations to keep the objects in mind and recognize which object emerges, the other interactions that require body and hand movement are environmental operations.

In computerized versions of psychological self-report questionnaires, the exams were administered in groups as depicted. Before commencing each examination, written instructions, examples, and oral instructions from the author were provided. The Mental Rotation Test (MRT), Perspective Taking-Spatial Orientation Test (PT-SOT), and Santa Barbara Sense of Direction (SBSOD) were administered by their standard procedures. Each student worked independently, and the exams were administered in the same order for all participants. Including the interval, the duration of the examination was one hour and 15 minutes.

The sample group was divided into two primary groups: Designers and non-designers. This study aims to determine whether being a designer or a participant affects spatial skills and the impact of these two characteristics on the game performance of individuals with comparable spatial abilities. Experiments were conducted controlled to answer research questions and reveal the abovementioned relationships. The age of 30 adults is between 20 to 35 who follow technological advancements. There were

differences in gaming behaviors and professional backgrounds; age and gender were selected similarly.

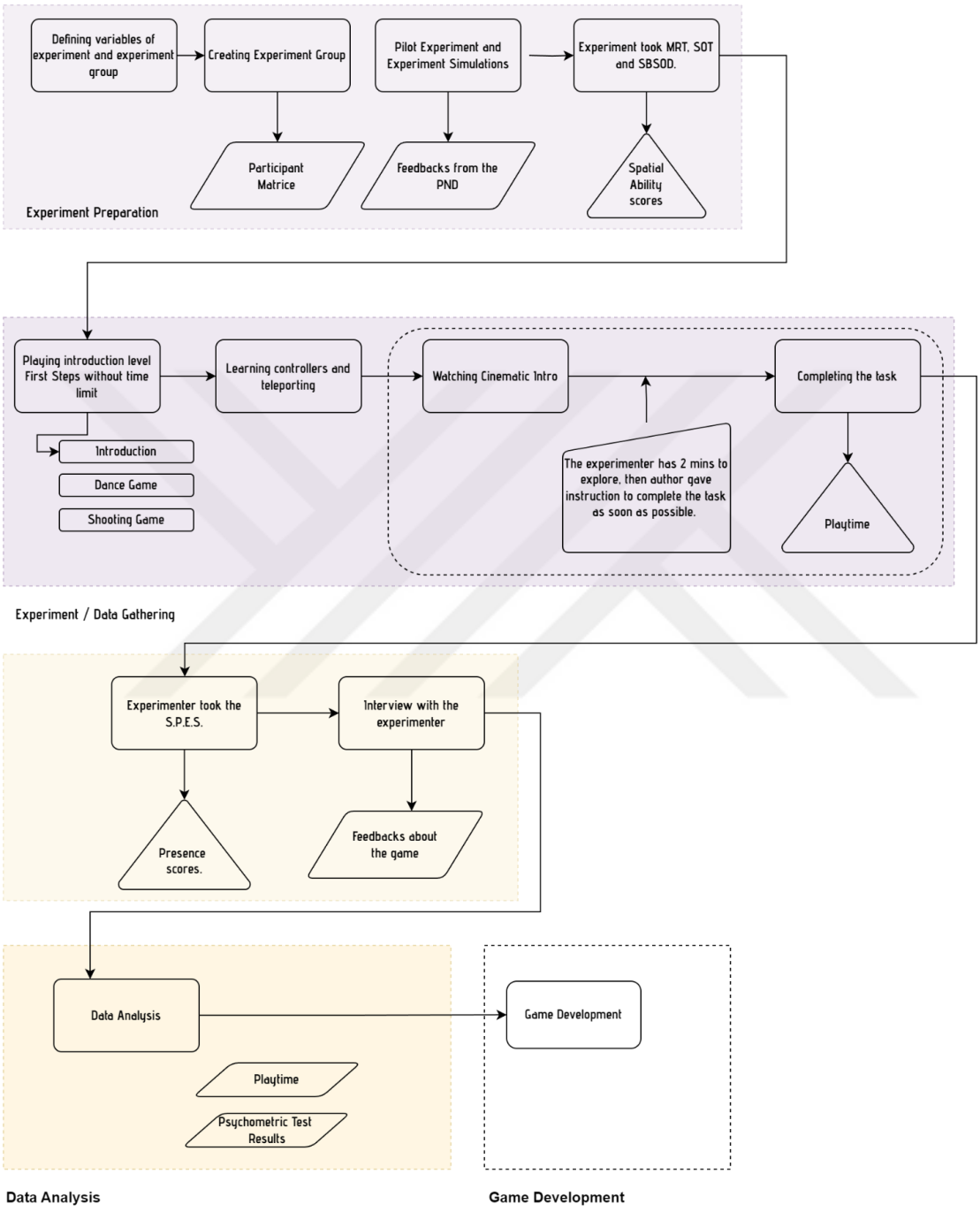


Figure 3.1: Flowchart of the research method.

3.1 Experiment Preparation

The VR game “Golden Gate” was created with Leman Figen Gül and Hakan Tong's invaluable input in “MBL 538 - Virtual Environments Studio” during the spring semester of 2022-2023 in ITU, with the enormous collaboration of Sena Ayca Metin and Fatih Erdil. The field area is visited to gather Yedikule-related information. Based on our visits and research, a storyboard for a VR game was developed as a group. According to legends about this place, famous for being an Ottoman-Byzantion fortress, the introduction level begins with the fortress and concludes with the Golden Gate.

The first version of the game was created using Unreal Engine 5.02. The Oculus VR Game kit will be used to create the VR experience. The team makes some of the 3D objects and models. Some were gathered from Quixel Bridge, a plugin for UE to add assets for the game.

The opening screen from the UE is in Figure 3.2. The most important part of the game development was optimization. However, there was a limitation to the polygon counts in the models. Because VR technologies of devices have not improved as expected, to enhance better visualization and freezing in the frames, we worked very carefully to get better results.

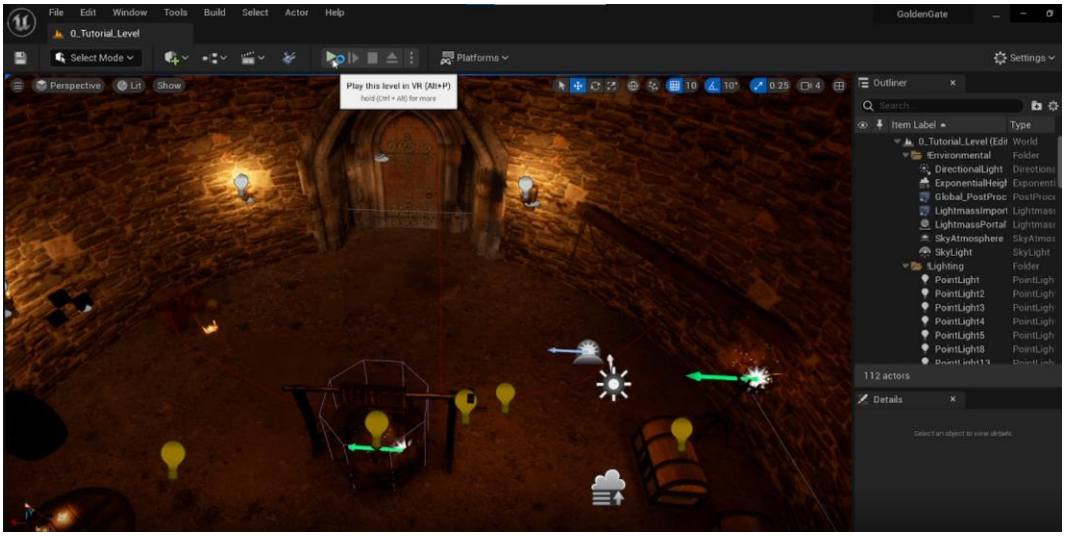


Figure 3.2: The opening screen of the Intro Level in Unreal Engine.

There will be portions of the game where players must perform more difficult spatial activities as they progress through the levels. Sound assets indicate the actual objects to interact and provide an immersive experience. The controllers work with Boolean encounters to provide interactions.

To start the experiments in determined places, the stages are clearly explained, and the purpose of the experiment is mentioned in the application form. The sample test screenshots from the game were handled in. The permission from the ITU Ethics Committee is in Appendix B.

Before participants took the pre-psychometric tests, they read informed consent documents and were permitted to publish their data unquestioningly.

3.1.1 Setting and apparatus

Hardware improvements for the Meta Quest 2 include a VR-specific Snapdragon XR2 processor and 6GB of RAM, which make for better graphics, smoother performance, and faster movement (URL 13). The Quest 2 was manufactured with the same refresh rate of 72 Hz as its predecessor. In the two years since its release, however, multiple firmware updates have increased the Quest 2's refresh rate to 120 Hz for some games and applications and 90 Hz for most others (Meta Quest 2: The King of VR, 2022).

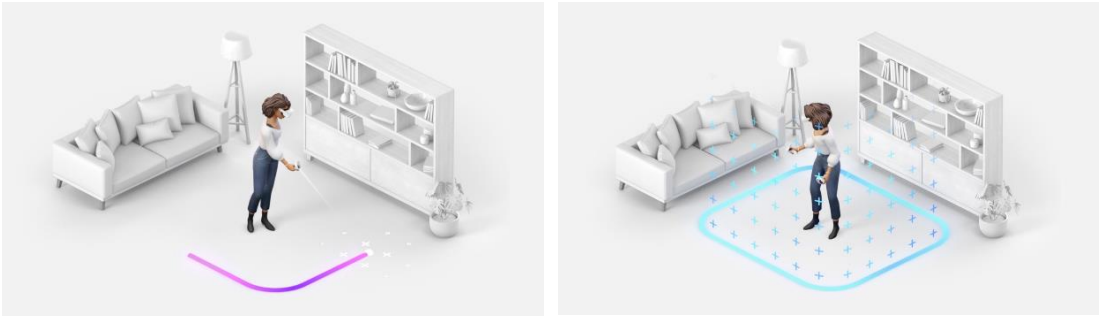


Figure 3.3: Setting Guardian in the Quest 2 (URL 13).

Before starting the experiment:

- The author, as an experimenter, prepares the environment to provide a safe area. The game area is 2x2 m, which is indicated with tape. It is enough to cover all possible movements. The introduction illustrates how to scan the area and set the

guardian system. The guardian system refers to the playable safe areas shown in blue in the correct Figure 3.3.

- The experimenter prepares the headsets for the participants. The lens width is controlled, and the tightness is adjusted not to cause a headache. The HMD is plugged into the computer so the experimenter watches the gameplay and warns the participant.
- After headset setup, the participant meets the controllers. The participant is blinded so that they realize the controller is coming through them, and the experimenter gives them the controller, see Figure 3.4.
- From now on, the participant can only receive verbal instructions. Participants are directed to open “First Steps for Oculus Quest 2”.
- After completing these steps, they all view a cinematic introduction video to learn where they are and what is expected of them. The participant has two minutes to gaze at the objects and retain them in mind for subsequent stimuli.
- Then, the experimenter reminds the stopwatch and begins timing each participant's interactions, recording their durations.

Figure 3.4: Guardian System towards the player with invisible corners.

3.1.2 Participants

Experiments were conducted in an isolated environment to answer research questions and reveal the relationships. Thirty adults between 20 and 35 familiar with technological developments participated in the experiments; their mean age was 27.54. Differences in gaming habits and professional backgrounds were observed, and participants' backgrounds were gathered in Table 3.1.

We created a participant matrix according to their gaming habits and professional backgrounds (Table 3.1). Player (P), Designer (D), Non-Player (NP), and Non-Designer (N) are the four groups used to examine the associations between gaming habits and professional background.

On the other hand, to qualify as a player, the participant must have played a mobile, PC, or console game for more than 10 hours per week or have at least five years of gaming experience, which includes 10 hours of experience per week in the last ten years.

Player / Non-player	Player																													
	Non-player																													
Genre	PC/Console																													
	Mobile																													
Domain	Designer									U	A	IA	CE	A	IA	A							A	CE	ID	A	A	A		
	STEM																													
	Health																													
	Social Sciences																													
Gender		M	M	M	M	M	W	W	W	M	W	W	W	M	M	M	M	W	W	W	W	W	M	M	M	M	M	M	W	W	W
Age		27	26	26	28	31	35	30	26	29	26	26	26	24	24	27	26	26	24	24	28	26	26	25	26	35	30	27	26	35	27
P. Code		PN-1	PN-2	PN-3	PN-4	PN-5	PN-6	PN-7	PN-8	PN-9	PD-1	PD-2	PD-3	PD-4	PD-5	PD-6	PD-7	NPN-1	NPN-2	NPN-3	NPN-4	NPN-5	NPN-6	NPN-7	NPN-8	NPD-1	NPD-2	NPD-3	NPD-1	NPD-2	NPD-3

A=architect
IA=Interior Architect
CE=civil engineer
ID= Industrial Designer
U=Urban planner

Table 3.1: The matrix of the participants.

3.1.2.1 Sub-groups: Designers

In the past, researchers collaborated with designers to explore spatial ability and presence in VR environments. This involved various methods, such as verbal protocols with architecture students, lecturers, and clients, to evaluate spatial mental imagery (Adharamadinka & Junaidy, 2022). Other experiments were conducted to measure designers' perceived level of risk and empathy when viewing designs in different situations (Zhang et al., 2022). Some studies focused on improving spatial skills through sketching architectural spaces in virtual environments (Gomez-Tone et al., 2021), while others aimed to understand spatial perception in both students and architects (Dokonal et al., 2016).

Research also looked into immersion and presence in geospace learning for designers, using presence scales (Carrera et al., 2021). Real-time 3D mesh rendering was utilized to increase presence among designers (Lesniak et al., 2016; Lesniak et al., 2017), and the relation between presence scale and design performance was explored (Faas et al., 2014). The relationship between spatial performance, spatial abilities, and presence in VR has yet to be studied among designers and non-designers.

3.1.3 Constraints

In contrast to trials conducted in physical environments, VR significantly influences its ability to portray a uniform and consistent experience. The player finds himself in the specified 2x2m area allocated for recreational activities. Once the designated play area has been established, a thorough scan of the location is conducted to ensure the absence of any items inside the area. This restriction is in place due to the inability of participants to see outside, as collisions with objects can be hazardous.

In addition, participants may experience migraines, vertigo, and nausea. When the lenses are worn too securely, migraines may result. One participant could not complete the exercise and reported feeling frightened and disoriented. This demonstrates that this environment is only suitable for some. Moreover, this individual is a designer believed to have a solid three-dimensional perception.

The restrictions imposed by the gadget were twofold: firstly, it experienced battery depletion throughout repeated trials, resulting in an extended procedure duration.

Another scenario included freezes, resulting in repeated noises consecutively, disrupting the participant. During this occurrence, temporal progression was halted, and the apparatus was expeditiously rebooted by pushing the power button to deactivate and reactivate it.

3.2 Pilot Experiment

In the pilot experiment, PN (player, non-designer) took the tests and then played the Golden Gate introduction level. The feedback coming from the PN-2 was:

- "*The participant needs a welcome or how-to-play this kind of introduction. Because I have never tried VR, playing without information about the controllers was hard*."
- *"A large number of items in the other game distracted me, and instead of concentrating on the time and seeking clues, I tried to try the pen to interact and opened the TV. This has an impact on my gaming time. I couldn't concentrate on the aim."*

Simultaneously, the participant proposed that the online administration of experiments, as opposed to traditional paper and pencil methods, would provide more efficacy in assessment and test transportation before the experiment's commencement. To facilitate the administration of the online exam, Google Forms was used to develop the test using authentic samples. Subsequently, all participant data was collected and organized in an Excel spreadsheet.

