Exploring the Effect of Display Type on Co-Located Multiple Player Gameplay Performance, Immersion, Social Presence, and Behavior Patterns

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Abstract: With advances in virtual reality (VR) technology, immersive head-mounted displays (HMDs) have become widely accessible. These devices have made social games and platforms like VRChat popular. Although the literature points to several factors that affect immersion and social presence, there has been no study that has explored the effect of social display setup on immersion and gameplay in multi-player social games. This work aims to shed light on this issue and investigates the effect of social display setup on gameplay performance and experience (i.e., immersion and social presence) in a multi-player competitive social game (i.e., Jenga). We conducted a one-way between-subjects experiment with 24 participants equally distributed in three groups (4 pairs of 2 participants in each group, who were all strangers to each other) according to three social display setups (2 small-screen tablets, 1 shared 40-inch large TV, and 2 VR HMDs). Our results indicate that (1) players gave a lower rating to challenge in the VR-based social setting than in the small-screen tablet display setting, and (2) gameplay behavior patterns are different among these social display setups.

1 INTRODUCTION

Playing with others (that is, social gameplay) is a prevalent and essential aspect of games, digital or otherwise. Many games that originated for single-player settings now have multiplayer modes (i.e., Call of Duty series) (Hudson and Cairns, 2014). It has been found that playing social games is an excellent approach to extend social networks, not only for young players attending high schools or universities (Eklund and Roman, 2017; Khanolkar and McLean, 2012) but also for community-dwelling older adults or older adults who are currently in nursing homes (Schell et al., 2016; Xu et al., 2022).

Until recently, mobile devices, PCs, and gaming consoles were the only choices for people to play social games with other players. With recent advances in virtual reality (VR) technologies, particularly in the form of affordable head-mounted displays (HMDs)(Monteiro et al., 2022), VR gaming has become an attractive alternative platform for people to play social games with others, either collaborating with or competing against each other (Liang et al., 2019). An online social platform called VRChat[1] has around 42k players playing the game during peak levels[2], where players gather in a chosen virtual space to explore and socialize. Population One[3] allows players to enter the battlefield in a group of three (random on-

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[1] https://hello.vrchat.com/
[2] Steam data https://steamplayercount.com/app/438100
[3] http://www.populationonevr.com/

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line players or friends) to play against other squads. In addition, VR games such as Beat Saber[4], Ragnarock[5], Fit XR[6] all allow players to compete with their friends and strangers. As a result, gamers now have three social settings for playing social games based on display types: mobile devices (e.g., smartphone, tablet), large displays (e.g., monitor, TV), and immersive VR (e.g., VR HMDs).

Common co-located social settings for two players among these displays are two mobile devices, one shared large display, or two VR HMDs. Because two players share a large display while mobile devices and VR HMDs are used by players separately, there can be significant differences and affordances between these social display settings regarding gameplay, social presence, and privacy and could bring forth different interaction behaviors (Chen et al., 2021b; Chen et al., 2021a; Chen et al., 2020). For instance, mobile devices and VR HMDs show a private user interface panel (e.g., skills cool-down time in Genshin Impact[7]) separately to each player, while a shared display must display all information to both players. Mobile devices and VR HMDs players could privately change tactics and player instructions in games like FIFA 23[8], but this information is visible to both players in a large shared display setting. Although the above information is hidden from the other mobile device users, they could always attempt to spy on the other player's display (Chen et al., 2020). However, this is impossible for VR players since the VR HMDs block the view of both players in the co-located setting, leading to a largely underexplored research area (i.e., social gameplay in VR).

Given the insights from previous research that physical proximity, communication tools, and gaming environments play a crucial role in shaping social presence and gameplay experiences (Voida et al., 2010; Derks et al., 2008; Monteiro et al., 2018), this study aims to explore further the impact of social display setups on co-located competitive gameplay. The following research questions (RQs) are proposed to guide this study:

(RQ1) How VR HMD setups affect co-located competitive gameplay performance and experience compared to 2D displays(i.e., immersion and social presence)?

