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Real-World and Virtual-World Practices for Virtual Reality Games: Effects on Spatial Perception and Game Performance

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Abstract: Researchers have been investigating ways to improve users' spatial perception in virtual environments. Very limited studies have focused on the context of virtual reality (VR) games. Tutorials with practices, a common element in games, are good opportunities to implement measures that improve players' spatial perception. Using an experiment, this paper investigates how two types of practices (real-world and virtual-world practices) influence players' spatial perception, game performance, and immersion in VR games. Given that spatial perception is viewed as an essential aspect of VR applications, the moderating role of spatial perception on the effect of practices in game performance is also explored. The results demonstrate that virtual-world practice is effective in improving players' spatial perception of the virtual environment of VR games. Real-world practice is suggested to be effective in enhancing spatial perception when it is averaged over multiple sessions. The results also suggest that spatial perception moderates the effects of practices on game performance. The results imply that practices in game tutorial can be a transitional environment for new players to enter a VR game.

Keywords: digital games; motor skill learning; spatial perception; virtual reality (VR)

1. Introduction

Playing virtual reality (VR) games involves perceiving a virtual environment and completing challenges. Some challenges, such as shooting, rely on players' spatial perception in the virtual environment. Improving players' spatial perception in the virtual environment may improve their gameplay performance and their immersive experience. While improved spatial perception in VR has been identified as an essential quality of VR applications and has been actively studied by researchers [1], spatial perception studies are mostly situated in contexts other than VR gaming. VR in the entertainment context (e.g., VR games) has not received much attention from the research community of spatial perception. Tutorials, common elements in digital games, are opportunities to implement practices to improve spatial perception. Furthermore, we propose an approach of real-world practice as a gradual transitional environment from the real world to the virtual world of VR games. The current study investigates the effects of two variations (real-world and virtual-world versions) of practices in game tutorial on spatial perception in the context of VR games. The findings will contribute to the literature on spatial perception and game designs, affecting how game designers see the purposes and benefits of VR game tutorials.

The next section reviews the related work. The rationale and goal of the current study are presented in Section 3. Sections 4 and 5 present the method and results. The implications are discussed in Section 6. A conclusion is drawn in Section 7.

2. Related Work

2.1. Spatial Perception in Virtual Environment

Allowing users to perceive space accurately in a virtual environment has been considered an important aspect of VR technologies and applications [1]. Spatial misperception can affect "task performance, quality of experience, and acceptance of VR" ([2], p.83) Researchers in the spatial perception field are interested in such capabilities of VR applications and relevant technologies [3–5]. The space around people's bodies can be divided into peripersonal space (reachable by hands, generally within one meter) and extrapersonal space (space beyond one meter around a person) [6]. Researchers in spatial perception in VR noted that users generally underestimate distances in virtual environments [1]. Improving users' spatial perception in a virtual environment affects various VR applications, including architectural design [7], construction practices [8], and serious games that assess motion disorders [9].

Researchers have been investigating approaches to improve spatial perception in VR, such as depth cues [10], visual effects applied to 3D content [9], haptic feedback [11], freedom of movement [12], visual and audio cues [13], and virtual environment setup [6,14]. These approaches are interventions focusing on user interactions with VR applications. Two approaches related to interventions that occur prior to such interactions are practice and transitional environment.

2.2. Familiar and Transitional Environment

Researchers have explored whether a virtual environment resembling a place familiar to users can influence user perceptions and experiences in virtual environments [15–17]. In a study on the influence of transitional environment on spatial perception, Interrante et al. [18] studied the influences of virtual replicas of a real room containing the participants on their distance estimation, finding no underestimation when the virtual room was an exact replica of the real room. In a follow-up study [19], they compared the influence of virtual replicas that were bigger, smaller, and identical to the real room, finding that participants underestimated distances when the virtual replicas were not identical. Replicating real environment was thus shown to have a positive effect on user spatial perception.

Exact replication cannot be applied to VR applications that provide virtual environments of physically impossible or infeasible proportion. Therefore, researchers have explored the idea of transitional environments [20,21], virtual rooms that replicate a real room to serve as an entrance to other parts of an otherwise unworldly virtual environment. Steinicke et al. [22] examined the idea of using a virtual room replica as a gradual transitional environment to a new virtual environment, replicating the laboratory containing the participants. After donning VR head-mounted displays, the participants could see the virtual replica and were prompted to talk to the researcher in order to persuade that they were still in the real world. The participants then triggered a button to open a virtual portal, a hole on one of the replica's walls, which allowed them to walk into the virtual world. After experiencing the virtual world, participants returned to the virtual laboratory through another portal. Participants commented on "being transferred to another world" through the virtual portal (p. 22). They found that such an approach led to significant improvements in their estimation of distances and sense of presence. Transitional environments have been shown to influence other aspects such as presence [23].

Instead of a virtual portal, Valkov and Flagge [24] presented a smooth immersion process in which a virtual replica of a real room gradually changed to a virtual environment by replacing the materials and geometry of the replica. Their results suggested that smooth immersion increases user engagement [24]. Jung et al. [25] adopted a stereo camera mounted on a head-mounted display to present a real room at the beginning of a gradual visual transitional process to a virtual environment. They found that the gradual transition offered a higher level of virtual body ownership and presence than an instant transition [25].