Feedback from the author:

"The long-lasting, complex alternate game contained several mechanics. The Golden Gate game was picked due to its many diversions and potential for additional elements."

3.3 Pre-experiment

Before commencing the inquiry, conducting psychometric evaluations on the subjects is imperative to substantiate the suppositions. These assessments are intended to validate our preliminary conjecture. The assessments conducted on the participants and their corresponding proficiencies are showcased in Figure 3.5. Although object recognition was not appraised in this study, it could be incorporated into future investigations.

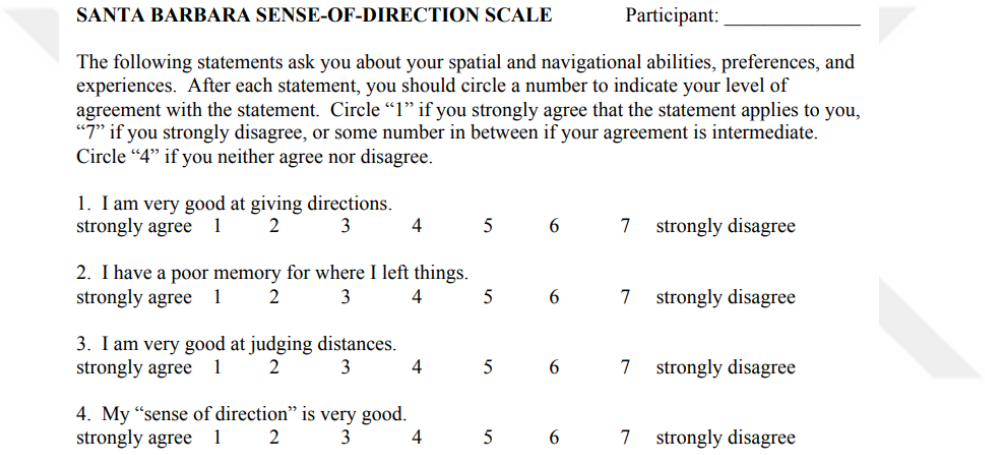
Figure 3.5: Psychological tests and targeted spatial abilities.

3.3.1 Pre-psychometric tests

Examining the relationship between individual differences in environmental spatial cognition and psychometric tests of spatial ability is one method for examining these differences. Activities like mental rotation of shapes, maze solving, and hidden figure detection are commonplace in these psychometric tests (Carrol, 1993; Hegarty et al., 2002). Card Rotation, Cube Comparison, and Paper Folding would load on the object manipulation spatial factor. In contrast, Object Perspective and Map Perspective would load on the spatial orientation factor, according to Kozhevnikov and Hegarty (2005). Also assumed to contribute to the SBSOD was the spatial orientation factor.

For the figural scale, the MRT was chosen, whereas the PT-SOT and SBSOD tests were utilized for the larger or environmental scales.

Participants will be given the Mental Rotation Test (MRT) (Peters et al., 1995), Perspective Taking/Spatial Orientation Test (Friedman et al., 2019), and Santa Barbara Sense of Direction Test (SBSOD) (Hegarty et al., 2002). The tests were scanned and put in a link (URL 14) to simplify and clarify. For participants to fill out a questionnaire before the experiment. For the experiment participants with insufficient English proficiency, SBSOD questions were translated into Turkish and processed through Google Forms with the original statements.



SANTA BARBARA SENSE-OF-DIRECTION SCALE Participant: _____

The following statements ask you about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.
strongly agree 1 2 3 4 5 6 7 strongly disagree

2. I have a poor memory for where I left things.
strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.
strongly agree 1 2 3 4 5 6 7 strongly disagree

4. My "sense of direction" is very good.
strongly agree 1 2 3 4 5 6 7 strongly disagree

Figure 3.6: SBSOD original sample questions (Hegarty et al., 2002).

3.3.1.1 Santa Barbara Sense of Direction (SBSOD) Test

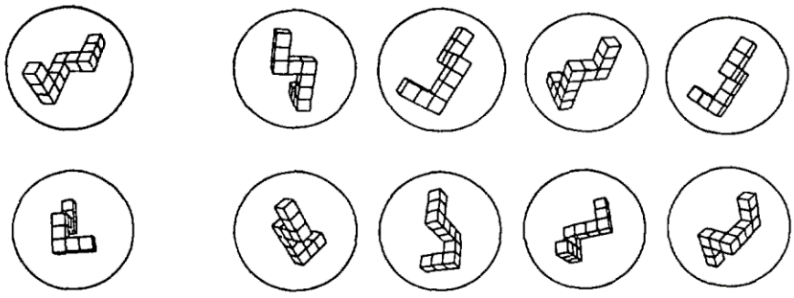
Using self-report measures to predict environmental spatial ability has shown more significant promise in cognitional studies to reveal navigational abilities. Kozlowski and Bryant were the first to develop this metric in 1977. The authors merely used a seven- or nine-point scale to assess the "sense of direction" (SOD) of their subjects. The question was simple: ‘‘How good is your sense of direction (SOD)?”

Self-reported measures are uncorrelated with performance because people overestimate their abilities (Hegarty, 2002). This holds even when asked about their logical, grammatical, or comedic prowess. However, the correlations found in Hegarty's (2002) research suggest that people are generally truthful and accurate when estimating their environmental spatial abilities. Our experiment, which had a relatively small number of outliers, supports the first claim. While overconfident participants were awarded higher scores for their sense of direction responses, a few underconfident participants were awarded lower scores. There are 15 questions on the scale; a few examples are stated in Figure 3.6. All questions can be seen in the App. A.1.

3.3.1.2 Mental Rotation Test (MRT)

The Mental Rotation Test (MRT) was created in 1978 by Vandenberg and Kuse based on the research of Shepherd and Metzler (1971). It consists of a participant comparing two 3D objects (or letters) rotated along some axis and stating whether they are the same image or mirrored. Behavioral studies investigate participants' interventions and characteristics to reveal this ability's process. The properties of characteristics are mostly gender, IQ, educational background, and profession. For instance, males perform better than females on the revised MRT, and students from the physical sciences perform better than those from the social sciences and humanities on the original MRT (Peters et al., 1995).

Figure 3.7: The sample questions from the original MRT (Vanderberg & Kruse,



The Mental Rotations Test has 20 questions; see in App. A.2, split into five groups of

four. Each question has a "criterion" figure, two correct answers, and two wrong answers called "distractors." Correct options are always the same structure as the criterion but are shown in a different order (Vanderberg & Kruse, 1978). For instance, in Figure 3.7, the left figure is this “criterion” figure; the participant should choose the correct two figures for this object: the first and fourth.

3.3.1.3 Perspective Taking- Spatial Orientation Test (PT-SOT)

A substantial body of evidence from experimental studies of spatial thinking (Huttenlocher & Presson, 1973) supports the distinction between the processes of perspective-taking and mental rotation. According to the authors, this spatial ability test measures spatial orientation ability linked to measuring environmental scale operations in VR. In the experiment, a computerized version of the test was administered. The Java-based application is set up, and the participants took it before the experiment. Their angular errors are gathered in the Excel table for comparison.

While the participant decides the direction and the angle, they rely on their ability to put themselves in the location of the “standing” object and estimate the “target” object. There is an example question in Figure 3.8; the whole question can be seen in the App. A.3.

3.4 Experiment

The game is used to quantify the task sequence and duration to disclose the game's dynamic relationships. Figure 1.1 depicts the experiment's six phases. They initially completed pre-psychological exams. In the orange section of the schematic, they all played "First Steps for Oculus Quest 2" in Figure 3.9. They learned the fundamentals of the controller and VR environment, including guardian systems and teleport.

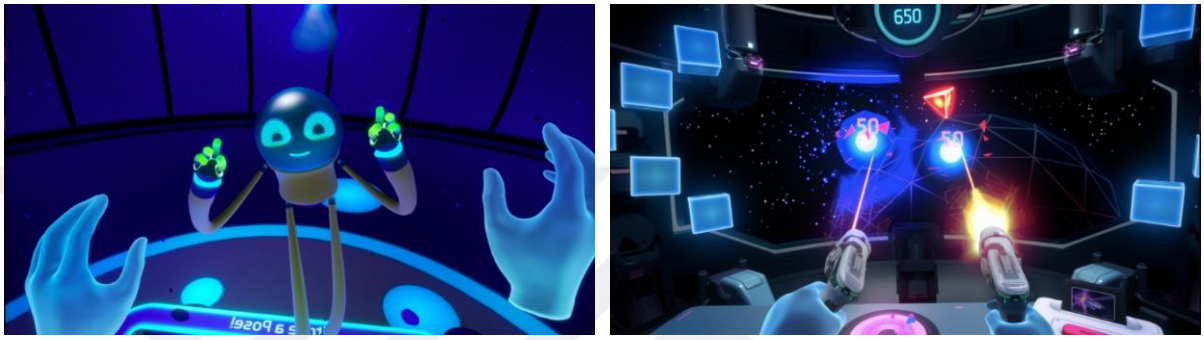


Figure 3.9: (left) The dancing part of First Steps for Oculus Quest 2; **(right)** The shooting part of First Steps for Oculus Quest 2.

Our primary objective is to assess the game's mechanics within the context of spatial abilities, enhance them, and establish the relationship between spatial ability and spatial presence. Previous research has only demonstrated a positive correlation with mental imagery, not other spatial abilities: Mental rotation, spatial taking ability, and spatial visualization were investigated in this thesis.

The VR Spatial Presence experience will be built with Unreal Engine 5 and integrated with the Oculus VR Game kit. The game will contain elements that encourage players to complete increasingly tricky spatial exercises as they progress through the stages. Controller vibrations provide feedback for boolean interactions, while sound effects indicate the correct action. The teleportation can be done with a suitable controller see Figure 3.10.

Golden Gate illuminated the Ottoman Empire's significant era and geographical area. The game has clues that align with the ancient legends. According to reports, there

were instances where snakes and centipedes emerged from the well located in the playground, symbolizing the representation of a well associated with the fortress known as "Kanlı Kuyu." The first indication is rotating the revolving wheel of the well to retrieve the snake residing within. Subsequently, it has been ascertained that the treasure tower, one of the towers within the Yedikule complex, served as a repository for valuable metals, currency, and adornments. The final interaction involves the emergence of gold nuggets from the wall. It is suggested that a modification be made to incorporate jewelry sourced from the chests within the game to align with the narrative. Yedikule, a location rich in narratives, can be effectively aligned with a criterion such as prior knowledge, rendering it appropriate for investigating spatial presence among those with a keen interest in history.

Figure 3.10: The opening scene from the game and teleportation for the movement.

3.4.1 Construction of a mental model

A flowchart will be created when determining whether Wirth's mental model is valid, as in Figure 3.11. According to Wirth, the participant should first determine if he is in space and, if so, what type of space he is in. This spatial response results in the Spatial Situation Model. This first level leads to the second level, where it is determined whether or not this location is a dungeon. This is a crucial question because if the player answers "no," he does not believe he is in the game environment, and we cannot mention the spatial presence. If the participant is persuaded that he is in the dungeon, they will experience "spatial presence," or the sensation of "being there." Then, we can determine his presence within the game environment.

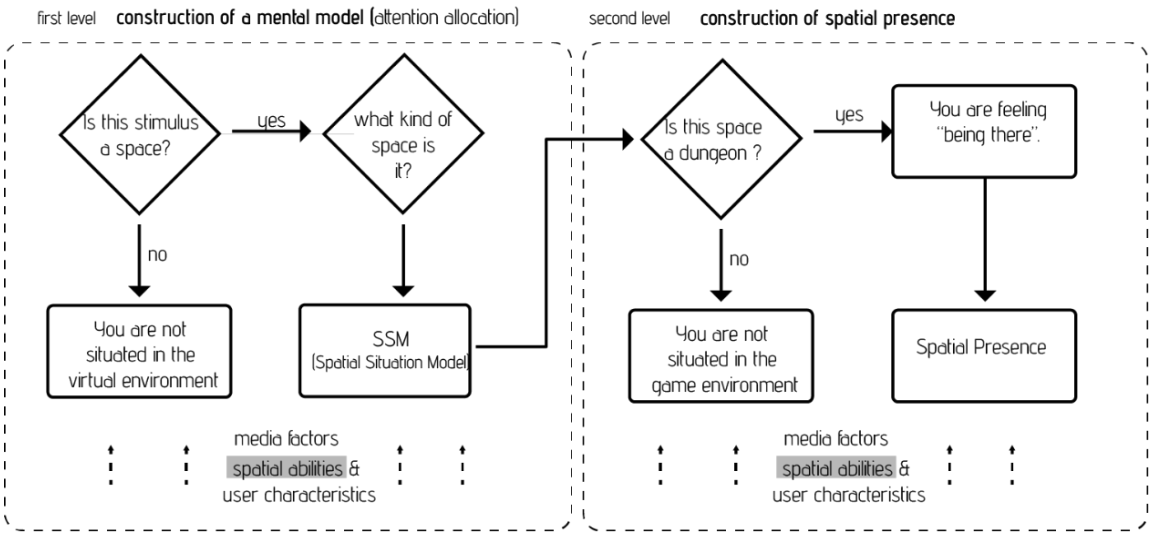


Figure 3.11: The construction of a mental model followed the rules from Wirth et al. (2007) (Taşdelen et al., 2023b).

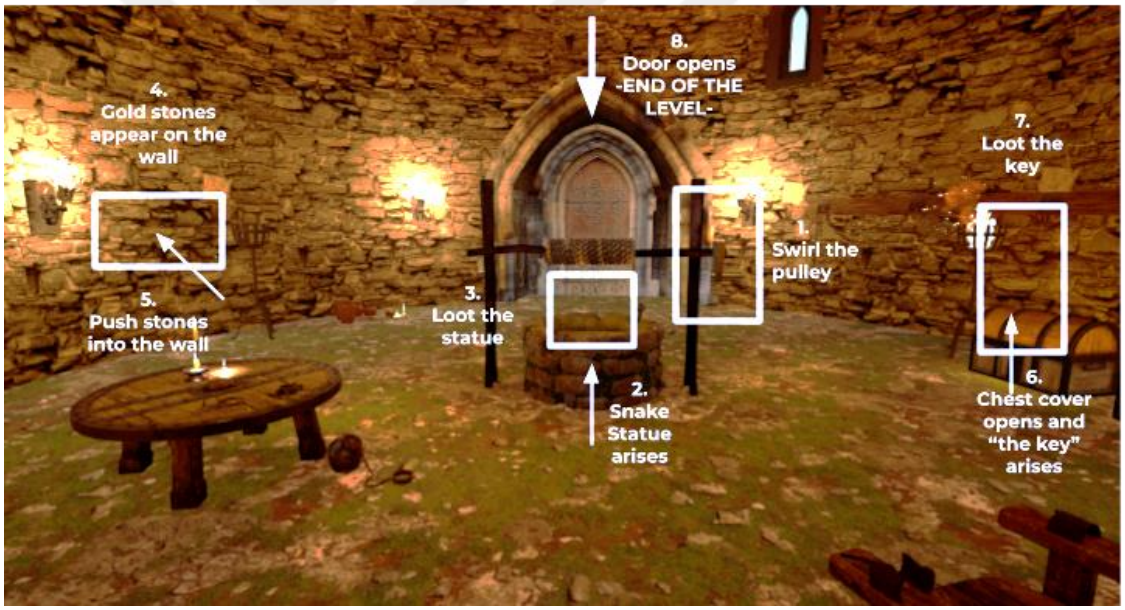


Figure 3.12: The opening scene from the game.