(RQ2) What are the behavior patterns of each social display setup when players play a co-located competitive game?

[4]https://beatsaber.com/
[5]https://www.ragnarock-vr.com/home
[6]https://fitxr.com/
[7]https://genshin.mihoyo.com/en
[8]https://www.ea.com/en-gb/games/fifa/fifa-23

To explore these two research questions, we have developed an in-house multiplayer game and conducted an experiment with the game to investigate three social display setups, which are two 8-inch small tablet displays (SD), one 40-inch large TV display (LD), and two VR HMDs, in a co-located Jenga game with 24 participants who are all strangers to each other. Figure 1 shows the three versions of the game used in the experiment. By examining the effects of different social display setups on co-located competitive gameplay, this study aims to contribute to a better understanding of how to enhance immersion, social presence, and overall gaming experiences.

Figure 1: Examples of paired users during the experiment: (a) small display setup: two participants each using one small tablet display, (b) large display setup: two participants playing the game via a shared large display, and (c) VR HMDs setup: two participants playing the game while wearing the VR HMDs.

2 RELATED WORK

2.1 Immersion and Gameplay

Immersion is an experience that is commonly mentioned by gamers, designers, and game researchers (Brown and Cairns, 2004). It involves a lack of awareness of time, a loss of awareness of the real world, and a feeling of being absorbed in playing a game. Most importantly, immersion results from a good, positive gaming experience (Jennett et al., 2008). It is worth noting that while various definitions of immersion exist, such as that of Slater (Slater, 2003), which focuses on the technical attributes of VR systems, our discussion centers around immersion as a subjective experience resulting from engaging gameplay rather than delving into the nuances of system-driven immersion.

Several studies have been conducted to investigate possible factors that could affect players' immersion during gameplay, such as display size, resolution, and frame rate (Hou et al., 2012; Wang et al., 2022; Wang et al., 2023) or controller type (Monteiro et al., 2020). The screen size of the gaming devices is a notable factor (Nakano et al., 2021). Thompson et al. (Thompson et al., 2012) conducted a study to compare the immersion level of playing the 'Fruit Ninja' game on the iPad 1, which in their study was the large display, and the iPod Touch 4, which was the small display. They found that playing 'Fruit Ninja' on the iPad could lead to a significantly higher immersion than on the iPod. Later studies have further confirmed that screens with larger sizes could provide a more involved, immersive gaming experience than smaller ones (Hou et al., 2012; van den et al., 2009; Beyer et al., 2014). Schild et al. (Schild et al., 2012) found that the type of 3D graphics could also affect the immersion level. Their experiment results showed that a stereoscopic display resulted in increased immersion than a monoscopic display. Similar findings were reported for VR displays in (Luo et al., 2021), which also reported that stereoscopic views in VR improved user experience. Cairns et al. (Cairns et al., 2014) found that the naturalness of the game controls influences players' immersion experience while playing mobile games. In line with Cairns et al. (Cairns et al., 2014), Pietschmann et al. (Pietschmann et al., 2012) found that motion-based input such as the Nintendo Wii Remote could result in a higher degree of immersion than a classic gamepad controller in a motion-based exergame. Similar results are also found in (Lindley et al., 2008; McEwan et al., 2012). In addition to the controller type, knowing how to control the game can also contribute to immersion (Brown and Cairns, 2004; Monteiro et al., 2020). Because these factors (i.e., content and controller input) could affect the perceived immersion in games, we have carefully controlled them in our experiment (more details in Section 3.1.2).