2.3. Practice and its Consequences

Previous studies have shown that actions influence visual perception [26,27]. Researchers sometimes adopt a preparation phase in their experimental procedure to allow participants to become familiar with a virtual environment and equipment setup (e.g., [28,29]). In the context of a driving simulation, Rousset et al. [30] showed that a training session offered the opportunity for participants to familiarize themselves with the virtual environment and device setup, improving the distance perceptions of some participants. Researchers have also suggested adopting practices (called "task training" or a "recalibration phase") as an approach to improve spatial perception in the virtual environment [31,32].

In the context of digital games, practice in a tutorial is a common feature [33]. Tutorials in VR games provide an opportunity for new players to practice, enabling player engagement with the virtual world. Such practice provides gameplay mechanics with fewer constraints, such as the absence of a time limit. Player ability must match the degree of difficulty in the game so that players can enjoy playing [34].

VR game practice usually occurs in the same virtual environment as the game itself. Very few studies [35,36] have examined placing practices for VR games in the real world. While investigating the potential of applying real-world practice to a VR gaming context [36], real-world practice that replicated a task of placing a ball in a target container in a VR game was compared with identical practice in a virtual world. The findings indicated that real-world practice could help new players build confidence and familiarize themselves with a VR game [36].

Confidence refers to the extent to which players believe that they can perform a task. Psychologists refer to this concept as self-efficacy [37,38]. Confidence is critical for motivating players in gameplay, as the self-efficacy theory of motivation [37] says that confidence in completing a task is a crucial aspect of motivation. Researchers have been studying confidence in relation to playing digital games; Constant et al. [39] conducted an experiment on the deviation between players' estimation of their own success rates and their actual game performance. They determined that participants overestimated their chance of success at the hardest level of a game [39], which was in agreement with related findings in cognitive psychology [40].

2.4. Measuring Spatial Perception

Perception of space is a subjective experience that cannot be observed directly. The literature provides three methods for measuring spatial perception: verbal estimates, perceptual matching, and visually directed actions. Verbal estimation refers to asking participants to verbally estimate a particular distance in any measurement unit or as a multiple of a given length [41]. While this method was reported to be considerably accurate for close distances, greater distances were often underestimated [42]. Perceptual matching refers to asking participants to match the distance to an object with the distance to a reference object [42]. A variation of the method is to match the sizes of two objects instead of the relative distances between the objects [42]. Distance estimation with this method tends toward slight underestimation [4,43]. The third measurement method, visually directed actions, has participants view a target object before blindfolding them and asking them to perform actions toward the object [42]. The most common actions are walking towards the target, throwing an object at it, and reaching out to it. Blindfolded walking estimations were reported to be fairly accurate up to distances of 25 meters [41,42].

3. Current Study

Two intervention approaches that can be performed prior to player interaction with a virtual environment to improve their experience are transitional environment and practice. Findings of previous studies have suggested that these interventions can improve various aspects of user experience, including spatial perception, immersion, and user confidence. VR game tutorials are supposed to be experienced before actual gameplay, offering the opportunity for intervention implementation. In this study, we examined the effects of two practice versions (real-world and virtual-world practice) on players' spatial perception, game experience, and performance. We also included a control condition that involved no practice.

Of the two interventions, practices are already a common element in game tutorials while transitional environments are relatively new in VR game tutorials. The approach of transitional environment explored in previous studies [18,19,22,24] required a virtual replica of the users' real environment (e.g., a laboratory, players' homes), presenting a substantial, if not impossible, challenge. Our first set of hypotheses is about the effects of practice on spatial perception:

Hypothesis 1.1 (H1.1). *For those who have received virtual-world practice, their spatial perception before gameplay is better than that of players without practice.*

Hypothesis 1.2 (H1.2). *For those who have received real-world practice, their spatial perception before gameplay is better than that of players without practice.*

Additionally, players are expected to perform better after they have received practice.

Hypothesis 2.1 (H2.1). *The game performance of players with virtual-world practice is better than that of players without practice.*

Hypothesis 2.2 (H2.2). *The game performance of players with real-world practice is better than that of players without practice.*

In this study, we took a different approach to transitional environment, examining a real-world replica of a tool and a challenge in the initial part of a VR game. The transitional environment used is real-world practice. Since transitional environments provide support for players to gradually transit from a real environment to a virtual environment, replicating a real room provides an environment "in between" the origin (i.e., the real world) and the destination (i.e., the virtual world). An environment similar to the virtual world instead of the real world, by extension, should also serve as a transitional environment as long as the environment is deemed to be in between.

Although an exact opposite of the idea of transitional environment explored in the previous studies should be a physical replica of a virtual environment (e.g., a virtual room) in the real world, it would be costly or impractical for the case of VR games, where most players enjoy their VR games in their homes with limited space. Based on this rationale, we view real-world practice as a superior transitional environment to virtual-world practice, making it more effective at improving spatial perception.