3.4.2 Interactions of the Golden Gate VR game

In the introduction level of the Golden Gate, there are four tasks and eight interactions to complete to finish the introduction level (see Figure 3.12 and Figure 3.13). The player gets the instructions about the tasks first: “The tasks must be completed in

sequence. Without the first, the second cannot occur. A particular sound will cease when a player interacts with the proper object."

1. The participant should first swirl the pulley. Then, a snake will appear through the pit.
2. The participant touches the snake, hears the voice, and realizes the boxes are coming from the wall.
3. The participant sees the black boxes on the wall and hears the opening sound from the treasure hunt.
4. The participant sees the key, touches it, and hears the gate sound.

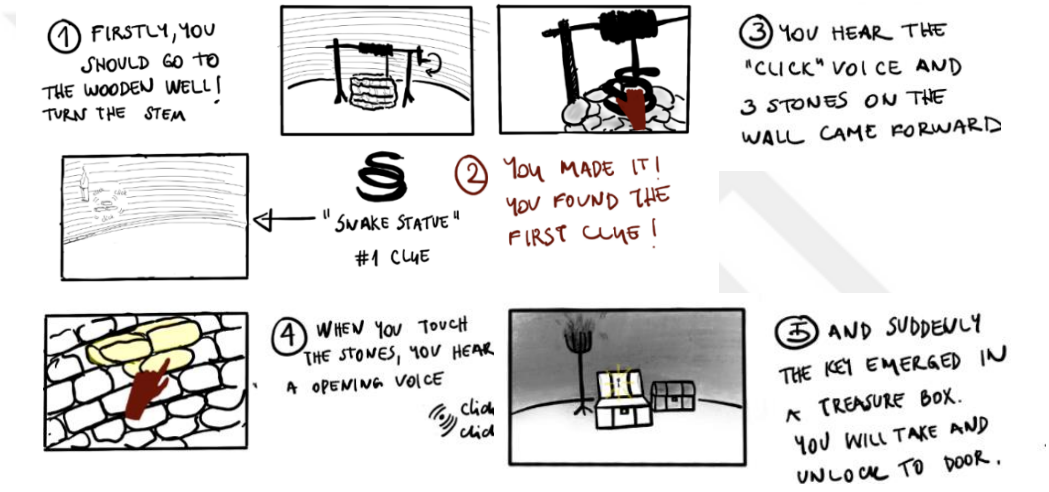


Figure 3.13: The storyboard of the introduction level.

3.5 Post Experiment:

The Spatial Presence Experience Scale measured users' sense of spatial presence. This was defined as a two-dimensional concept encompassing a change in the user's self-location and perceived action possibilities (Hartmann et al., 2016). In the first part, the questions aim to measure self-location. The following ten questions then reveal possible action situations—the initial experiments aimed to test a particular group and determine its effect on the results. Figure 14 can be used to explore self-report questions; the whole test can be seen in Appendix C.

Sub		Item
SL	1	I felt like I was actually there in the environment of the presentation.
SL	2	It seemed as though I actually took part in the action of the presentation.
SL	3	It was as though my true location had shifted into the environment in the presentation.
SL	4	I felt as though I was physically present in the environment of the presentation.
SL	5	I experienced the environment in the presentation as though I had stepped into a different place.
SL	6	I was convinced that things were actually happening around me.
SL	7	I had the feeling that I was in the middle of the action rather than merely observing.
SL	8	I felt like the objects in the presentation surrounded me.
SL	9	I experienced both the confined and open spaces in the presentation as though I was really there.
SL	10	I was convinced that the objects in the presentation were located on the various sides of my body.
PA	1	The objects in the presentation gave me the feeling that I could do things with them.
PA	2	I had the impression that I could be active in the environment of the presentation.
PA	3	I had the impression that I could act in the environment of the presentation.
PA	4	I had the impression that I could reach for the objects in the presentation.
PA	5	I felt like I could move around among the objects in the presentation.
PA	6	I felt like I could jump into the action.
PA	7	The objects in the presentation gave me the feeling that I could actually touch them.
PA	8	It seemed to me that I could do whatever I wanted in the environment of the presentation.
PA	9	It seemed to me that I could have some effect on things in the presentation, as I do in real life.
PA	10	I felt that I could move freely in the environment of the presentation.

Figure 3.14: SPES Questionnaire (Hartmann et al., 2016).

Figure 3.15: Some participants from the experiment while playing the game.

3.6 Results

The trials concluded by engaging in gaming and completing the SPES test. A series of experiments were done using a sample size of 30 individuals, sample participants in Figure 3.15. Before the experiments, participants completed psychometric exams, engaged in gaming activities, and provided comments. All the test results are gathered

in an Excel sheet, and the mean and standard deviation are calculated. The Excel sheet is then uploaded to Rapidminer to find correlations.

Upon examining all the results, it has been shown that being a player impacts game time (r_P= -0.54). It has been observed that being a designer has little impact on the SOT and SBSOD tests (r_{SOT}=-0.35, r_{SBSOD}=0.33). It is important to remember that to establish a significant correlation, the effect size (r) value should exceed 0.5. Table 3.2, shown below, elucidates the relationship between game duration and spatial competence and the role of being a designer player.

			r value						
	M	SD	1	2	3	4	5	6	7
1. Age	27.10	.085							
2. Being a player	-	-	-						
3. Being a designer	-	-	-	-					
4. Playtime	5.55	0,08	-0,079	-0,54	-0,09				
5. MRT	5,5	3,15	-0,18	-0,02	0,11	-0,21			
6. SOT	55,21	43,34	0,05	0.14	-0,35	0,14	-0,40		
7. SBSOD	4,65	0,95	0.04	0,22	0,33	-0,21	0,13	0,12	

Table 3.2: Correlation matrix with mean and standard deviation of spatial ability tests.

MRT and SBSOD scores were found to have a very weak correlation with performance, whereas SOT did not (r_{MRT}=-0,21; r_{SBSOD}=-0,21 and r_{SOT}=0,14).

Analyzed outcomes revealed that the self-location presence score was higher (4,07) than the possible action score (3,86). In other words, although the players could swap locations within the game, they needed more confidence to move freely in a virtual environment. According to Wirth et al.'s (2007) SSM model, development continued in the first phase but reached a standstill in the second.

According to the results, players with a lower presence score complete the game more quickly. This could be because the player still needs to mentally transition to the virtual world and is still attempting to complete the game as quickly as possible.

Table 3.3: Correlation matrix with mean and standard deviation of SPES.

				r value					
		M	SD	1	2	3	4	5	6
1.	Age	27.40	085	.	.	.	.	.	
2.	Being a player	-	-	-					
3.	Being a designer	-	-	-	-				
4.	Playtime	5.55	0,08	-0,079	-0,47	-0,09			
5.	SPES-SL	4,03	0,59	0,15	-0,24	0,12	0,28		
6.	SPES-SA	3,78	0,77	0,07	-0,14	0,35	0,06	0,77	

As shown in Table 3.2, participants who were not also designers possessed the highest levels of spatial awareness and navigational skills. The top non-player designers had high mental rotation and presence scores in the same table. Non-player designers were distributed most equitably across the four categories.

As demonstrated in Table 3.3, individuals with more remarkable spatial ability do not always have a time advantage when completing tasks. A correlation exists between spatial orientation task performance and presence, but a larger sample size is required to test the second hypothesis.

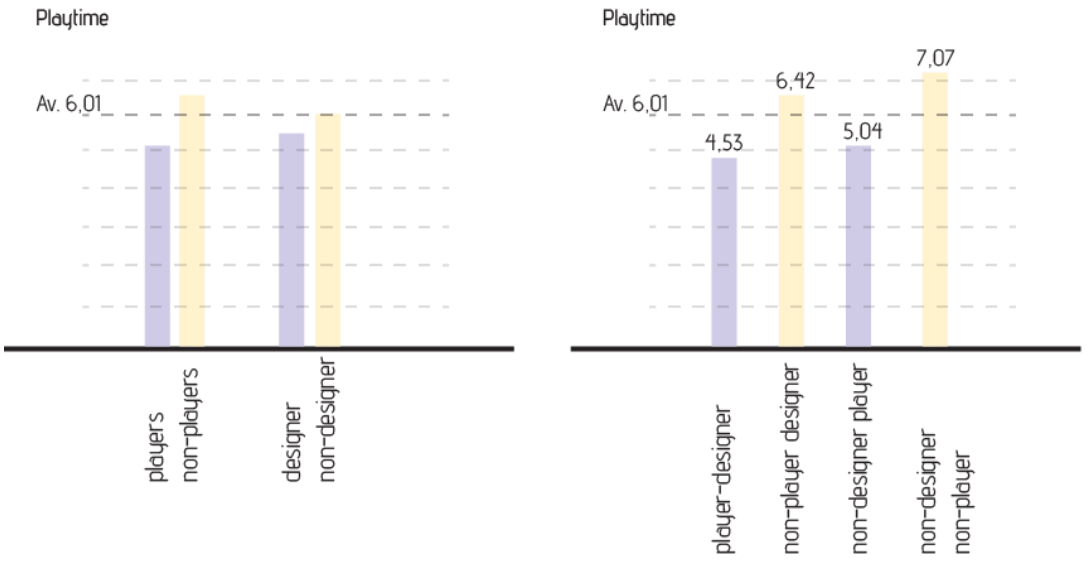


Figure 3.16: (left) Comparison of average playtime due to being a player and designer; (right) comparison within sub-groups.

Upon analyzing the game's play-time, it was seen that both the player and designer groups exhibited superior performance within their respective areas; see Figure 3.16 (left). The non-player group has attained an average duration above the statistical average. The correlation table, Table 3.2, only provides significant findings worth highlighting on being a player, r_P=-0.54. The correlation value shown in the figure in our experiment exhibits the highest level of strength.

Upon analyzing the outcomes of the MRT results in Figure 3.17, it becomes evident that the designers have achieved the most optimal outcome. Two key aspects affect the MRT- occupation as a designer and frequent engagement in gaming activities. However, further investigating the group matrix, it becomes apparent that the designers who are not players are responsible for attaining the superior outcome. Table 3.2 did not provide any significant findings worth highlighting.

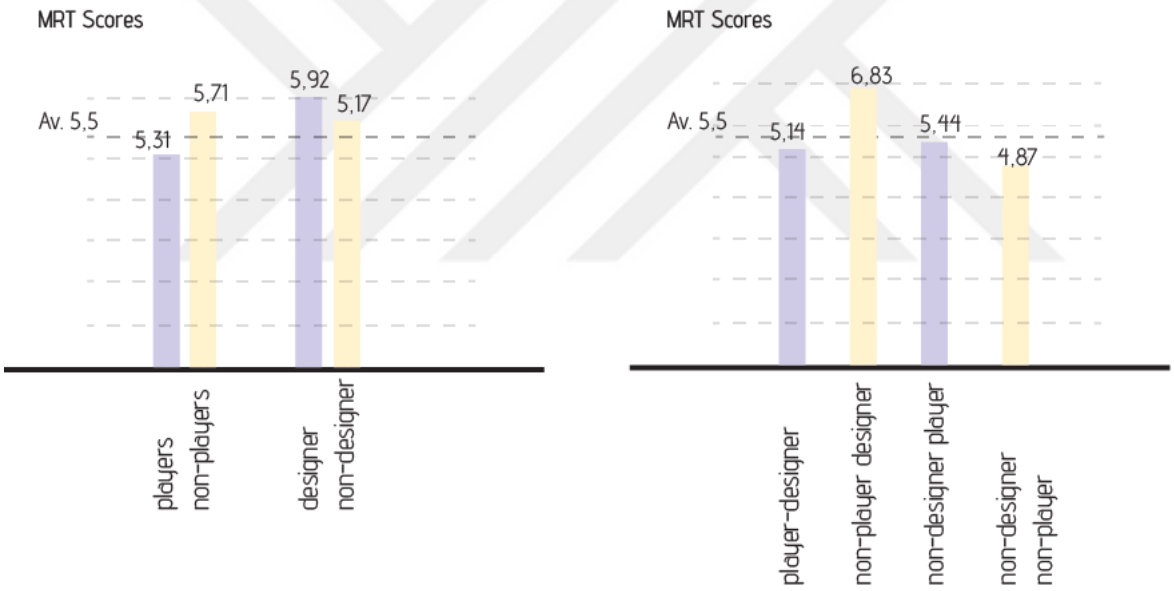


Figure 3.17: (left) Comparison of MRT scores due to being a player and designer; (right) comparison within sub-groups.

Upon analysis of the SOT scores, it becomes evident that the designer team attained the most notable outcomes, see Figure 3.18 (left). Furthermore, this distinction is readily apparent among non-designer groups of participants. While being a designer plays a crucial role, being a player does not affect the SOT results. In this assessment

that assesses angular inaccuracy and its rotations, achieving a low score is important. It may be said that the design team has a significant level of proficiency in spatial orientation and perspective-taking. In further investigation in Table 3.1, being a designer and MRT results have a weak correlation between SOT results, respectively r_D=-0.35 and r_{MRT}=-0.40. Given the objective of obtaining a favorable outcome in this examination, it is essential to note that negative numbers are the desired outcomes. The test revealed a notable disparity between the groups; see Figure 3.18 (right).

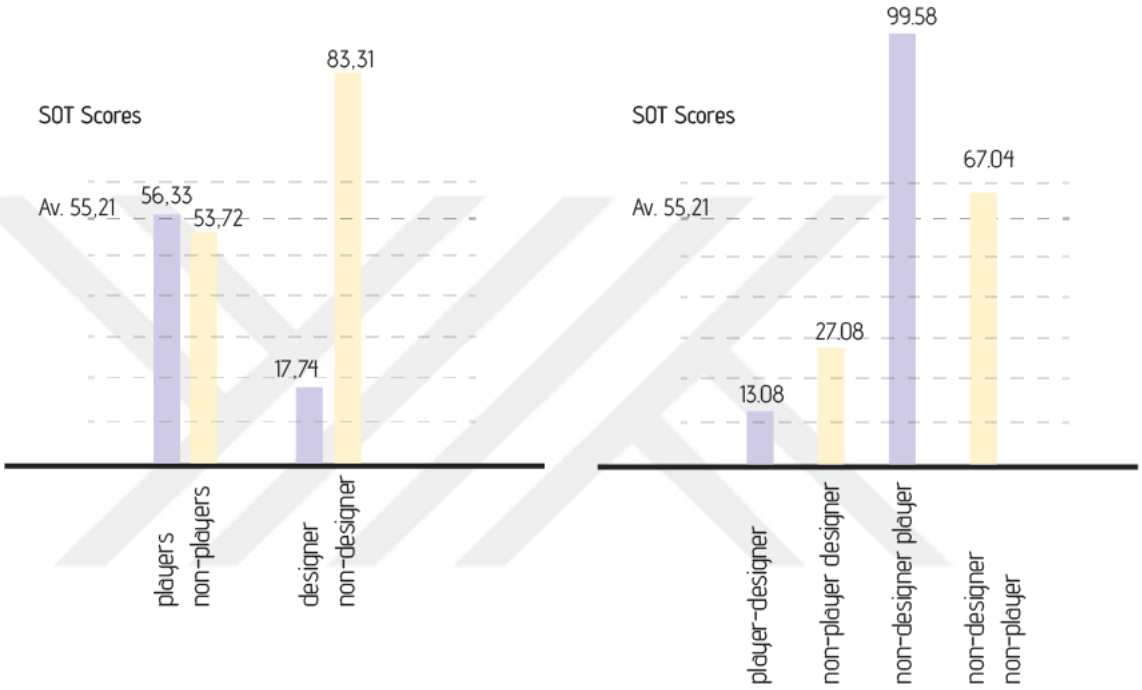


Figure 3.18: (left) Comparison of SOT scores due to being a player and designer; (right) comparison between sub-groups.