The level of challenge is also a positive predictor of the immersion level during gameplay. To increase players' immersion level, game designers could either increase the difficulty of the content (Qin et al., 2009; Cox et al., 2012) or put a leaderboard with the players' friends on it to a game (Park et al., 2017). Regarding the social aspect, Cairns et al. (Cairns et al., 2013) found that social play enhances the sense of being in the game where interaction is through the game. Likewise, social entities could also enhance immersion (Liszio et al., 2017). In short, playing against other players inherently makes the level of challenge dynamic and unpredictable, and having a social component in the game can influence immersion levels.

Although research reported that players could be more immersed in VR HMDs than a large display (e.g., monitor or TV) when playing a first-person shooter game (Amin et al., 2016) and exergame (Xu et al., 2020; Xu et al., 2021), the results might vary due to the type of game used in the experiment or the length of gameplay. For example, Fairclough and Burns (Fairclough and Burns, 2013) found that VR HMDs could not increase the level of immersion in a racing game compared to a 5-inch LCD monitor and a 40-inch LCD TV. Results from Walch et al. (Walch et al., 2017) showed similar findings in a different racing game, where they tested a VR HMD against a setup with multi-flat screens. Furthermore, Xu et al. (Xu et al., 2019) also found that VR could not lead to higher immersion than a 50-inch 4K TV for 3-minute gameplays with an exergame. Similar findings have been observed in our types of applications, like those focused on learning (e.g., see (Lu et al., 2023)).

To our knowledge, no study has been conducted to examine the effect of social display setup on immersion in a co-located social game setup. Therefore, our study aimed to shed light on this largely underexplored area.

2.2 Social Presence and Gameplay

One of the definitions of social presence that is generally well-accepted is that it is the "sense of being together with another" person (Biocca et al., 2003). Some existing literature suggests that social play could have a negative role in immersion. For instance, Sweetser and Wyeth (Sweetser and Wyeth, 2005) noted that social interaction can often interrupt immersion in games, which is understandable because immersion is about being in the game while playing socially requires one to be aware of what is happening outside the game—–in the case of social presence, to be aware of the other player(s). However, a later study by Cairns et al. (Cairns et al., 2013) showed that players were more immersed when playing against another person rather than playing against the computer, regardless of whether the other player was online or in the same room, as long as the other player was part of the game.

There is limited research on exploring the factors that could affect social presence. The location where a game is played might be one factor. Studies (Gajadhar et al., 2008; Cairns et al., 2013; De Kort et al., 2007) found that playing social games in a co-located setup could result in a higher social presence than a remote setup (i.e., playing a social game online). However, while it was suggested that location does not guarantee behavioral engagement between players (Magerkurth et al., 2004), the seating and viewing arrangements (Sommer, 1967) were the key to increase behavioral engagements (e.g., eye contact). Therefore, the location may contribute to social presence between players during gameplay (De Kort et al., 2007) and, as such, needs to be controlled in our experiment. The input type (Wolbert et al., 2014; Abeele et al., 2013) has also been found to have an effect on social presence. For instance, Abeele et al. (Abeele et al., 2013) found that players experienced more social presence (in involvement-empathy) when playing with a steering wheel than a classic controller in a racing game. In short, based on this review, we needed to control the seating arrangement in our experiment so that it would not affect the perceived social presence during gameplay.

The effect of social display setup on social presence in a co-located social game setup was previously studied in (Kauko and Häkkilä, 2010). Their results suggested that social presence was not significantly different when playing in LD condition (using two 21-inch LCD monitors as one single large display) and SD condition (using two smartphones). Nevertheless, to our knowledge, no study has explored the difference between VR HMDs and traditional display setups (SD and LD) regarding social presence. Our research aims to fill this gap.