Hypothesis 1.3 (H1.3). *For those who have received a real-world practice, their spatial perception before a gameplay is better than that of players who have received a virtual-world practice.*

Regarding the impact on game performance, as reality is more familiar to players, it may be a better environment for players to improve their skill than a virtual environment. However, real-world practice is dissimilar to the virtual environment. Similarities between the practice environment and the gameplay environment may give a stronger advantage to virtual-world practice at improving game performance.

Hypothesis 2.3 (H2.3). *The game performance of players with virtual-world practice is better than that of players with real-world practice.*

Practice helps new players acquire basic skills for a game while improving confidence. It remains unclear which version of practice would give new players higher confidence before gameplay.

- RQ1: Does real-world practice give players more confidence prior to gameplay than virtual-world practice?

The current study focuses on spatial perception within the context of VR games. Spatial perception has been seen as a key aspect in user experience of VR applications. There is limited understanding of the role of spatial perception in relationships between gaming elements and game performance. It would be interesting to examine whether spatial perception influences the effects of practice on game performance. It is possible that spatial perception plays a moderator role in the effects of practices on game performance. Another way to see it is that players' varying levels of spatial perception may influence the effectiveness of practices on game performance. It is possible because if players have different levels of spatial perception within a virtual environment, the influence of practice on game performance during VR gameplay may be enhanced or compromised.

- RQ2: Does spatial perception moderate the effects of practice on game performance?

4. Method

4.1. Study Design

Unlike a previous study that focused on practice that replicated all required tasks in a VR game [36], the current study focused on real-world practice that only replicated some challenges in a VR game. The independent variable (practice) included three conditions: no practice (control condition), virtual-world practice (VR condition), and real-world practice (reality condition). Comparing the control and reality conditions would inform on the effectiveness of real-world practice compared to no practice, while comparing the reality and VR conditions would inform on the effectiveness of real-world practice by using virtual-world practice as a benchmark.

In total, 67 participants (54 of whom were female) with different levels of gaming experience were recruited on a campus of a government-funded university in Hong Kong. Their ages ranged from 18 to 42 years (mean [M] = 23.8, standard deviation [SD] = 4.3). Among the participants, 44 had experience playing video games with lengths of experience ranging from 2 to 18 years. All of the participants indicated that they had no experience playing VR games. While substantially more females made up the sample, gender differences in spatial perception of a virtual space have not been found previously [1]. However, the current context is digital gaming. The distribution of the participants' years of gaming experience across the three conditions is not significantly different ($F(2.41) = 0.36$, $p = 0.70$). The participants with no experience playing video games were evenly distributed among the control, VR, and reality conditions (7, 8, and 8, respectively).

4.2. Materials: VR Game and Practices

A VR game, *Room on Fire,* was designed for this experiment. In the game narrative, the player is trapped in a room that is on fire. The player must extinguish the fire with a water pipe attached to their forehead and can only move their head. A spoon-like tool is attached to the player's face, allowing the player to catch a ball from a dispenser on their left. The player must catch and transfer the ball to a target container on their right. For every ball that is placed in the target container, the water pipe is activated for 10 seconds, allowing the player to extinguish the fire.

The player must then move their head to control the direction of the water spray and extinguish a portion of the fire. To complete the game, the player must extinguish five fires in the room within 10 minutes. The game was developed using Unity and Oculus Rift DK2. Screenshots of the game are displayed in Figure 1. Two types of practice tutorials were created for this study: real-world and virtual-world practice. The ball-transfer task in the game was replicated in both versions of the practice tutorial while the task of spraying water from above the player's head was not replicated.