Upon analyzing the results of the SBSOD study, it becomes evident that engaging in gaming activities does not yield any discernible impact, see Figure 3.19 (left). On the other hand, being a designer holds much influence. The most favorable outcome is achieved by individuals who are not actively participating in the game but rather involved in its design. Upon examining the correlation table in Table 3.2, it becomes evident that only being a designer has a weak correlation on SBSOD results, namely r_D=0.33.

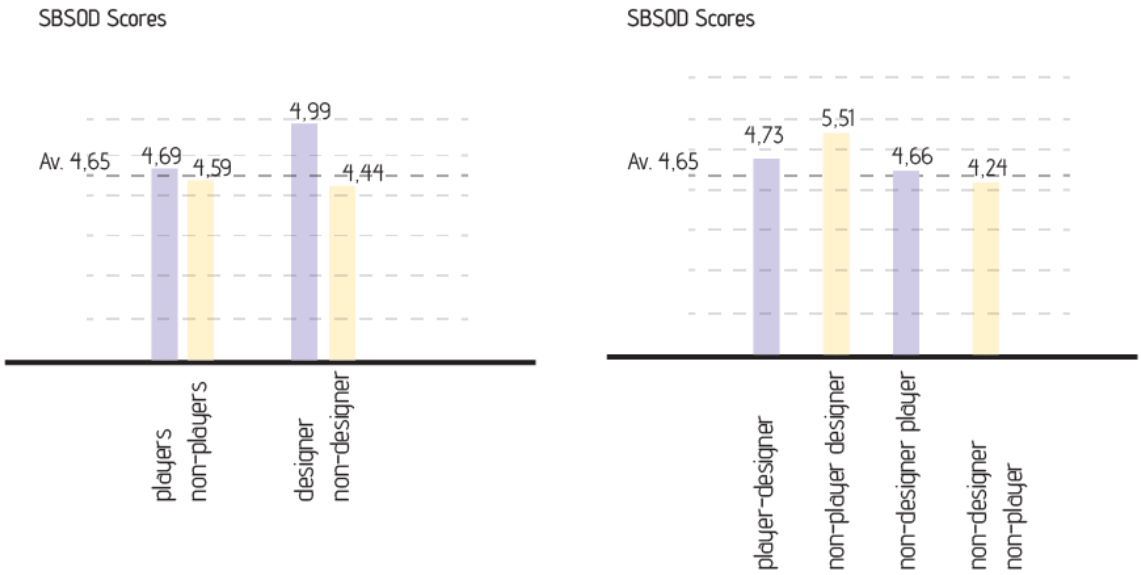


Figure 3.19: Comparison of SBSOD scores due to the group matrix; (left) comparison between groups; (right) comparison between sub-groups.

No significant correlation was found between engaging in gaming activities or pursuing a career as a designer and the outcomes of SPES-Self Location (SL). After examining the optimal outcomes, no discernible superiority was observed among any particular group. Table 3.2 shows a weak correlation between SL and playtime and being a player, namely r_{PT}=-0,24 and r_{P}=0.28, in Figure 3.20.

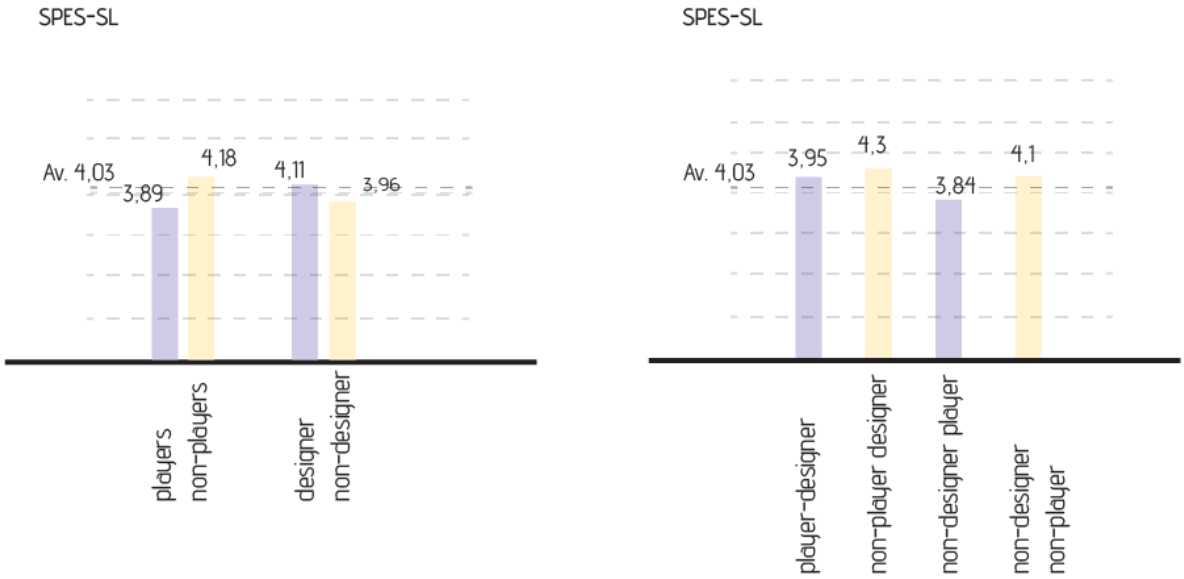


Figure 3.20: Comparison of SPES-Self Location scores due to the group matrix; (left) comparison between groups; (right) comparison between sub-groups.

In the comparative analysis in Figure 3.21 (left), the designers achieved the greatest outcomes initially, followed by the non-gaming group, among the major cohorts. Upon closer examination, it can be determined that the most superior team consisted of non-gaming designers and had two specific traits, as detailed in Figure 3.21 (right). To put it differently, empirical evidence suggests that engaging in game playing does not have a discernible impact on one's state of present. The outcomes may vary for those with a penchant for puzzle-solving games or a keen interest in historical sites. Based on the data shown in Table 3.2, it can be seen that there exists a limited impact associated with the occupation of being a designer in the outcomes of Possible Actions in SPES.

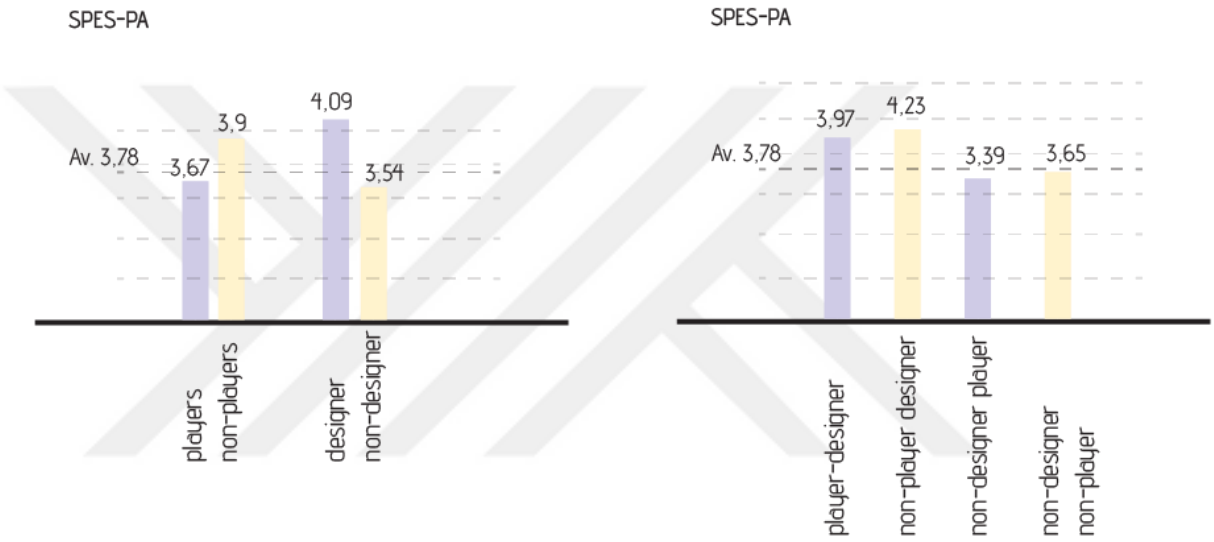


Figure 3.21: Comparison of SPES-Possible Actions scores due to the group matrix; (left) comparison between groups; (right) comparison between sub-groups.

In summary, the presence scales can be affected by being a designer mostly, then being a player and playtime. In addition to that, being a designer has a significant impact on SOT results. Additionally, MRT outcomes have a weak correlation with SOT results. It means people with a better mental visualizer or a great mental model have a better perspective-taking ability or spatial orientation. With this connection, people with a higher spatial orientation should have a better presence result. When the binary correlation is investigated, the impact of SOT on SPES – PA, there is a weak correlation, namely r_{Bin}= -0,34.

3.7 Discussion

Even though the participants could relocate their sense of location within the game, many still needed to be convinced that they could truly engage in meaningful actions within the virtual world. The average ratings for possible actions and self-location should represent the VR game's performance. As a result of the expectation that the game mechanics will be enhanced later to provide higher scores for potential actions, the connection between game interactions needs to be adequately established. The impact of presence-interaction will be contrasted to scores not generated using the established game mechanics.

There are plans to build VR games that improve interaction quality, delivering more genuine and captivating experiences. The spatial cognition paradigm will be used in future research endeavors to evaluate the cognitive requirements associated with these interactions.

The connection between spatial ability and presence has considerable implications for research into game design and other virtual environment applications. Multiple architectural production techniques contribute to the expansion of the gaming industry. Exposing the disciplines and methods of relationship research is essential for identifying knowledge deficits and possible future research areas. This study could influence future research at the intersection of architecture, VR/AR, gaming, and spatial cognition. The study suggests that design expertise has a greater impact than playing experience or time spent playing games on the presence scales. It might depend on the designer’s 3D perception. In some cases, such as SOT results, the designer’s outcome is dramatically higher than the non-designer. As mentioned above, SOT impacts presence; it must be considered and further investigated.

Providing natural interactions is significant in mechanics. Participant-object interaction should resemble the natural environment, as shown in Figure 3.22.

The objective is to establish a connection between our experiment and the findings of previous studies that positioned spatial presence and spatial abilities in VR in the 2.7 Section. Uz-Bilgin and Thomson (2021) developed a cell game for high school adolescents to help students learn cell biology. Students learned about the game, wore

headgear and hand controls, and experienced VR environments. Students played the game independently for 25 minutes in class. Players received technical support with the HMD and hand controllers but no content or game direction from researchers. This study investigates spatial presence in a VR learning environment by examining the influence of prior content knowledge, VR experience, and game experience. The objective is to understand better how learners perceive and experience spatial presence within the context of a VR educational game.

Coxon et al. (2016) used a VR setting with a cityscape where participants could move around using handheld controllers. Participants were told to look around the area for two minutes. However, the participants did not execute various complicated tasks or interact in any way with their environment. Users' ability to form a mental map of their VR surroundings depends on their involvement in the experience. This capacity may be attainable without paying close attention to one's surroundings or relying on one's ability to form mental images of those surroundings. They investigated how HMD users' visuospatial imagery, mental rotation, and topographical memory were compared and contrasted. They discovered a link between spatial presence and visual-spatial imagery but not between spatial presence and other spatial skills.

According to the paradigm proposed by Wirth et al. (2007), visuospatial imagery is a precursor to the first stage of spatial presence, which entails constructing a mental representation of the surrounding space. We found a weak correlation between spatial orientation abilities and spatial presence. Given the limited sample size, achieving Wirth's proposed outcome could have been attainable. Consequently, it is advisable to pursue further experimentation in future investigations.

Uz-Bilgin and Thomson (2021) discovered that the level of game experience did not emerge as a significant predictor of spatial presence for adolescents; the same results appeared in our cases for adults. A weak correlation(r_P=-0,22) exists between presence scores and being a player. Lin et al. (2013) similarly did not see a statistically significant impact of computer experience and game-playing experience on spatial presence.

The primary aim of the study conducted by Paest et al. (2023) was to examine the potential influence of three-dimensional perception on the sense of presence experienced within virtual worlds. The experiment includes a real environment, an immersive VR environment, and a non-immersive VR environment. Their participants were mainly designers; they were indicated as "Experience with 3D virtual environments". Their findings imply that the perception of three-dimensional (3D) stimuli or perception may not significantly impact the subjective experience of presence. The findings indicate that it may not be necessary to use advanced depth representation and visualization techniques in applications to provide highly immersive experiences. Based on the obtained results, it is possible to draw certain conclusions regarding the degree of realism exhibited by the environment. It is thus reasonable to deduce that other factors influencing presence should be given higher priority. Hence, rather than assessing the levels of realism and depth representation in VR, it may be more appropriate to establish a correlation with the participant's spatial cognitive abilities.

Unlike previous research, this study has three main differences to reveal the process in VR. Firstly, the environment is realistic and intractable, like the Yedikule Fortress in Istanbul. Secondly, the pre-test was evaluated to measure spatial intelligence to argue the game performance relations with spatial abilities. Unlike the gameplay time, the experiment steps were similar to Uz-Bilgin and Thomson's (2021) study. According to the participant, with the prior games to teach the participant VR environment and controllers, the experiment lasted between 2 and 15 minutes.

Furthermore, the investigation in VR included the examination of mental rotation capacity, perspective-taking ability, and performance tasks, in addition to Uz-Bilgin and Thomson's study (2021). It has been indicated that there is a correlation between perspective-taking ability and presence. On the other hand, the distinction is in categorizing the game we have built as a puzzle-solving game rather than an educational one. By implementing the necessary enhancements, the game has the potential to serve as an educational tool, shedding light on a significant era and geographical area of the Ottoman Empire. Given that the game in issue was not designed for educational purposes, the emphasis on prior knowledge was not

prioritized. The game has clues that align with the ancient legends. According to reports, there were instances where snakes and centipedes emerged from the well located in the playground, symbolizing the representation of a well associated with the fortress known as "Kanlı Kuyu." The first indication is rotating the revolving wheel of the well to retrieve the snake residing within. Subsequently, it has been ascertained that the treasure tower, one of the towers within the Yedikule complex, served as a repository for valuable metals, currency, and adornments. The final interaction involves the emergence of gold nuggets from the wall. It is suggested that a modification be made to incorporate jewelry sourced from the chests within the game to align with the narrative. Yedikule, a location rich in narratives, can be effectively aligned with a criterion such as prior knowledge, rendering it appropriate for investigating spatial presence among those with a keen interest in history.