3 EXPERIMENT

3.1 Task

3.1.1 Jenga

A digital version of the classical social game Jenga was developed using the Unity3D game engine (see Fig. 2 for the game prototype for the three platforms). Jenga is selected as the testbed with the following criteria: (1) for the players: rules are simple and possible novelty bias is low; (2) for the experiment: factors such as game content (model, audio, graphics) and control mechanism can be easily controlled across the platforms, in addition, because it is a turn-based game, the potential impact due to network latency can be minimized (although it is already at a very low level; see below); (3) for the displays types: Jenga can be comfortably played in all displays where many other types of games could suffer issues such as simulator sickness (especially in VR HMDs). Further, Jenga is a good representative of a competitive social game since (1) it presents a head-to-head challenge in real time, (2) players can observe opponents' movements while thinking about and planning their next move, and (3) it affords opportunities for players to distract each other or socialize.

We used the Photon Unity Networking unit[9] to enable multiplayer functions for our game. By selecting a local server, we were able to control the latency to less than 50 milliseconds—the actual range was between 20 to 50 for the SD and VR groups which, according to previous research, is an acceptable level for online games (Pantel and Wolf, 2002; Claypool and Claypool, 2006; Jarschel et al., 2011).

3.1.2 Control Mechanism

All versions used the same controller mechanism to interact with the game.

At the beginning of a player's turn, a block would be highlighted in yellow, indicating that this block can be selected by the player who is currently playing. Players could turn the left joystick up/down/left/right to highlight another block for later selection. Pressing "A" on the controller selects the highlighted block and turns its color to red (from yellow), indicating that this block has been selected. Once selected, players can move the red block vertically leftward/rightward/forward/backward with the left joystick (i.e., left/right/up/down).

To move the block up or down, players need to press the "Y" button and move the left joystick up/down. To rotate the block, players need to press the "Y" button and move the left joystick left/right; the block can be rotated clockwise/counterclockwise around its center axis.

The right joystick is used to allow the camera's rotation to change viewing perspectives. When it is moved left/right, the viewing perspective changes horizontally, and when it is moved up/down, the perspective changes vertically. The left/right trigger buttons allow zooming in and out. When a block is selected, the player can press button A again to deselect the block, which will now follow the physics laws and fall down. If no blocks fall to the ground, the other player takes the turn.

3.1.3 Rules

We followed the rule of the Jenga game[10] to ensure the game is intuitive and easy to understand. At each turn, the player needs to use the controller to select one block from the tower and then place it on the top of the tower to complete its turn. If any block falls from the tower or the tower collapses, the player who made the block or the tower fall would lose the game; otherwise, the next player starts their turn. For each turn, users have 99 seconds to decide which block to move and where in the tower to place it.

3.2 Experiment Design

We followed a one-way between-subjects experimental design with a social display setup as the independent variable with three groups; that is, two small

[9] https://assetstore.unity.com/packages/tools/network/photon-unity-networking-classic-free-1786

[10] https://jenga.com/about.php

Figure 2: Interface of the game for the tablet and HMD versions: (a) from Player 1's perspective and (b) from Player 2's perspective when it is Player 1's turn. (c) The interface for the shared large display when it is Player 1's turn. We ensured that all three social display setups shared the same game content (i.e., models, materials, textures) and control.

tablet displays (SD), a large shared TV display (LD), and two VR HMDs (VR). For each group, participants were asked to play the game three times. The advantage of applying this design for the study was that participants would have enough gameplay experience before completing the questionnaire, and the length of the experiment could be controlled within an hour.

Utilizing a one-way between-subjects experimental design with three distinct social display setups (small tablet displays, a large shared TV display, and VR HMDs) as the independent variable allows for a direct comparison of the impact of each setup on co-located competitive gameplay experiences. By having participants play the game three times, they are given the opportunity to become familiar with the gameplay and controls, thus minimizing the influence of learning effects on the outcomes and allowing for a more accurate assessment of the social display setups' effects.

The game was played in pairs of 2 participants who were randomly assigned to each group (i.e., SD, LD, VR). The participants assigned to each pair did not know each other before the experiment (we ensured this prior to the study by asking if they knew each other).