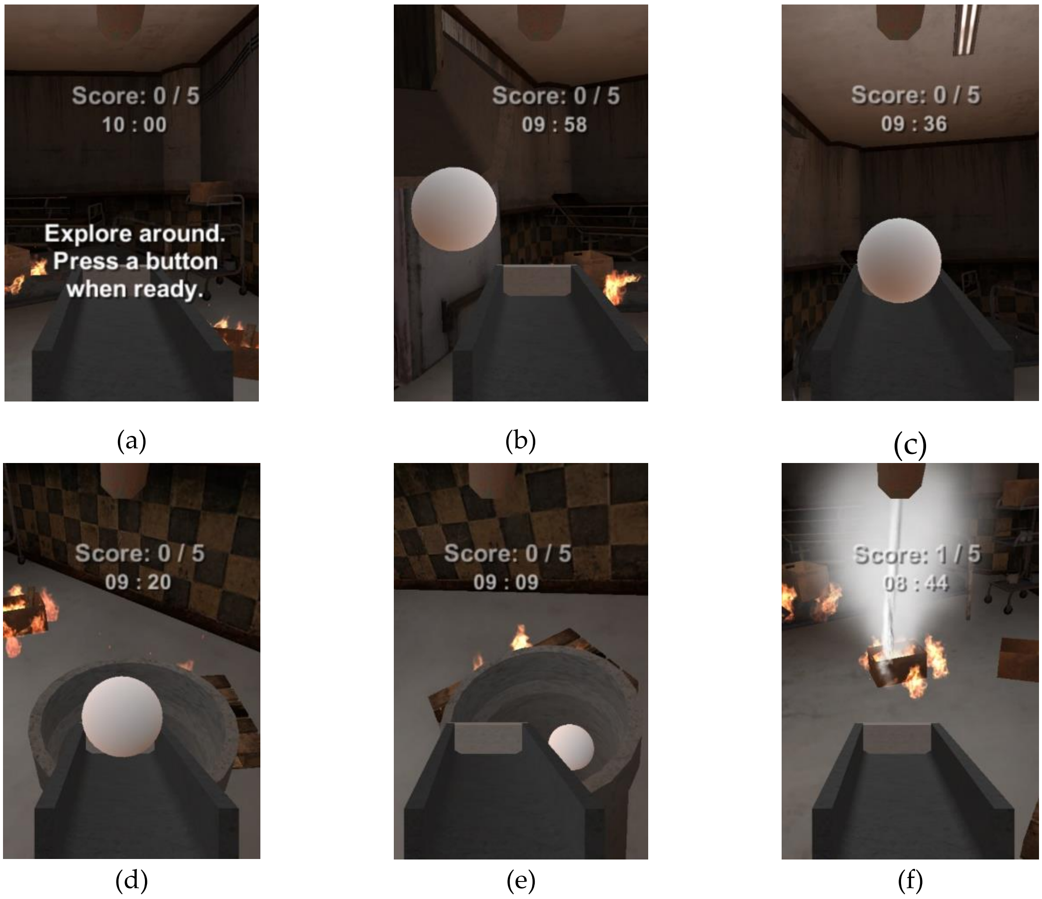
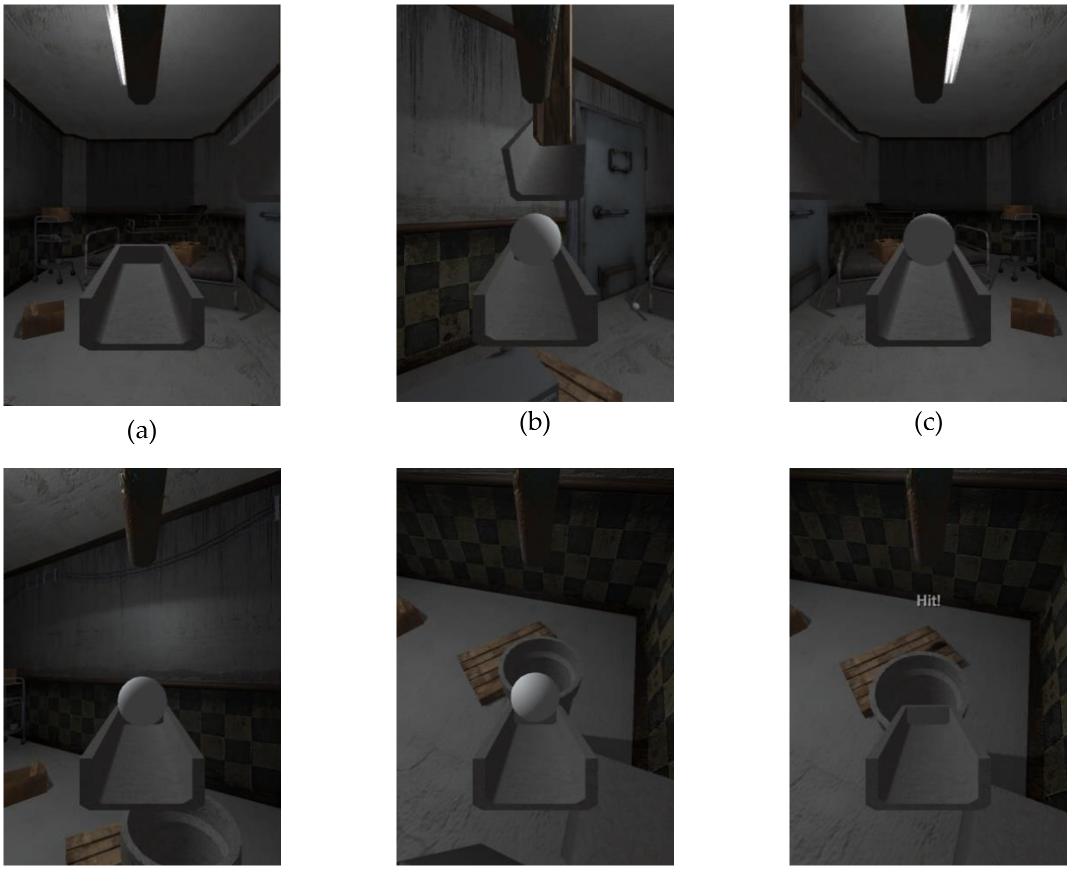


Figure 1. Screenshots from the game *Room on Fire*. (**a**) The player is permitted to observe the virtual environment until a button is pressed, starting the game. (**b**) The player turns left to receive a ball from the dispenser. (**c**) The player carries the ball. (**d**) The player transfers the ball to the target container on the right. (**e**) The ball enters the target container. (**f**) The water pipe dispenses water, allowing the player to extinguish a fire.