Figure 3.22: Natural interactions from the participant.

3.7.1 Review of the game mechanics

Examining the presence results reveals that the game's interactions are insufficient, as the average value of conceivable actions appears lower than self-location, namely 4,04 and 3,79, in Figure 3.23. For this reason, the participants' results must be analyzed due

to the statements that fall below the average, and the game must be modified based on which actions need to be revised.

The lowest scores belong to PA-1, PA-8, and PA-9 statements. Which are:

> **PA-1:** *The objects in the presentation gave me the feeling that I could do things with them.*
>
> **PA-8:** *It seemed to me that I could do whatever I wanted in the presentation environment.*
>
> **PA-9:** *It seemed to me that I could have some effect on things in the presentation, as I do in real life.*

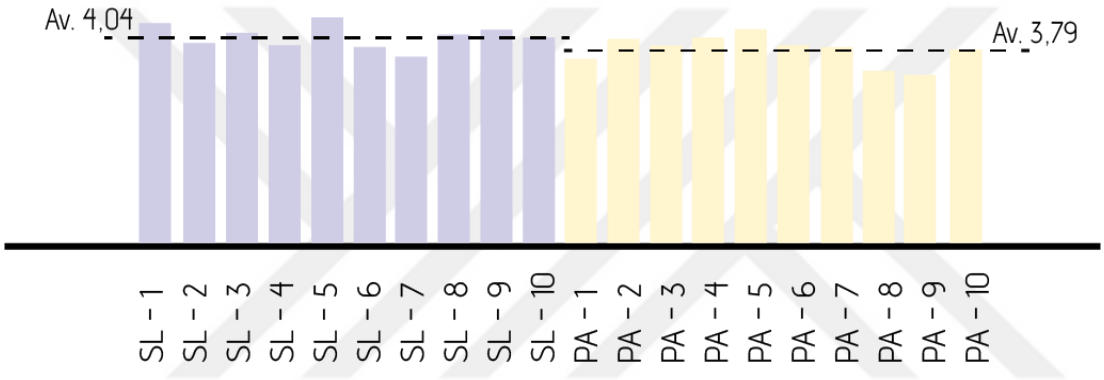


Figure 3.23: SPES items and their average scores from the first experiment.

3.7.2 Review the art of the game

The backdrop components in the game will be evaluated as a consequence of our experimental procedures. In this section, an analysis of the SPES test results about Self Location will be conducted to identify areas for potential improvement. Specifically, attention will be given to questions with the lowest average scores to generate ideas for their growth. The lowest scores belong to the SL-2, SL-4, SL-6, and SL-7 statements. Which are:

> **SL-2:** *It seemed I took part in the presentation's action.*
>
> **SL-4:** *I felt as though I was physically present in the environment in the presentation.*
>
> **SL-6:** *I was convinced that things were happening around me.*

SL-7: *I felt I was in the middle of the action rather than merely observing.*

These results in Figure 3.23 indicate that participants lack interaction and are not 100% immersed in the game environment. They feel like observers, not actual players. The interactions should be reorganized to enhance these results, and all objects must be interactable.

Based on the discoveries mentioned above, the compounds that need enhancement are enumerated in Figure 3.24. In game development, the test results below the average were considered efficient of the game for both the self-location and probable actions situations.

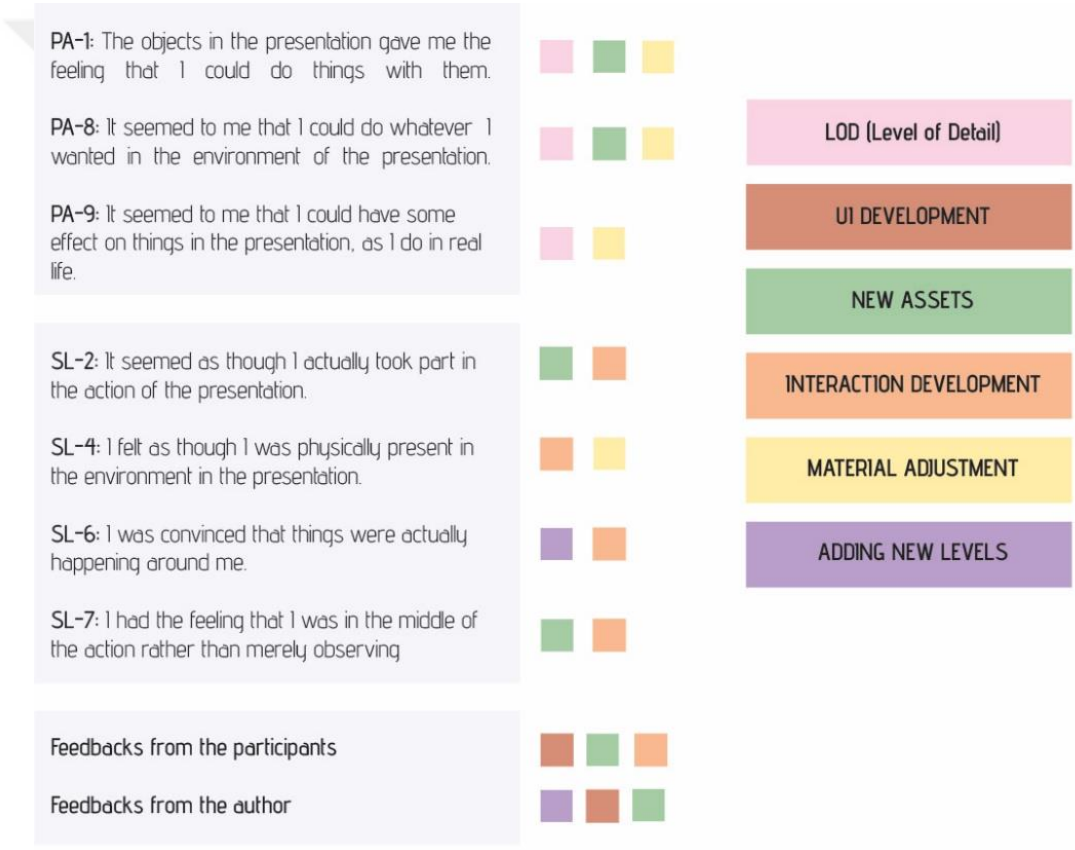


Figure 3.24: The necessary improvements of the game according to SPES results.

A table was constructed to display the outcomes of the lowest scores, with the related questions listed underneath them in Figure 3.24. The feedback from the participants

and the author was gathered and labeled with the development steps in different colored boxes. A six-step development section has been proposed as a potential resolution to the issues above. The steps above, denoted by distinct colors, are juxtaposed with the requisite difficulties, generating a cognitive diagram illustrating the allocation of problem-solving methods to specific problems in the game.

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4. THE DEVELOPMENT OF THE GAME MECHANICS THROUGH THE FEEDBACK AND TEST RESULTS

This section will outline the inadequacies and interventions of the innovations proposed by the author. Based on the findings of the preceding psychological assessments, it became imperative to promptly rectify the interactions as not all objects within the environment were being engaged with. This deficiency resulted in a diminished quality of the overall experience. Adopting an alternative interaction style, which facilitates improved communication, would be beneficial to address this issue. Feedback from individuals who experienced the game indicated a desire for more comprehensive information before immersion. Additionally, some participants reported encountering corrupted or improperly positioned materials within the game.

In the previous part, an examination of data analysis and game evaluation was conducted. Upon a comprehensive evaluation, an additional level will be included in the game. To do this, new models and level topologies have been developed. Subsequently, existing connections were rectified, and novel interactions were included. In future studies, it is planned to include administering the enhanced iteration of the game to individuals belonging to the same experiment group.

4.1 User Interface Developments

With this addition, which the participant requires from the pilot experiment since the game opens directly without any button, it is planned that the player will get information and make a more game-like entry in Figure 4.1. The credits include the first version's creators. By clicking the "about" button, the player might have information about the game story by watching the cinematic intro video or flash cards. Before commencing the game, we positioned the written narrative as a flashcard (see Figure 4.2). The cinematic introduction required the player to comprehend the historical context and temporal setting.

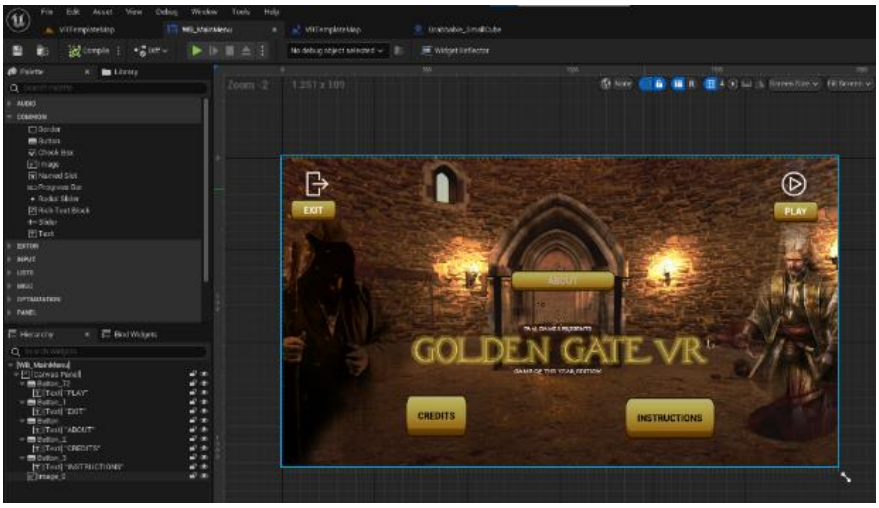

Figure 4.1: Adding UI for the first scene.

Figure 4.2: An example from the game introduction's flash cards.

4.2 Re-designing and Adding New Game Assets

The current phase of game development will encompass a total of five distinct stages. Incorporating a new asset into a pre-existing game might provide challenges, particularly when the asset's texture is already prepared. In the Unreal Engine, various stages exist in inspecting textures and reloading materials. The following steps provide a comprehensive breakdown of the activities performed at each step.

Level design (i) entails the creation of a specific level's layout and atmosphere using specialized editor tools. This method permits the positioning of objects and the establishment of the overall design. Integration (ii) is incorporating newly acquired assets into an ongoing undertaking. This objective can be easily accomplished by

employing instruments such as Quixel Bridge. The manipulation of lighting (iii) within a certain level is essential for creating the desired atmosphere and ambiance. Unreal's real-time lighting system facilitates the creation of dynamic and realistic lighting effects. Implementing distinct gameplay mechanics and interactions (iv) for the level is an unavoidable step that renders objects interactable. This endeavor was accomplished through the use of scripting or the implementation of Blueprints. To achieve a seamless gameplay experience by improving the performance of the game's levels, optimization (v) is essential. Modifying the settings, establishing appropriate Levels of Detail (LODs), and optimizing textures and materials to increase overall efficiency is recommended.

4.2.1 Editing Materials in Unreal Engine

Materials have been modified, and the quality has been increased. The maps were re-added when the additional content was produced for this. The static models were converted to Blueprint when the material arrangement was complete and suitable for the grab interaction. The implementation of textures in Unreal Engine was revisited, resulting in the reorganization of textures to enhance the visual quality of objects. Additionally, the introductory level offers an increased number of interactive items. The organization of the materials and the final result are in Figure 4.3.

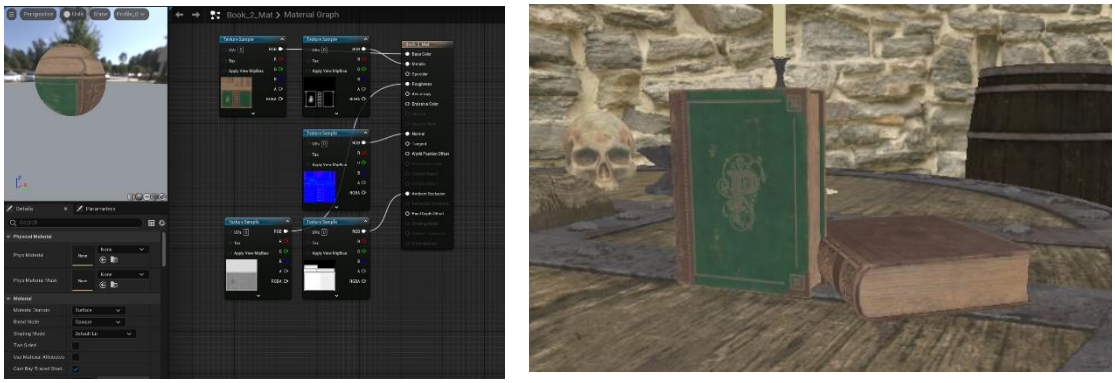

Figure 4.3: Material editing in Unreal Engine.

4.3 Fixing Grab Interaction

It can be said that understanding the interactions necessary for VR games is crucial, as immersion is heightened through interaction. As a result of feedback, the interactions could be increased and developed. For this reason, the interaction part of all objects

has been revised, and the "physics" part, which provides features such as falling to the ground when thrown as in the everyday world, has been adjusted.

The following steps were followed on a sample candle object see Figures 4.5 and 4.6:

1. The “GrabComponent” component is added in Unreal Engine. The part that will be holdable is re-organized for proper interaction.

2. The object is checked whether it is a movable option from the part of "Mobility."

3. The grab type has been changed to snap; when the player tries to grab it with his hand, the objects will stick to their hand.

4. The holdable part of the object has been adjusted.

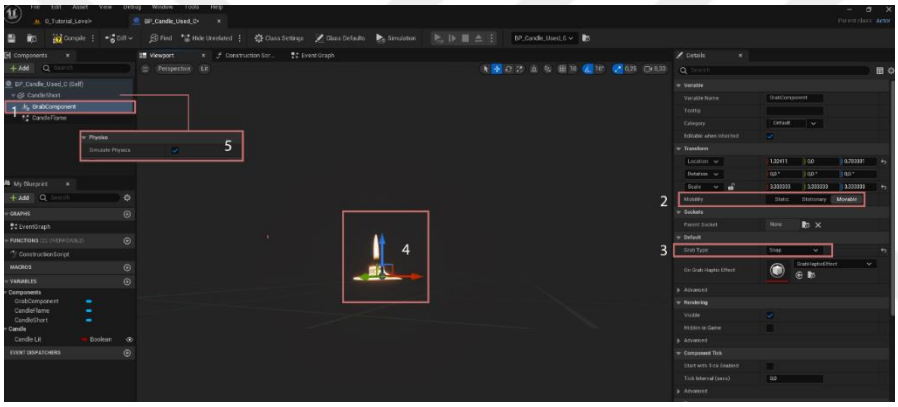

Figure 4.4: Fixing grab component in Unreal Engine step by step.