3.3 Apparatus and Setup

In the SD setup, players were asked to sit next to each other and play the game on two NVidia Shield tablets via attached IPEGA controllers (see Fig. 1a). The tablets had a 1920 x 1200 resolution screen, 2Gb of memory, 2.2 GHz NVidia k1 processor. For the LD setup, players were asked to sit next to each other and play the game in front of a 40-inch 4K TV using an Xbox wireless controller each (see Fig. 1b). The game was run on a Windows PC, which had an i7 6700k CPU, 16 GB of memory, and a GTX 1070 dedicated graphics card. We used Oculus Rift CV1 as our VR HMDs for the VR setup, where the two VR HMDs were connected to 2 Windows PCs, which had the same specifications as the LD setup. Players were asked to stand in a zone next to each other and play the game using the same Xbox controllers as the LD group (see Fig. 1c). To avoid confounding factors, we controlled the game content, control input, and seating arrangement (i.e., next to each other), because as stated earlier they could have an impact on both immersion and social presence (Cairns et al., 2014; Pietschmann et al., 2012; Lindley et al., 2008; Sommer, 1967).

The SD and LD setups in our study followed the setup used in a previous study (Kauko and Häkkilä, 2010), except the players are sitting next to each other in our SD setup. During the experiment, the devices in SD and VR settings were connected and synchronized over a network connection (see Section 3.1.1). We also adjusted all versions based on display refresh rate to achieve a comparable and smooth gaming experience (VR = 90 Hz, PC = 60Hz, Tablet = 60Hz).

3.4 Measurement

3.4.1 Performance Data

We collected the number of turns players took during the game as a performance measure.

3.4.2 Questionnaire Data

We used (1) Immersive Experience Questionnaire (IEQ) (Jennett et al., 2008) for measuring immersion and (2) Social Presence in Game Questionnaire (SPGQ) (De Kort et al., 2007) for measuring social presence. Both IEQ and SPGQ questionnaires use 5-point Likert scale.

The IEQ comprises five subscales representing independent clusters of variables: Cognitive Involvement (CI), Emotional Involvement (EI), Real World Dissociation (RWD), Challenge, and Control. To tailor the IEQ for our study and obtain more precise and relevant measurements, we adapted and expanded the questionnaire. For instance, instead of directly inquiring about the game's overall challenge, participants were asked to assess the challenge of selecting a block, moving it out, and placing it on top of the tower separately. The adapted IEQ includes 45 questions, with 12 questions for CI, 11 questions for EI, 8 questions for RWD, 8 questions for Challenge, and 6 questions for Control. We used both negative and positive wording in the questions to control for potential effects caused by question phrasing.

Similarly, we adapted and expanded the SPGQ to better suit our study. For example, rather than asking whether players paid close attention to each other, participants were asked whether they paid attention to their opponent's gameplay specifically. The adapted SPGQ consists of 17 questions, with 6 questions for Empathy, 5 questions for Negative Feelings, and 6 questions for Behavioral Engagement.

The rationale behind adapting and expanding the IEQ and SPGQ is to increase the sensitivity and specificity of the measures to the unique characteristics of our study. By customizing the questionnaires to better align with the gaming context and specific aspects of the gameplay experience under investigation, we can collect more accurate and relevant data. This, in turn, will enable us to understand better the impact of social display setups on immersion and social presence in co-located competitive gameplay, providing a stronger basis for drawing conclusions and making recommendations.

In total, the questionnaire utilized in our study comprises 53 questions, with 45 sourced from the adapted IEQ and 17 from the adapted SPGQ. Among these questions, nine were shared by both IEQ and SPGQ (see Appendix for details).

3.4.3 Qualitative data and Behaviour Observation

During the gameplay, an onsite experimenter acted as an observer, responsible for observing participants' behaviour and taking notes. We used an unstructured observation study focusing on users' behaviour: (1) Do they collaborate or compete, (2) What are players' feelings, (3) How is their physical behaviour when it is their turn and the opponent's turn? In addition, the experimenter also took notes on the verbal communication participants had.