For the virtual-world practice, a VR program was created (Figure 2). In the practice program, a spoon-like tool similar to the tool used in the VR game was placed in front of the player's face in the virtual world. The player controlled the tool by moving their head. A target container and a ball dispenser were placed in locations identical to the game. When the player turned left, a ball was dispensed, allowing the player to transfer the ball to the target container. Each player was given 1 minute to practice.

For the real-world practice, a replica of the spoon-like tool was created (Figure 3). The tool was attached to a pair of goggles. A small plastic bucket was placed to the right of the participant as a physical replica of the target container. A researcher stood on the left of the participant. During practice, the participant wore the goggles (with the tool attached). Every time the participant turned left, a researcher placed a ball in the spoon-like tool, and the participant was asked to practice transferring balls to the small plastic bucket. The researcher acknowledged for each ball the participant successfully put into the target by saying 'Hit!'. Each participant was given 1 minute to practice.



(a) (b) (c) (d) (e) (f)

Figure 2. Screenshots from VR practice. (**a**) The player starts in a room. (**b**) The player turns left to receive a ball from the dispenser. (**c**) The player transfers the ball. (**d**) The player reaches the target container on the right. (**e**) The ball is placed into the target container. (**f**) When the ball enters the target container, the word "Hit!" is displayed.

(a) (b)

Figure 3. Equipment for real-world practice. (**a**) A view from the front. (**b**) A view from the back.

The design of the VR game covered both the peripersonal and extrapersonal spaces. The target container for the balls was within hand's reach (peripersonal space) in the virtual environment [6]. The fires in the virtual room were situated in locations beyond hand's reach (extrapersonal space).

The two versions of practice only covered the challenge of transferring balls (i.e., the challenge happens in peripersonal space). A reason for this was to resemble the situations where the practice in game tutorials can only cover part of in-game challenges, a common design direction in most digital games. Another reason was to simulate a situation where real-world practice can only replicate a part of a VR game that is feasible in the real world. For this VR game, the ball transferring part was feasible in the real world while the fire extinguishing part was not. The elements in the VR game, including the tool, the design of the room, and the background story, were inspired by previous works [35,36].

4.3. Measurements

Three areas corresponding to the hypotheses and research questions were examined: confidence with the game before gameplay, spatial perception, and game performance. Confidence was measured using a 7-point Likert scale survey question: "How confident are you in playing the video game?"

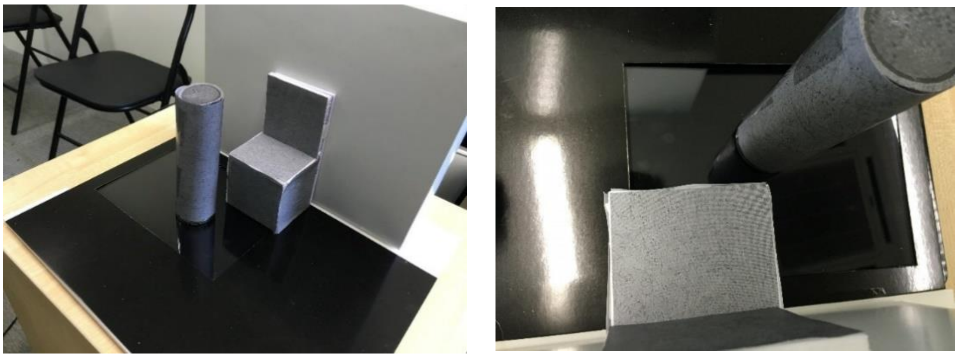
Spatial perception was measured by asking participants to position an object in a physical model of the VR game environment (Figure 4). Perceptual matching was adopted as a measurement of spatial perception. A simplistic physical model was constructed to resemble the player's position and the target container in the game. Figure 4a shows a chair representing the player's position in the game. The wall behind the chair provides an orientation reference. The cylinder represents the target container. Figure 4b shows an iPad under the cylinder that is running an application that records the coordinates of the cylinder. The coordinates were recorded every time spatial perception was measured. It was measured twice in the procedure, once before gameplay (after practice, if any) and once after gameplay.

Many methods exist for measuring player performances [44,45] and studies have used different measurements for different types of game [46]. In the current study, game performance was measured with the time spent to complete all the challenges. The less time spent on finishing the challenges, the better the game performance is.

4.4. Procedure

Participants were randomly assigned to the three conditions. The number of participants in the control, reality, and VR conditions were 22, 24, and 21, respectively. When the participants arrived the laboratory, they were briefed on the procedure. After giving written consent, the participants completed a questionnaire regarding background information, such as gender and age.

A PDF document introducing the VR game was shown to the participants after the questionnaire was completed. This introductory document presented the narrative, rules, and gameplay instructions along with some screenshots of the game. Participants in the reality condition then took part in real-world practice (according to Section 4.2 above); those in the VR condition received virtual-world practice (according to Section 4.2 above); and those in the control condition did not receive practice. Before playing the game, participants were asked to indicate their confidence with the game with a 7-point Likert scale. To measure their spatial perception, they were also led to a simplified model of the game environment (Figure 4) and asked to position a cylinder (representing the target container) relative to where the player would be. Participants then put on the VR headset and reminded to explore the game environment. When each participant felt ready, they told the researcher to start the game. Upon finishing the game, each participant removed the VR headset. Participant spatial perception was measured again and finally, they were debriefed. Each session lasted for 45 to 60 min.