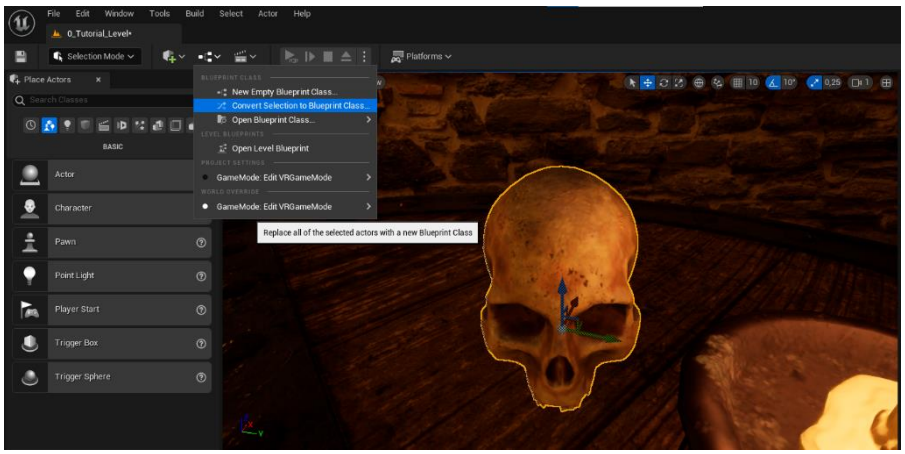

Figure 4.5: Turning C^{++} objects to Blueprint class.

4.4 Adding the first level to the game

Following the introductory level, the player must access the dungeon by its designated entrance. Upon successfully utilizing the ultimate key to gain access, the player will

then engage in three additional interactive encounters within the confines of the dungeon. The narratives surrounding the Yedikule Dungeons will likely inspire future interactions. The storyboard was utilized to construct the various settings to incorporate the initial episode. All the riddles include historical traces connected to the Yedikule Fortress and its legends.

The player enters the dungeon after completing the introduction level. There are six dungeons with halls; in each dungeon, the player can find new objects to interact with. Initially, the player needs to find parchment paper to solve the riddle. Secondly, there are pouches filled with gold coins. Lastly, the player must throw the golden snake into another well in the last dungeon.

After completing the level design and the room modeling process, adjustments were made to the texture settings. The method of illumination and optimization was subsequently carried out sequentially, as outlined in section 4.3. The final results of a random dungeon are in Figure 4.7.

While developing the new level, much consideration was given to incorporating the input received. Additionally, new interactions were included as part of the design. For instance, the utilization of spinning wheels to navigate between platforms, the act of accessing and perusing recently acquired publications, and the engagement in reading parchment paper, among other activities.

Figure 4.6: The scene examples from the first level.

4.5 Optimization

In gaming, optimization is often understood as the capacity of a game to function efficiently across various computer systems. The optimization technique aims to maintain consistent gameplay and graphic quality across all platforms. Each player is familiar with the often-seen gaming settings, namely 'low,' 'medium,' 'high,' and 'ultra.'

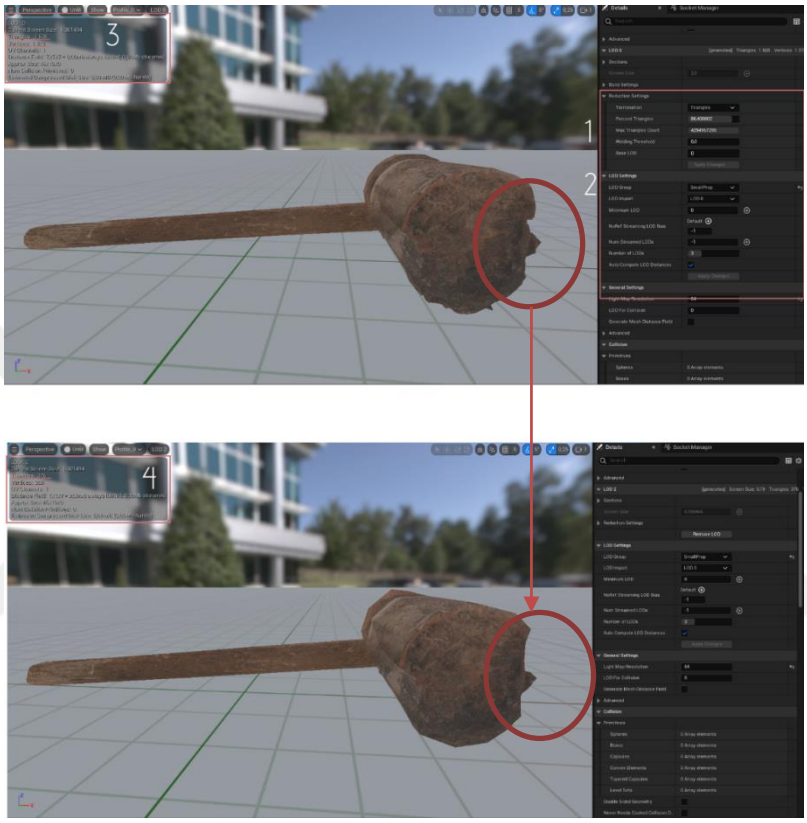

Figure 4.7: The transformations of static mesh objects with LOD reduction settings.

4.5.1 Level of detail

A technique for reducing mesh complexity as objects move away from the viewer is known as Level of Detail (LOD). This method reduces engine load while rendering complex scenes. Before the development process, Golden Gate had objects that contained only one slot LOD. So, it is decided to add one or two slot LOD for the things according to their mesh counts.

For this, the following steps were followed on a sample candle object see Figure 4.8:

1. In the first part, the mesh count should be decreased.

2. The LOD levels are changeable, and there are also automatic LOD processes the Unreal Engine handles with a minimum crash. The LOD levels are set to 3 for these assets.
3. In the LOD 0, there are 1,508 triangles. The player sees this object in detail while they are very close.
4. In the LOD 2, there are 376 triangles. While the player moves away, the LOD changes from 0 to 2.

4.6 Discussion

The primary objective of this study is to address the existing research gap by investigating the process of generating the spatial presence experience inside a VR puzzle game. Furthermore, this study examined the possible impact of users' spatial abilities, gaming experience, and professional background on forming spatial presence. It was found that being a designer weakens spatial presence; when the playtime gets longer, spatial presence scores get higher. There is no correlation between gaming experience and spatial presence. Regarding spatial aptitude, there is a weak correlation between spatial orientation skills and spatial presence.

The perception of immersion, characterized by the unique sense of being fully present inside a specific spatial context, is a fundamental aspect of the architectural experience. This thesis highlights the possibilities of using comparable approaches to assess architectural projects' spatial feasibility and experiential quality. By assessing people's spatial performance and degrees of presence inside a virtual environment, architects and designers may get significant information about the potential impact of their designs on end-users.

The use of presence scales may provide valuable insights for developing user-centered design concepts in architectural VR applications. In the context of VR, if the sense of presence is increased, architects and designers may strategically use this phenomenon to develop VR experiences that are both captivating and productive for clients and stakeholders. Secondly, (VR puzzle games, particularly those designed for architects and designers, can be utilized as a training instrument to enhance spatial skills and presence. This may be especially useful for students and professionals seeking to improve their architectural design skills.

The results suggest that spatial abilities and presence play a significant role in architectural design. This prompts a discussion on the potential integration of VR training or spatial skill development inside architectural education programs. Moreover, the proficiency of designers in spatial abilities and their degree of presence may influence their efficacy in using virtual reality architectural design tools. There might be a correlation between the spatial abilities of designers and their efficiency in generating and comprehending virtual architectural spaces.

Hence, the redevelopment was based on psychometric test results and player feedback. This approach can be used as a new method to validate game immersion. Nevertheless, it is essential to acknowledge that “Golden Gate” is still in its nascent development phase. The level of interactions inside the game fell short compared to other well-acclaimed games. The results obtained from our experiments were consistent. Our int in level design surpasses our competence in interaction, as shown by the observable disparity in the presence scale. This observation demonstrates that despite being a self-report assessment, the game's shortcomings may be discerned using the presence test. The extent to which the player is encircled in the game we develop may also be determined via these tests. One potential strategy to enhance players' in-game performance is incorporating instructional levels that facilitate developing and honing mental talents directly influencing game performance.

4.7 Conclusion

This thesis aims to conduct a systematic inquiry into spatial performance by applying a specialized gaming environment as a means of exploration, accompanied by self-report psychometric questionnaires. The knowledge acquired via this methodology transcends the boundaries of the gaming domain and has considerable potential for wider use, notably in architecture and spatial design.

To investigate the relationships among the topics above, a series of experiments were conducted, comprising of pre-test, game experiment, and post-test phases. A total of 30 individuals between the ages of 25 and 35 were selected to participate in the previous assessments. The study examined disparities in gaming habits and professional backgrounds among the participants. The game environment development started during the lecture conducted at ITU, with subsequent stages being

constructed based on participant feedback and the outcomes of spatial presence experience tests.

The first suggestion was substantiated as there was a weak observed association between playtime duration and mental rotation and sense of direction, namely %21 (r =0,21). Participants with better mental rotation and sense of direction skills demonstrated a quicker completion time in the game throughout the trial. A link might be identified by examining a more extensive dataset in future research. The extent to which playtime is influenced by an individual's role as a player has been previously examined in several research; Section 1 referred to it.

The second hypothesis was about establishing a negative correlation between spatial presence and spatial orientation; this is because while the best score of SOT is minimum, SPES scores should be maximum. A correlation was discovered between possible action subsets of the spatial presence test but not significant enough to eliminate the association with self-location. This hypothesis has been partially validated because there is no correlation between spatial presence and other spatial abilities.

The third hypothesis suggested that the group of designers would perform better in spatial aptitude tests and SPES tests. The group of individuals with a background in design had superior performance across all tests compared to the group without a design background while also demonstrating a shorter duration of playing time. Furthermore, the part above of the hypothesis was validated. On the other hand, the performance of the player-designer in testing was not consistently optimal. In the subsequent section of the third hypothesis, it was posited that the participants would get the highest scores in MRT, SOT, and SPES. Despite having the smallest playing time, this particular group had superior outcomes compared to the other groups. The team's highest scores in the MRT and SPES assessments were achieved by those who have no gaming habits and come from a design background. Upon examining the findings above, it can be posited that those engaged in the design field have an enhanced ability to see objects in three dimensions, surpassing that of individuals with gaming habits. Based on these findings, we can conclude that being a designer fosters superior 3D perception compared to gaming habits and creates a more effective structure for spatial presence.

Furthermore, the spatial orientation test scores of the designer group exhibit much greater disparities than those of the non-designer group, with a magnitude that is five times smaller. This finding demonstrates that, similar to prior research, there is evidence indicating that the spatial performance of architecture students tends to improve in the results of their education, despite the lack of correlation between mental rotation and navigation skills and the occupation of becoming a designer. Contrary to expectations, the player-designer group did not get the highest scores on the spatial ability test. The cross-sectional group of the experiment yielded the most favorable outcomes for both the designer and non-player groups. The underlying factors contributing to the lack of impact of gaming habits on spatial ability performance have yet to be fully understood. The existing body of literature indicates that gamification positively impacts the quality of STEM education. There ought to exist a link between an individual's gaming habits and their performance in spatial ability tasks. However, it is improbable that being a designer has influenced this relationship reciprocally. As previously discussed, being a player alone influences the duration of playtime.

In summary, this thesis establishes the groundwork for a comprehensive investigation of the concepts of presence, spatial performance, and their complex interplay with game design, and it may apply to architectural design in the future. Through utilizing virtual environments and psychometric assessments, this approach provides an intriguing insight into the capacity of architects and designers to conceive spaces that not only fulfill their practical objectives but also establish a profound connection with the human condition, thereby enhancing the well-being of their occupants.

4.8 Further Researches

In further investigations, this study framework can broaden its scope to include social presence. Examining physical or virtual situations that include the presence of several persons may provide valuable insights into the intricacies of human interaction within these settings. Numerous scholarly investigations have been conducted to explore the phenomena of social presence in virtual worlds. However, applying this inquiry to actual architectural spaces has the potential for further exploration. Such an approach might provide fresh perspectives on the effect of design on social interactions and connectedness among persons.

At some point, the findings of this thesis addressed the pre-cognitive processes necessary for experiencing a sense of belonging, which can be mentioned as “spatial presence” within the context of space construction. Although those with higher spatial skills would likely exhibit a greater presence, the use of pre-game training might potentially mitigate this disparity in future research. At the same time, it has been observed that apart from the spatial layout, the significance of interaction and its direct impact on the participant's experience is evident. This proposition implies that although realism is prioritized in creating gaming environments, there are instances when it may be necessary to deviate from realism and embrace speculative spaces to enhance performance and efficiency.

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APPENDICES

APPENDIX A: Pre-psychometric Tests

SANTA BARBARA SENSE-OF-DIRECTION SCALE Participant: _____

The following statements ask you about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.
strongly agree 1 2 3 4 5 6 7 strongly disagree

2. I have a poor memory for where I left things.
strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.
strongly agree 1 2 3 4 5 6 7 strongly disagree

4. My "sense of direction" is very good.
strongly agree 1 2 3 4 5 6 7 strongly disagree

5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).
strongly agree 1 2 3 4 5 6 7 strongly disagree

6. I very easily get lost in a new city.
strongly agree 1 2 3 4 5 6 7 strongly disagree

7. I enjoy reading maps.
strongly agree 1 2 3 4 5 6 7 strongly disagree

8. I have trouble understanding directions.
strongly agree 1 2 3 4 5 6 7 strongly disagree

9. I am very good at reading maps.
strongly agree 1 2 3 4 5 6 7 strongly disagree

10. I don't remember routes very well while riding as a passenger in a car.
strongly agree 1 2 3 4 5 6 7 strongly disagree

11. I don't enjoy giving directions.
strongly agree 1 2 3 4 5 6 7 strongly disagree

12. It's not important to me to know where I am.
strongly agree 1 2 3 4 5 6 7 strongly disagree

13. I usually let someone else do the navigational planning for long trips.
strongly agree 1 2 3 4 5 6 7 strongly disagree

14. I can usually remember a new route after I have traveled it only once.
strongly agree 1 2 3 4 5 6 7 strongly disagree

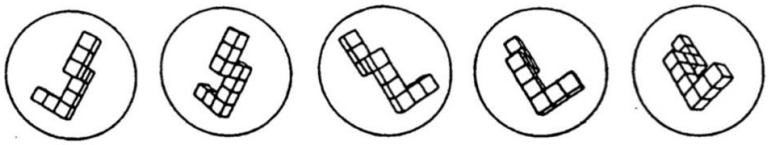
15. I don't have a very good "mental map" of my environment.
strongly agree 1 2 3 4 5 6 7 strongly disagree

Appendix A.1: Santa Barbara Sense of Direction Scale (SBSOD) test.

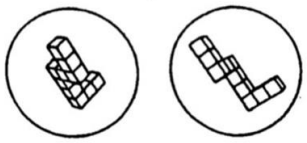
Date_____
School_____
Class_____
Grade_____
Sex_____

M.R.T. Test

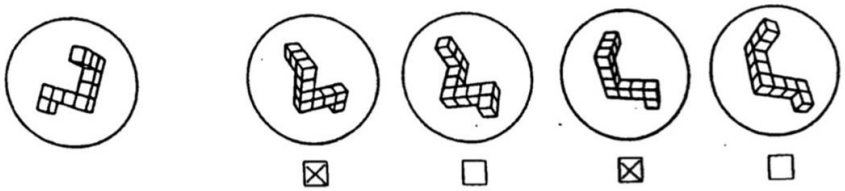
This is a test of your ability to look at a drawing of a given object and find the same object within a set of dissimilar objects. The only difference between the original object and the chosen object will be that they are presented at different angles. An illustration of this principle is given below, where the same single object is given in five different positions. Look at each of them to satisfy yourself that they are only presented at different angles from one another.