After the gameplay, we also asked participants to provide feedback on the game, their opinions on the social game settings, and their overall gameplay experience.

3.5 Procedure

Before the experiment, participants were briefed on the purpose of the experiment and asked to sign the consent form and complete a pre-experiment questionnaire. Participants were told to be competitive and try to win the game. After, all pairs were given training sessions to get them familiar with the game and especially how to select and manipulate the blocks, because a previous study suggested that control mechanisms could also affect immersion (Brown and Cairns, 2004). They then entered the experiment stage, where they had to play in the assigned setting for three rounds. Between each round, they could rest as much as they wanted. Then, they were asked to complete the 53-question questionnaire mentioned in the Measurement section. The experiment was conducted in a research lab where no participants could be seen by others. The experiment lasted at least 30 minutes for each pair of participants.

3.6 Participants

Twenty-four participants (16 males and 8 females) aged between 20 to 25 (M = 21.95) years old were recruited from a local university campus and were rewarded with snacks and refreshments at the end of the experiment. Twelve of them played digital games on a weekly basis. 50% of our participants had previous experience interacting with VR HMDs before the experiment, but none of them were regular VR users. Fourteen of them had played Jenga before, mostly with their friends.

Based on participants' own ratings from the pre-experiment questionnaire, the three groups had no statistically significant difference in participants' background information, game experience, and device familiarity.

4 RESULTS

We analyzed the data using the one-way ANOVA with social display setup (SD, LD, VR) as the between-subjects variable. Tukey's HSD was used for pairwise comparisons. All the statistical analyses were performed using IBM SPSS 24.

IEQ. Table 1 shows the descriptive statistics for the IEQ and its subscales. There was no significant effect of social display setup on the overall Immersion scores ($F_{2,21} = 0.267, p = 0.77$). Regarding the IEQ subscales, ANOVA tests yielded a significant difference between social display setups on the feeling of Challenge ($F_{2,21} = 4.946, p = 0.017$), while post-hoc analyses indicated that playing the game in SD could result in a significantly higher challenge than in VR ($p < .05$). In addition, there was a trend toward significance regarding Emotional Involvement

Table 1: Means (standard deviation) of IEQ overall score and its subscales.

IEQ Components	SD (N=8)	LD (N=8)	VR (N=8)
Immersion	103.88 (6.20)	106.41 (9.47)	104.07 (7.03)
Cognitive Involvement	32.72 (4.78)	31.78 (2.16)	30.56 (2.46)
Emotional Involvement	19.77 (1.51)	23.05 (3.99)	22.09 (2.16)
Real World Dissociation	25.27 (2.40)	24.94 (3.14)	25.38 (4.02)
Challenge	***11.44 (1.35)****	11.13 (1.69)	***9.38 (1.16)****
Control	14.69 (1.99)	15.52 (2.09)	16.67 (2.44)

Table 2: Means (standard deviation) of SPGQ overall score and its subscales.

SPGQ Components	SD (N=8)	LD (N=8)	VR (N=8)
Overall SPGQ	6.63 (1.06)	6.25 (0.84)	6.26 (0.69)
Empathy	2.63 (0.40)	2.56 (0.37)	2.40 (0.72)
Negative Feeling	1.63 (0.75)	1.40 (0.37)	1.68 (0.47)
Behavior Engagement	2.38 (0.62)	2.29 (0.65)	2.19 (0.48)

($F_{2,21} = 2.967, p = 0.07$). No other significant effects were found between social display setups on Cognitive Involvement ($F_{2,21} = 0.837, p = 0.45$), Real World Dissociation ($F_{2,21} = 0.039, p = 0.96$), and Control ($F_{2,21} = 1.662, p = 0.21$).