(a) (b)

Figure 4. (**a**) The setup adopted to measure spatial perception. (**b**) A top view of the setup.

5. Results

Table 1 shows a summary of the results.

Table 1. Summary of results.

Measurements	Control (N = 22)		VR (N = 21)		Reality (N = 24)	
	M	SD	M	SD	M	SD
Game Performance (seconds)	137.05	32.56	98.33	20.49	117.46	23.33
Confidence (7-point Likert Scale)	3.91	1.15	4.48	1.25	5.00	1.10
Spatial Perception before Gameplay (cm)	8.78	1.82	7.09	1.71	7.85	2.46
Spatial Perception during Gameplay (cm)	6.90	2.42	5.56	2.06	5.38	1.69

5.1. Spatial Perception

Since spatial perception was measured twice (before and after gameplay), it was analyzed with a two-way mixed analysis of variance (ANOVA) using a between-subject variable (the study conditions) and a within-subject variable (time of measurement: before and after gameplay). In the two-way mixed ANOVA, there was a significant difference across the three conditions (F (2,64) = 5.01, $p < 0.05$, $\eta^2 = 0.14$) and a significant difference across the two time points (F (1,66) = 45.69, $p < 0.001$, $\eta^2 = 0.42$). There was no significant interaction between condition and time (F (2,64) = 0.90, $p = 0.41$).

The main effects of the two variables were deemed significant. In a Bonferroni corrected post hoc analysis, it was found that spatial perception measurements in both reality and VR conditions (averaged across the two time points of measurement) were significantly more accurate than the control condition (both comparisons had $p < 0.05$). There was no significant difference between the spatial perception measurements of the reality and VR conditions ($p = 1.00$). In general, the two versions of practice improved player spatial perception. The results indicated a significant main effect across time. The estimated mean of spatial perception improved from 7.91 cm (95% confidence interval (CI): 7.41 cm, 8.41 cm) before gameplay to 5.95 cm (95% CI: 5.45 cm, 6.45 cm) after gameplay.

In a post hoc analysis focusing on the spatial perception before gameplay, a Bonferroni test revealed that the spatial perception of participants before gameplay in the VR condition (M = 7.09 cm, SD = 1.71 cm) was significantly more accurate ($p < 0.05$) than that of participants in the control condition (M = 8.78 cm, SD = 1.82 cm), supporting H1.1. The test revealed no significant differences for spatial perception between the reality condition (M = 7.85 cm, SD = 2.46 cm) and the control condition, and no significant difference between the VR condition and the reality condition. H1.2 and H1.3 were not supported.

With a focus on the second time point (i.e., after a gameplay), a Bonferroni test revealed that the spatial perception in the reality condition (M = 5.38 cm, SD = 1.69 cm) was significantly more accurate ($p < 0.05$) than that of participants in the control condition (M = 6.90 cm, SD = 2.42 cm). No significant differences were found between the VR condition (M = 5.56 cm, SD = 2.06 cm) and the control condition, or between the reality condition and the VR condition. The real-world practice showed significant improvement on spatial perception after gameplay.

5.2. Game Performance and Confidence

An ANOVA of game performance indicated significant differences among the participants in the different conditions (F (2,64) = 11.94, $p < 0.001$, $\eta^2 = 0.27$). In a post hoc analysis, a Bonferroni test revealed that the game performance of participants in the VR condition (M = 98.33 s, SD = 20.49 s) was significantly higher ($p < 0.001$) than that of participants in the control condition (M = 137.05 s, SD = 32.56 s). The test also revealed that the game performance of participants in the reality condition (M = 117.46 s, SD = 23.33 s) was significantly higher ($p < 0.001$) than that of participants in the control condition ($p < 0.05$). Finally, the test revealed that the game performance of participants in the VR condition was significantly higher than that of participants in the reality condition ($p < 0.05$). Therefore, H2.1, H2.2, and H2.3 were supported.

An ANOVA of player confidence indicated significant differences among the participants in the different conditions (F (2,64) = 5.02, $p < 0.01$, $\eta^2 = 0.14$). In a post hoc analysis, a Bonferroni test revealed that the confidence of participants in the reality condition (M = 5.00, SD = 0.24) was significantly higher ($p < 0.01$) than that of participants in the control condition (M = 3.91, SD = 0.25). The test also revealed no significant difference in player confidence between the participants in the VR condition (M = 4.48, SD = 0.26) and the participants in the control condition. It revealed no significant difference in player confidence between participants in the VR condition and those in the reality condition. The confidence of participants who received real-world practice was significantly higher than that of those who did not have practice. Therefore, in answer to RQ1, real-world practice was shown to improve player confidence before gameplay.