Below are two drawings of new objects. They cannot be made to match the above five drawings. Please note that you may not turn over the objects. Satisfy yourself that they are different from the above.



Now let's do some sample problems. For each problem there is a primary object on the far left. You are to determine which two of four objects to the right are the same object given on the far left. In each problem always two of the four drawings are the same object as the one on the left. You are to put Xs in the boxes below the correct ones, and leave the incorrect ones blank. The first sample problem is done for you.



Go to the next page

Adapted by S. G. Vandenberg, University of Colorado, July 15, 1971
Revised instructions by H. Crawford, U. of Wyoming, September, 1979
Images digitized and reprinted by Susanna Douglas, University of Texas, March, 1996

Figure 1: Mental Rotation Test by G.S. Vandenberg

Appendix A.2: Mental Rotation Test (MRT).

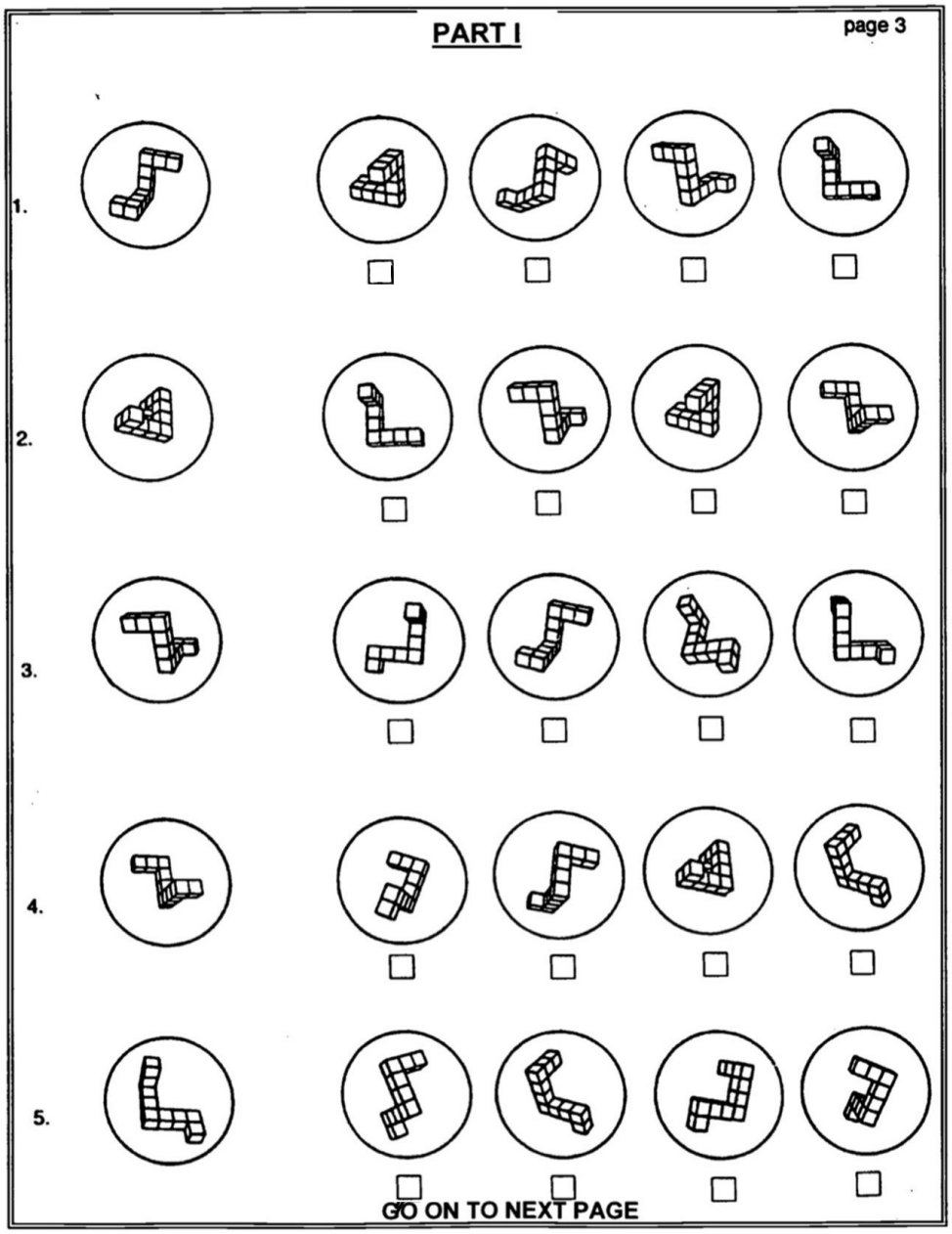


Figure 1 (continued)

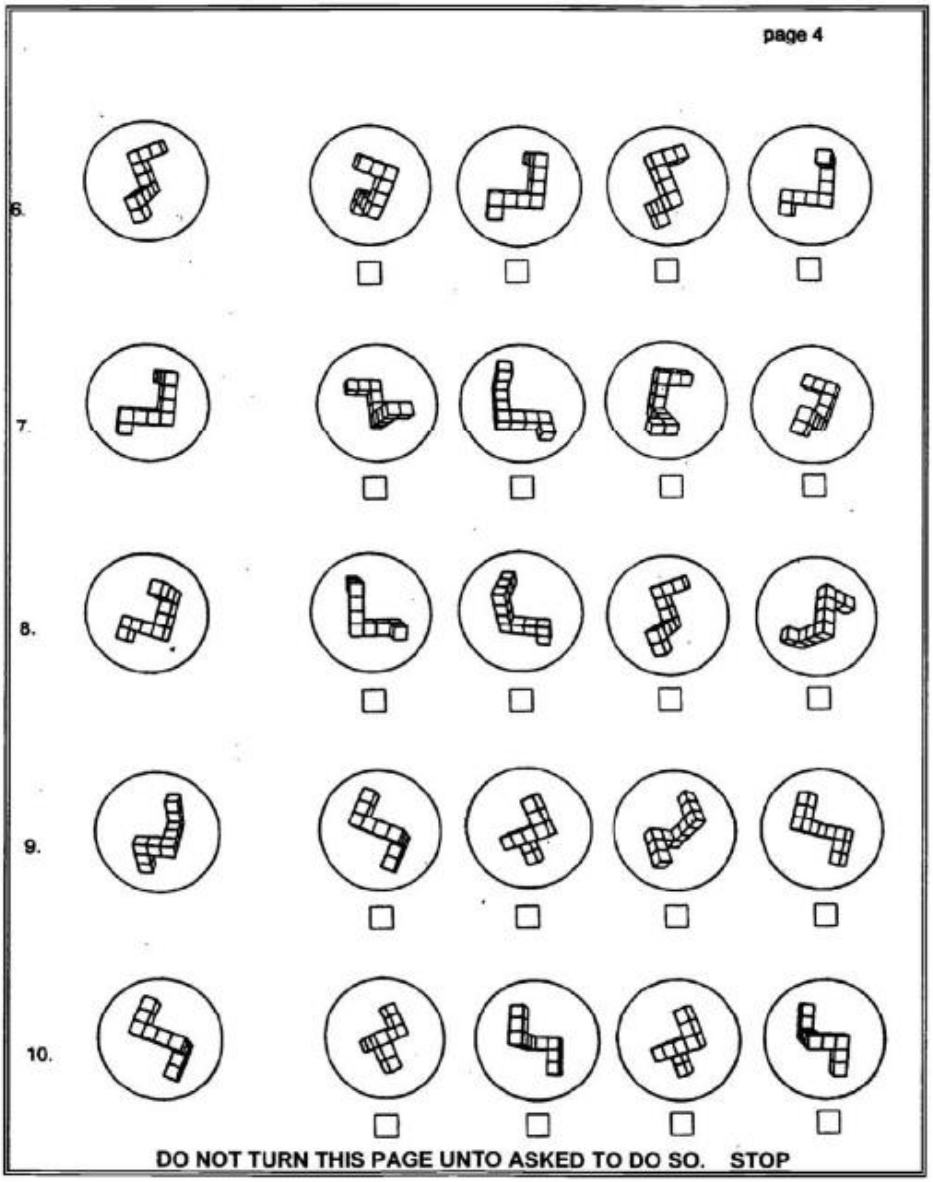


Figure 1 (continued)

Spatial Orientation Test

This is a test of your ability to imagine different perspectives or orientations in space. In this task, you will see a picture of an array of objects with a statement below it, together with an "arrow circle". You will be asked to imagine that you are standing at one object in the array and facing another object. Your task is to draw a line showing the direction to a third object from this perspective. On each trial, you will be asked to imagine standing at a different first object, facing a different second object, and then to draw a line to a different third object.

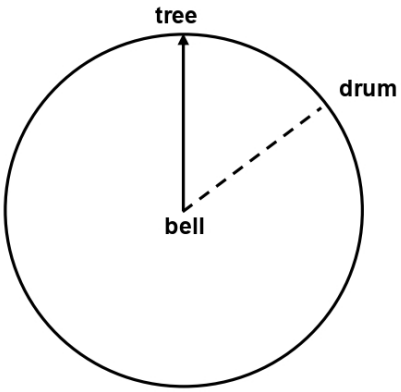
You respond by drawing a line on the arrow circle. The center of the arrow circle represents your imagined location (at the first object) and the vertical arrow represents your imagined perspective (facing the second object). You need to draw the direction to a third object from this facing direction.

Look at the sample item below. In this example you are asked to imagine that you are standing at the bell facing the tree. Your task is to draw a line indicating the direction to the drum. In the sample item this line has been drawn for you. In the test items, your task is to draw this line on the arrow circle. Can you see that if you were at the bell facing the tree the drum would be in the direction shown by the dotted line? Please ask the experimenter now if you have any questions about what you are required to do.

Array of Objects

Example:
Imagine you are standing at the **bell** and facing the **tree**. Point to the **drum**.

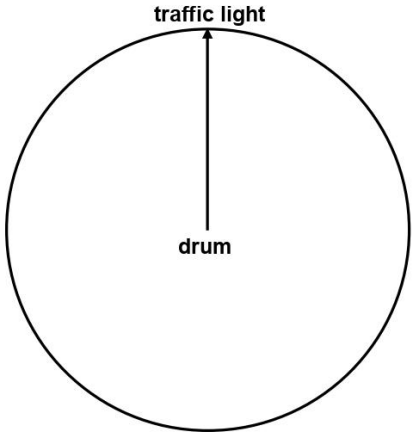
Arrow Circle



Appendix A.3: Perspective Taking - Spatial Orientation Test

Now you will do a practice trial. Draw a line to indicate your answer. Please do not pick up or turn the test booklet, and do not make any marks on the array of objects. Once you have drawn your answer the experimenter will give you a transparency in which the correct answer is drawn in red. Place the transparency over your answer and compare your answer to the correct answer.

Imagine you are standing at the **drum** and facing the **traffic light**. Point to the **wheel**.



Now you will do the test. There are 12 items in this test. You will have 5 minutes to complete these items.

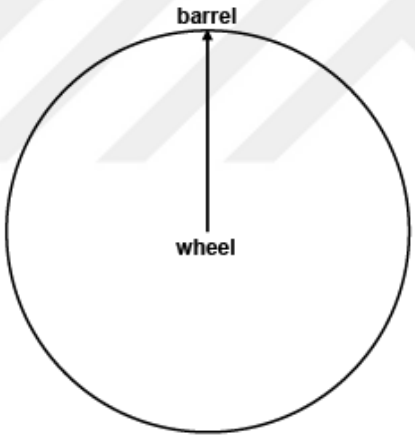
Please try to respond accurately, but do not spend too much time on any one item.

Please do not pick up or turn the test booklet, and do not make any marks on the array of objects.

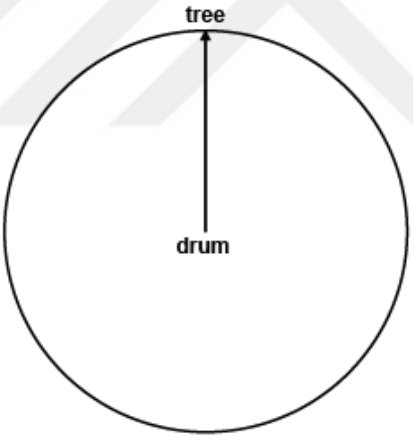
Ask the experimenter if you have any final questions about this task.

When you are ready to start, please let the experimenter know.

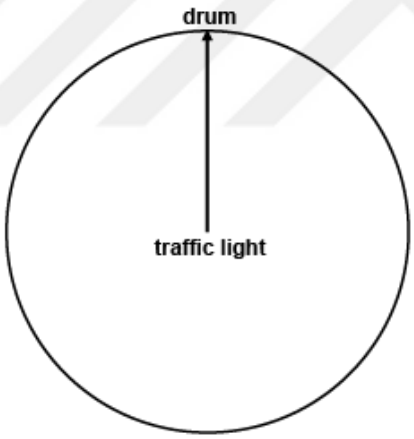
Imagine you are standing at the **wheel** and facing the **barrel**. Point to the **traffic light**.



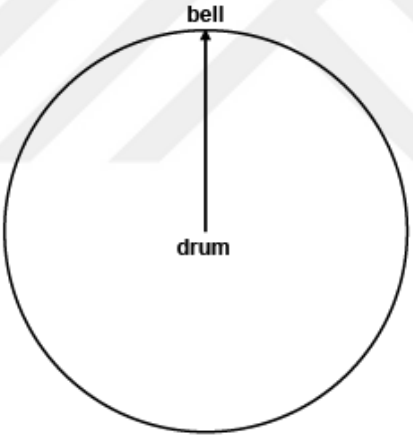
Imagine you are standing at the **drum** and facing the **tree**. Point to the **wheel**.



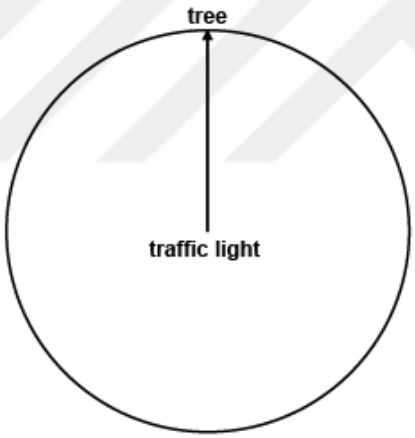
Imagine you are standing at the **traffic light** and facing the **drum**. Point to the **trash can**.



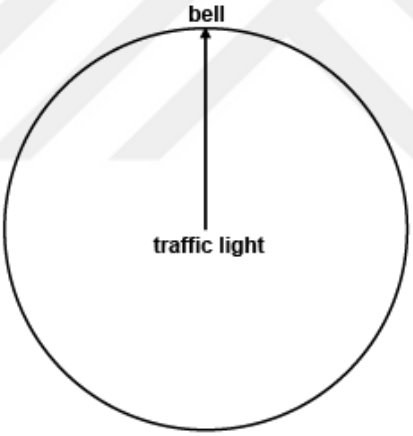
Imagine you are standing at the **drum** and facing the **bell**. Point to the **wheel**.