SPGQ. The results of SPGQ components can be found in Table 2. There was no significant effect of social display setup on SPGQ overall score ($F_{2,21} = 0.473, p = 0.63$). We could not find any significant effect of social display setup on all SPGQ subscales: Empathy ($F_{2,21} = 0.414, p = 0.67$), Negative Feeling ($F_{2,21} = 0.561, p = 0.58$), and Behavior Engagement ($F_{2,21} = 0.205, p = 0.82$).

Gameplay. On average, the number of turns in SD, LD, and VR is 6.42 (std = 2.78), 10.42 (std = 6.40), 7.75 (std = 3.77), respectively. There was no significant effect of social display setup on the number of turns played during the experiment ($F_{2,33} = 2.374, p = 0.11$).

5 DISCUSSION

5.1 RQ1: Would Social Display Setups Affect Co-Located Competitive Gameplay Performance and Experience

We found that statistically, social display setup did not have an influence on overall immersion and social presence. Although there was no significant effect of display type on overall immersion, we did observe that players felt less challenged (i.e., challenge subscale from IEQ) when playing the Jenga game in VR than in the SD (despite the VR setup was the condition where their opponents often intentionally verbally distracted the players). One possible explanation might be that VR provided a better spatial view for players to observe which block to select, how to move it without moving the other blocks, and where on the top of the tower to place it. But this is challenging in small tablet displays.

5.2 RQ2: What Are the Behavior Patterns of Each Social Display Setup when Players Play the Co-Located Competitive Game?

The behavior patterns were discussed based on our observations (e.g., players' social behavior patterns and their comments) during the gameplay sessions and the qualitative feedback that was collected in the post-experiment questionnaire.

SD (Two Separate Tablet Displays). Although it was clearly stated to be a competitive game, participants mentioned that it was fun to spy on and try to guess how the other player interacted with the game by watching their devices to find out their thoughts and learn from their strategies. Also, the pair of participants enjoyed seeing the facial and body expressions of the other player. Moreover, they were also observed to have communicated and talked quite a lot with each other.

LD (A Large Shared TV Display). We observed participants have a higher willingness to participate in the other player's turns in this setup because this shared display allows players to observe how the other player interacted with the game in a direct way. Overall, we found participants laughing the most and that they showed more signs of trying to play the game in a cooperative way than the other two setups, even though we have clearly stated to the players that they should try to be as competitive as they could and try to win the game). In many instances, they shared their observations (e.g., "You should not select that block") and even encouraged their opponents ("Come on, you can do this," or "You shouldn't try that") to do better. They were less focused on selecting the block from the tower on their own and often discussed with their opponents what would be the best block to move. They mentioned that instead of trying to make the tower collapse during their opponent's turn, they would rather be exploring how high they could stack the blocks without making the tower fall. This could have been the reason why the number of turns appears to be the highest in the LD setup. Like the SD setup, the pairs were seen talking and gesturing to each other quite often.

VR (Immersive Head-Mounted Displays). In general, we observed a very different interaction pattern in VR compared to the other two setups. Players' attitude and behaviour is more competitive in the VR setting and more focused on the game than the co-located opponent. Communication between players is relatively limited. When it came to the player's turn, the player was very focused on (1) observing the best block to be selected, (2) moving out the block extremely carefully, and (3) placing the selected block on the top of the tower. In contrast, when it was their opponent's turn, they tried to distract their opponents by verbally making statements like "The tower is going to collapse" and "Don't waste your time, you are going to lose." This could be because this is the only condition that players cannot see the physical appearance of the co-located opponent. In contrast, players in the SD and LD groups can easily observe how the other player played the game and their facial and body reactions. VR group is the only group that participants (N=8) mentioned being very competitive, while participants in SD and LD felt that they were playing the game more for pleasure and enjoyment than for competition, trying to win the game.