5.3. Moderation Analysis

To answer RQ2, moderation analysis (to test for any moderating effects of spatial perception before gameplay on the effects of the practice on the game performance) was performed with Model 1 in Hayes's PROCESS macro version 3.1 for SPSS version 25 [47]. Practice was coded with the control condition as the reference group. The interaction effect of spatial perception and the practice variable was marginally significant ($p = 0.058$). The conditional effects of the two types of practice on game performance vary at different levels of spatial perception.

When the spatial perception was at 5.79 cm (i.e., one SD below the mean), virtual-world practice had a significant effect of on game performance ($p < 0.0001$) compared to no practice. At this level of spatial perception, the conditional effect of changing from no practice to virtual-world practice was −57.58 seconds (with a 95% CI: −82.81 s, −32.35 s). In other words, virtual-world practice reduced the time to complete the challenges by an average of 57.58 seconds. At this level of spatial perception, the conditional effect of real-world practice on game performance was marginally significant ($p = 0.056$), which was an average of -24.32 seconds (with a 95% CI: −49.32 s, 0.67 s).

When the spatial perception was at 7.92 cm (i.e., the mean), both virtual-world and real-world practice had significant effect on game performance ($p < 0.0001$ and $p < 0.005$, respectively). At this level of spatial perception, the conditional effect of virtual-world practice on game performance was −37.46 seconds (with a 95% CI: −54.59 s, −20.33 s) compared to no practice. The conditional effect of real-world practice on game performance was −23.19 seconds (with a 95% CI: −38.96 s, −7.41 s) compared to no practice.

When the spatial perception was at 10.05 cm (i.e., one SD above the mean), the real-world practice had a significant effect on game performance ($p < 0.05$). At this level of spatial perception, the conditional effect of real-world practice on game performance was an average of −22.05 seconds (with a 95% CI: −41.21 s, −2.89 s). The conditional effect of virtual-world practice at this level of spatial perception was not found significant ($p = 0.19$).

To compare the conditional effects between the real-world and virtual-world practice, the moderation analysis was repeated with the reference group changed to the VR condition. The interaction effect of spatial perception and the practice variable remained the same, which was marginally significant ($p = 0.058$). When the spatial perception was at 5.79 cm (M-SD), the conditional effect of virtual-world practice on game performance was significantly different from that of real-world practice ($p < 0.005$). At this level of spatial perception, a change from virtual-world practice to real-world practice caused players to spend an average of 33.26 seconds more completing the game (with a 95% CI: 13.83 s, 52.69 s). When the spatial perception was 7.92 cm (M) and 10.05 (M+SD), the conditional effect of virtual-world practice was not significantly different from real-world practice ($p = 0.08$ and $p = 0.72$, respectively).

To recap, the conditional effect of virtual-world practice on improving game performance (as compared to no practice) was significant when the spatial perception was at the mean and at a more accurate level (M-SD). The conditional effect of real-world practice on improving game performance was significant when the spatial perception was at the mean and at a less accurate level (M+SD). The difference in the conditional effects between virtual-world practice and real-world practice was deemed significant only when the spatial perception was at a more accurate level (M-SD).

6. Discussion

Regarding spatial perception, H1.1 was supported, indicating virtual-world practice was effective at enhancing players' spatial perception of the virtual environment before playing a VR game. H1.2 was not supported, indicating that real-world practice provides insignificant enhancement of spatial perception before gameplay. However, according to the results of the mixed ANOVA, participants who received real-world or virtual-world practice had significantly better spatial perception of the virtual environment of the VR game (averaged across time). This suggested that the real-world practice was effective at enhancing spatial perception, but its effect may not be strong enough to be shown as significant immediately following practice. The spatial perception of players with real-world practice may be better after one to two gameplay sessions than those without practice. The time variable in the analysis also showed significant effect, indicating participants had significantly improved spatial perception after their first gameplay session. This is consistent with the previous studies [28–30], which stated that practice in (or opportunities to interact with) a virtual environment increase users' spatial perception of the virtual space.

The hypotheses about the effects of the two practice forms on game performance (i.e., H2.1, H2.2, and H2.3) were supported. Both real-world and virtual-world practice were effective at enhancing players' game performance. Although the real-world practice happened in a more familiar environment (i.e., the real world), the virtual-world practice was more effective than the real-world practice at improving game performance. On the other hand, the real-world practice was shown to significantly improve player confidence, which was not the case for virtual-world practice. This suggests that having real-world practice may be helpful to the players in areas other than game performance.

Although the moderation analysis of the spatial perception only showed a marginally significant moderator effect on the influence of practices on game performance, the results suggested an interesting pattern, implying that when the spatial perception is the more accurate, the virtual-world practice is more helpful in improving game performance. However, as spatial perception became less accurate, real-world practice became more helpful at improving game performance.

6.1. Theoretical Implications

The results of the current study offer several theoretical implications. Firstly, a game tutorial is a valid opportunity to provide practice to players, improving spatial perception of a VR game's virtual environment. Even if the practice covers challenges in peripersonal space only while the gameplay involves challenges in peripersonal and extrapersonal spaces, practice still helps improve spatial perception and game performance.