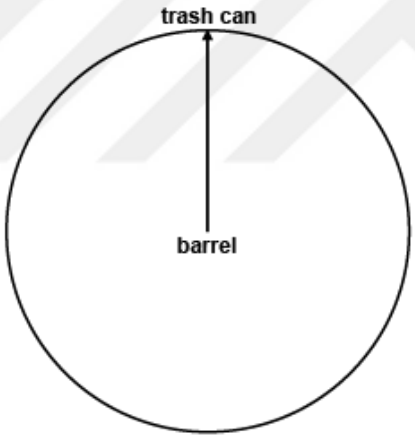
Imagine you are standing at the **traffic light** and facing the **tree**. Point to the **barrel**.



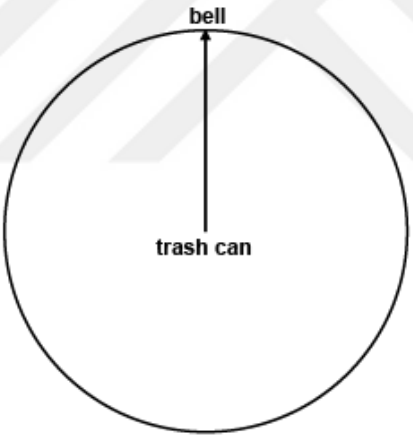
Imagine you are standing at the **traffic light** and facing the **bell**. Point to the **wheel**.



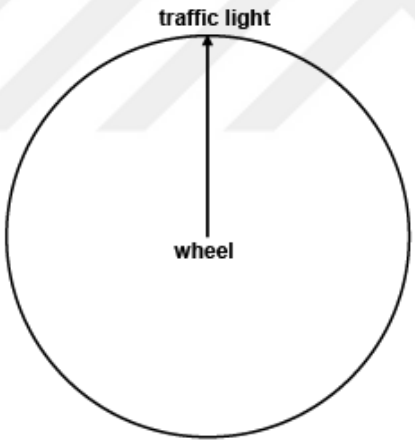
Imagine you are standing at the **barrel** and facing the **trash can**. Point to the **bell**.



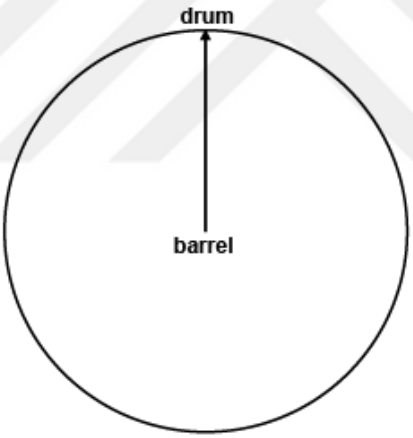
Imagine you are standing at the **trash can** and facing the **bell**. Point to the **traffic light**.



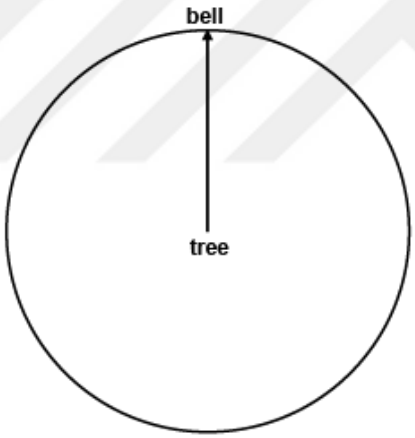
Imagine you are standing at the **wheel** and facing the **traffic light**. Point to the **tree**.



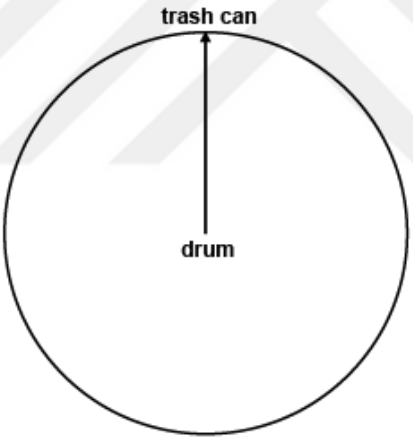
Imagine you are standing at the **barrel** and facing the **drum**. Point to the **wheel**.



Imagine you are standing at the **tree** and facing the **bell**. Point to the **trash can**.



Imagine you are standing at the **drum** and facing the **trash can**. Point to the **barrel**.



APPENDIX B: Ethics Committee

İSTANBUL TEKNİK ÜNİVERSİTESİ
SOSYAL VE BEŞERİ BİLİMLER İNSAN ARAŞTIRMALARI ETİK KURULU
DEĞERLENDİRME SONUCU

PROJE NUMARASI: 357 **TARİH: 30/03/2023**

1.	**Projenin Adı ve Yürütücüsü:** The Quest of Presence in Puzzle-Solving Games in VR by Developing Spatial Performance Through Interactions Doç.Dr. Derya Güleç Özer (Tez Danışmanı) Dr. Öğr. Üyesi Ayşegül Akçay Kavakoğlu (Eş Danışman) Merve Taşdelen (Y. Lisans Öğencisi)
2.	**Projenin Amacı (azami 100 kelime) :** *Yapay nesnelerin sanal ortamdaki deneyimi ve orada olma yanılsaması, sanal gerçeklik (SG) ortamının birincil bir sağlayıcısıdır. Sanal bir ortamda konumlanmış olma inancı, uzamsal bulunma olarak adlandırılmaktadır. Bazı çalışmalar sanal gerçeklik ile uzamsal zeka arasındaki ilişkiyi araştırsa da, kullanıcıların sanal gerçeklik oyun ortamlarında nasıl bir uzamsal varlık oluşturdukları belirsizliğini korumaktadır. Bu bağlamda, çalışma oyun mekaniği ile uzamsal bulunma kavramı arasındaki ilişkileri ortaya koymaya çalışmaktadır. SG bulmaca çözme oyunlarında uzamsal varlık deneyimi inşasını ve özelliklerini detaylandırmaya çalışmaktadır. SG bulmaca çözme oyunları, oyuncuların çevreleriyle etkileşime girmesini ve içindeki nesneleri manipüle etmesini sağlayarak bulunma hissini geliştiren daha sürükleyici ve ilgi çekici bir deneyim sunabilir. Bu çalışmada bulunma-mekansal performans ilişkileri önceki çalışmalar temel alınarak incelenmekte ve mekansal tanımlama açısından analiz edilmektedir. Bu çalışma kapsamında mekansal yetileri yüksek olan insanların oyun içi performanslarının diğer katılımcılara göre daha başarılı olacağı öngörülmektedir. Mekansal bulunmanın etkileşimle ilişkili olduğu kanıtlanmıştır. Oyun içi etkileşimlerdeki performansın mekansal yetiye bağlı olduğu bu sebeple de bulunma ile mekansal yetinin de bir ilişkisi olduğu ortaya konulmak istenmektedir.*
3.	**Projenin Yöntemi (azami 100 kelime) :** *Golden Gate adlı SG oyunu, yukarıdaki hipotezi test etmek ve detaylandırmak için bir vaka çalışması olarak kullanılacaktır. Devam eden bu çalışmanın beş adımı vardır: (1) Oyun ortamının geliştirilmesi, (2) Görsel-uzaysal yetenek için ön psikometrik değerlendirme (Ön Test: PTSOT (Perspective Taking/Spatial Orientation Test), MRT (Mental Rotation Test) and SBSOD (Santa Barbara Sense of Direction) (3) SGOyunu Deneyimi, (4) Deneyimlerin değerlendirilmesi (5) Oyun ortamının yeniden geliştirilmesi. Oyuncuların deneyimleri, Mekansal Varlık Deneyimi Ölçeği (S.P.E.S) ile ilgili Zihinsel İmge, Rotasyon ve Mekansal Oryantasyon açısından değerlendirilecektir. Bu yazıda ilk dört adım ayrıntılı olarak ele alınacaktır.*

Appendix B: Ethics committee approval.

☐Proje değerlendirilmiş ve etik açıdan uygun BULUNMUŞTUR.

☐Proje değerlendirilmiş ve etik açıdan uygun BULUNMAMIŞTIR.

☐Proje değerlendirilmiş ve etik kurul belgesine GEREK DUYULMAMIŞTIR.

Projenin Adı ve Yürütücüsü: **TARİH: 30/03/2023**

Doç. Dr. Derya Güleç Özer (Tez Danışmanı)

Dr. Öğr. Üyesi Ayşegül Akçay Kavakoğlu (Eş Danışman)

APPENDIX C: Spatial Presence Experience Scale

Name:
Surname:

Please fill in this questionnaire according to Golden Gate VR.

Likert Scale .
5: I agree.
1: I do not agree

Table 1

The Spatial Presence Experience Scale (SPES) – self-location (SL) and possible actions (PA)

Sub		Item
SL	1	I felt like I was actually there in the environment of the presentation.
SL	2	It seemed as though I actually took part in the action of the presentation.
SL	3	It was as though my true location had shifted into the environment in the presentation.
SL	4	I felt as though I was physically present in the environment of the presentation.
SL	5	I experienced the environment in the presentation as though I had stepped into a different place.
SL	6	I was convinced that things were actually happening around me.
SL	7	I had the feeling that I was in the middle of the action rather than merely observing.
SL	8	I felt like the objects in the presentation surrounded me.
SL	9	I experienced both the confined and open spaces in the presentation as though I was really there.
SL	10	I was convinced that the objects in the presentation were located on the various sides of my body.
PA	1	The objects in the presentation gave me the feeling that I could do things with them.
PA	2	I had the impression that I could be active in the environment of the presentation.
PA	3	I had the impression that I could act in the environment of the presentation.
PA	4	I had the impression that I could reach for the objects in the presentation.
PA	5	I felt like I could move around among the objects in the presentation.
PA	6	I felt like I could jump into the action.
PA	7	The objects in the presentation gave me the feeling that I could actually touch them.
PA	8	It seemed to me that I could do whatever I wanted in the environment of the presentation.
PA	9	It seemed to me that I could have some effect on things in the presentation, as I do in real life.
PA	10	I felt that I could move freely in the environment of the presentation.

Appendix C: SPES Questionnaire

APPENDIX D: Literature Mapping

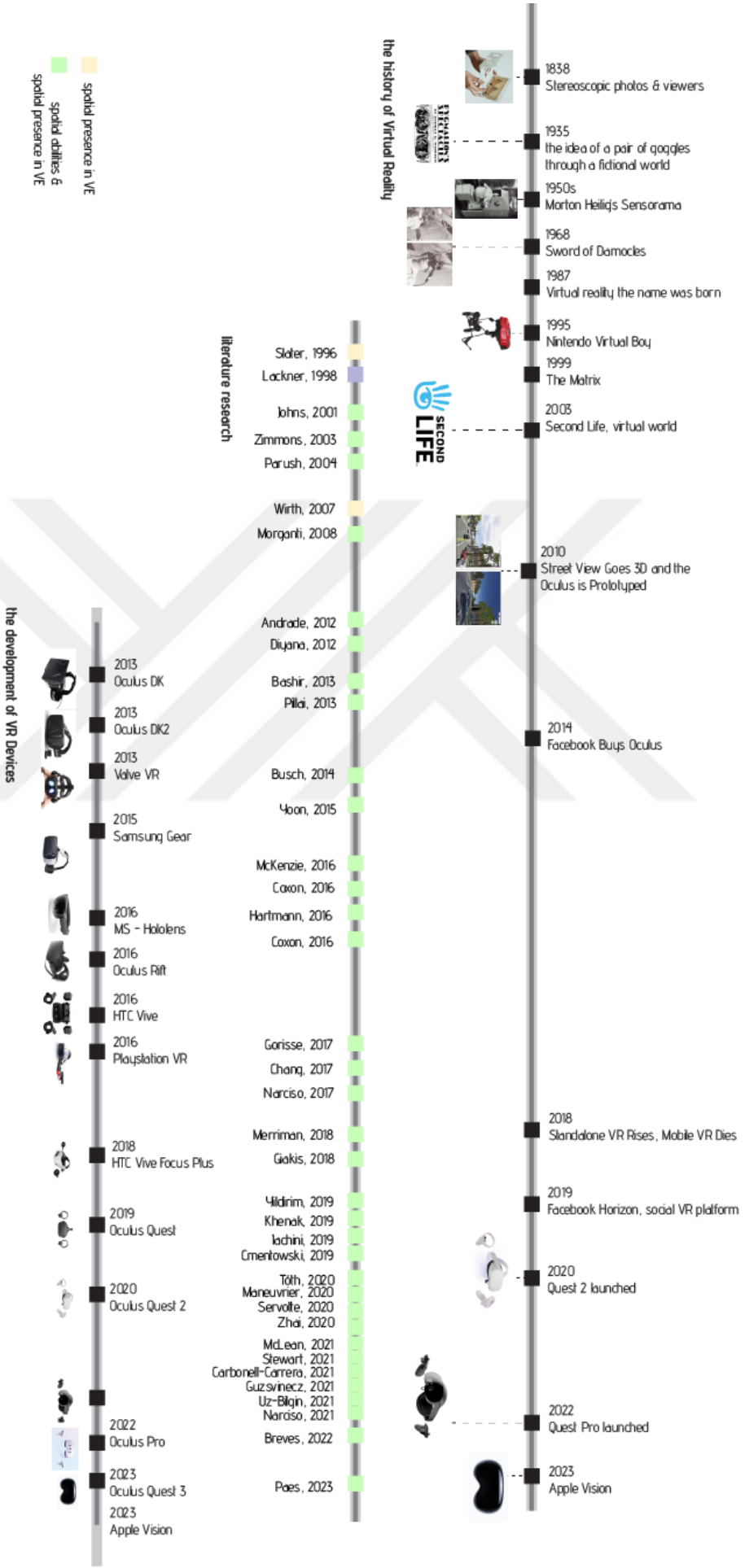


Figure 2.11: Literature mapping with VR developments and history of VR.

CURRICULUM VITAE

Name Surname : Merve Taşdelen

EDUCATION :

- **B.Sc. :** 2019, Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture

PROFESSIONAL EXPERIENCE AND REWARDS:

- 2022, Spirala Community Home, Architectural Competition – Honourable Mention

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Taşdelen, M., Özer, D.G., Akcay Kavakoglu, A. (**2023a). "Exploring the Research Trajectories in VR Game Environments: A Systematic Review on Spatial Ability and Presence Relationship," *17th MSTAS* Conference Proceedings, Medipol University Publications, pp.139-158. e-ISBN 978-605-4797-65-3 (Conference Proceeding).
- **Taşdelen, M., Özer, D.G., Akçay Kavakoğlu, A**. (2023b). The Quest of Spatial Presence by Puzzle-Solving Games in VR. Digital Design Reconsidered - Proceedings of the 41st Conference on Education and Research in Computer Aided Architectural Design in Europe (eCAADe 2023) - Volume 2, Graz, 20-22 September 2023, pp. 833–842

OTHER PUBLICATIONS, PRESENTATIONS AND PATENTS:

Taşdelen, M. (2022). Deneysel Tiyatro Sahnelerine Parametrik Biçim Grameri ile Sahne-Parter Düzeni Önerilmesi . Journal of Computational Design , 3 (1) , 155-176 . DOI: 10.53710/jcode.981647