5.3 Strength of the Study

The strengths of our research include: (1) our experiment examined the effect of social display setup with three different devices (SD, LD, VR) on gameplay performance, immersion, and social presence in co-located competitive games—–to our knowledge, we are the first ones to conduct this research; (2) factors (e.g., content, controller mechanics, seating arrangement) that could affect the experiment are well controlled since previous research (Schild et al., 2012; Cairns et al., 2014; Pietschmann et al., 2012; Lindley et al., 2008; Sommer, 1967) suggested that these factors could affect immersion or social presence during gameplay; and (3) the experiment setup followed the previous study (Kauko and Häkkilä, 2010).

5.4 Recommendation, Limitation, and Future Work

We identified a potential risk in that, when players were standing and wearing VR HMDs next to each other, it may lead to collisions between players in co-located play because players cannot see each other. In our experiment, the experimenter would inform the players if there might be any potential collisions when necessary, but it is not practical in real life if such a game is provided to users. We recommend that game developers add an avatar (which can be customized by players) into the game so that players can see each other's virtual avatars. This could not only enhance immersion (Hooi and Cho, 2012) but could also make the user become aware of the other players' location to avoid collisions.

We also identified some limitations of this research. We only involved participants who were strangers to each other—that is, each pair of participants did not know each other before the experiment. Future work could explore the effect of social display setups on friends or those who are at least acquainted with each other because psychological involvement has been reported to be higher when friends interact with each other than when strangers do the same (Gajadhar et al., 2008). Nevertheless, our study allowed us to ensure that the observed effects are more likely to be attributed to the differences in display setups rather than the nature of the relationship between the participants.

Our research, which focused on the "Jenga" game in VR settings, aimed to delve into the complexities of player interactions in co-located social spaces. The purpose of using such setups, particularly with VR headsets, was to establish a baseline by comparing the impact of VR to traditional co-located gaming experiences. We created the framework for understanding VR HMDs' function in boosting social presence and immersion in gaming by doing so. Given that the Jenga game requires strategic thinking, coordination, and precision, our findings can be interpreted as insights into multiplayer engagement in comparable games. However, it is helpful to understand the results within their individual context. Our emphasis on co-located settings provides a distinct advantage, laying the groundwork for future study on VR's potential to upgrade or modify these gaming experiences and increase player social interactions. Future research could look into how social display arrangements affect games that are more focused on collaboration. According to prior research (Mayer et al., 2018; Emmerich and Masuch, 2013), player perceptions of social presence might vary between collaborative and competitive game modes.

Some might consider our sample size small; however, in the context of an exploratory study, a smaller sample size can be considered acceptable as the primary goal is to investigate initial trends and generate hypotheses for further research rather than to make definitive conclusions or predictions (Rosenthal and Rosnow, 1995). The sample size of twenty-four participants in this study, while relatively small, can provide valuable preliminary insights into the effects of social display setups on co-located competitive gameplay experiences.

6 CONCLUSION

This paper has investigated the effect of social display setup (two small-screen tablet displays, a 40-inch shared TV, and two VR HMDs) on two important determinants of user experience (i.e., immersion and social presence) when playing a multi-player competitive game in a co-located setting. Our experiment with three groups of 8 pairs of participants each (that is, 24 participants in total) indicates: (1) playing Jenga in VR is less challenging than in the small-screen tablet displays, and (2) gameplay behavior patterns are different among these social display setups. With the emergence and integration of newer platforms into people's daily activities, there is a need for further research and attention from researchers and developers to make social games more enjoyable by leveraging the social and technical affordances of each platform type. Platforms such as VR and AR will play a transformative role, and with a better understanding of their inherent affordances, it is possible to use them to improve people's experiences interacting with digital information and with each other.

The data gleaned from our experiment can provide a comprehensive look at how social display setups affect players' immersion and social presence. Given our findings, it becomes increasingly evident that the choice of social display setup has nuanced effects on user experience, as VR might make a game like Jenga less challenging. This reiterates the importance of understanding platform-specific affordances and nuances, ensuring that games retain their core experience. As newer technological platforms continue to be integrated into our daily lives, there is a chance to improve the quality of social gaming.

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