Secondly, real-world practice can be as effective as virtual-world practice and can be better than no practice at all, but the effect becomes significant only if measurements are averaged across time. This contributes to the literature of spatial perception by suggesting that real-world practice can be adopted as a type of transitional environment to enhance and prepare players' spatial perception. This view of replicating virtual environment elements in the real world as a transitional environment is innovative. Although statistical significance of the result is not conclusive, the results offer evidence that warrants further research into this approach.

Thirdly, spatial perception seems to have a moderating influence on gameplay in VR games, affecting practice's effect on enhancing players' game performance. The moderating effect has different implications for real-world and virtual-world practice as the spatial perception varies, indicating that if the spatial perception of a player varies, the effect of practice on their game performance will vary as well. Virtual-world practice tends to be more effective at improving game performance if a player's spatial perception is more accurate. If a player's spatial perception were less accurate, real-world practice would be more helpful. Furthermore, if there are limitations to improving a player's spatial perception, real-world practice may provide support. Practice within the virtual environment is not the only option. Limitations on improving player spatial perception may include a lack of visual distance cues in the virtual environment caused by design requirements, issues with the VR hardware design, and player cognitive ability to perceive virtual space.

Fourthly, spatial perception in VR games is definitely worth further research. Such research may not directly affect VR gameplay, but it may influence the effects of practice in tutorials. The effects of various elements (e.g., narratives, character designs) in a VR gaming experience can potentially be influenced by spatial perception. The attention to the role of spatial perception in the entertainment context is presently limited. The current findings offer justification for future studies to focus on the role of spatial perception in the effects of various elements of VR games.

Finally, real-world practice was effective at making new players more confident before their first gameplay session. Players understood that they were practicing only some of the tasks required in the game, yet the real-world practice remained effective at giving them confidence. This finding indicates the strength of real-world practice as a preparation for VR gaming, suggesting that practicing tasks in the real world can improve player confidence in performing tasks required in a VR environment. In the experiment, virtual-world practice was not demonstrated to be effective at improving player confidence. Thus, the real world is suggested to be a suitable place for new players to gain confidence for a VR game.

6.2. Practical Implications

The study proposes to use the tutorial as an opportunity to provide practice with the goal of improving players' spatial perception of the virtual environment of a VR game. The results have indicated that VR game designers should consider viewing game tutorials as a means of improving players' spatial perception before they enter the core gameplay of a VR game. The moderating role of spatial perception suggests that spatial perception may not directly affect the gameplay experience but it may influence the effects of various elements such as tutorials in a VR game.

The study also proposes an approach for VR game practice in the real world to improve spatial perception. This approach does not require a virtual replica of the real environment (as do other transitional environments explored in previous studies [20–22,24]) when a player starts a VR game, expanding its applicability. The approach of real-world replica of VR game elements may be limited in some contexts, as VR games can offer beneficial experiences and interactions not possible in the real world. However, some VR game elements are based on the real world, such as guns in the VR shooting game *Arizona Sunshine* (2016) being based on physical guns. Our approach to real-world replication can only replicate parts of the physical forms of tools and mechanics in the challenges that are possible in the real world. This limits the applicability of the approach. However, we believe it remains applicable to many cases, such as shotgun gameplay in *Raw Data* (2016) and archery shooting in *The Lab* (2016).

Another limitation of real-world practice is that real-world replicas of virtual-world items must be tailor-made for each VR game, which may increase costs and prevent distribution across online sales channels. However, there are examples where game companies have sold games with physical boxsets via traditional channels: the *Nintendo Labo* (2018) series and *Ring Fit Adventure* (2019) for the Nintendo Switch game console. The success of these cases demonstrates the commercial feasibility to develop games with physical props.

A limitation of real-world practice is that visual effects in VR games, such as fire and holograms, cannot be replicated in real-world practice. We actually see this as a benefit because fewer effects can reduce the risk of spoiling details of the actual game. Real-world practice allows players to practice with tools and challenges without sacrificing any surprises planned in a VR gameplay by the game designers.

6.3. Limitations

The current study has its limitations. Only three aspects of the virtual world experience are covered herein: game performance, confidence, and spatial perception. Therefore, future studies should investigate other aspects of virtual experiences. Despite the limited coverage of the aspects of virtual experiences, the results of the current study reveal interesting patterns about the moderating role of spatial perception. This warrants future studies on the influence of spatial perception on various aspects of the entertainment experience of VR.

A relatively simple VR game was used in this study. Future studies should investigate the effects of real-world practices on other types of VR games or virtual environments. For instance, the results of the current study were obtained using only one VR game called *Room on Fire*. The challenges built into this game require players to perceive distances, which qualifies as a material for the study. However, many other different forms of VR game mechanics are available that require perception of the virtual space, such as shooting moving targets (e.g., zombies) and lobbing objects by using controllers (e.g., basketballs). Therefore, other forms of game mechanics should be analyzed in future studies.

7. Conclusions

This paper explored the effectiveness of two versions of practice (virtual-world and real-world practice) at enhancing players' spatial perception of the virtual environment in a VR game. Practicing before entering a VR game was found to be an effective means of enhancing spatial perception. Despite the fact that the virtual world is not fully replicated in the real world, real-world practice is also effective. The study revealed that spatial perception might moderate the influence of practice on game performance.

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