Research Article

Simulation & Gaming
2022, Vol. 53(3) 237–252

DOI: 10.1177/10468781221094473
journals.sagepub.com/home/sag
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Understanding the Effects of Mixed Reality on Video Game Satisfaction, Enjoyment, and Performance

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Abstract

Background. With the rising demand for the use and application of modern immersive technologies, recent studies have investigated the user experience of augmented reality (AR) and virtual reality (VR) for video game purposes. Despite AR's and VR's pervasiveness in the video game industry, research studies into the effects of mixed reality (MR) on video game experience are scarce. This study examined the impact of MR on video game satisfaction, enjoyment, and user performance of first-time users.

Method. Participants played the same strategy video game across two platforms, an MR headset and a mobile device. A short version of the Game User Experience Satisfaction Scale (GUESS-18) and the Enjoyment scale (ENJOY) were used to measure satisfaction and enjoyment.

Results. Results demonstrated that MR provided greater overall satisfaction, engrossment, creativity, and personal gratification. In addition, results revealed higher overall enjoyment, challenge/improvement, and engagement in the MR condition. Interestingly, participants performed better with the mobile version. No statistical differences were found between the conditions regarding the

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GUESS's usability, audio aesthetics, visual aesthetics, and the ENJOY's pleasure and competence.

Conclusion. The study provides insight into how MR influences satisfaction and enjoyment for video games. Playing a video game in mixed reality has the potential to enhance the user experience of game players despite the possibility of simulator sickness and worse performance than traditional mobile environments. Features of the gameplay that enhanced as well as diminished video game experience are discussed.

Keywords

mixed reality, augmented reality, video game satisfaction, enjoyment, user performance, mobile gaming

Background

How a player interacts with a video game can significantly alter their experience with the gameplay. For example, a player could experience a game differently, depending on whether they play it with a mouse and keyboard, joystick, or a game controller. The quality of the screen, auditory features, subtitles, etc. affect the game experience too. However, to date, literature is limited about the differences between video game experiences played in immersive environments and traditional platforms, such as a mobile device (Pallavicini et al., 2019). As the utility of mixed reality (MR) burgeons across different domains, it continues to gain popularity with improvements in computing, following virtual reality (VR) and augmented reality (AR). However, the question arises of how MR technology can translate into and influence the video game experience. This research compares user performance and perceptions of video game experience using MR and a mobile device.

VR, AR, and MR

Immersive technologies, encompassing VR, AR, and MR, provide individuals with engaging experiences that transcend the physical realm (Derby et al., 2020). Although these terms are often used interchangeably with the homogeneous concept of computer-generated environments and objects in the real world (Mäenpää, 2021), the interactions between virtual elements, users, and the world around them differ significantly. VR fully immerses users in a synthetic, computer-generated environment existing in a virtual space (Craig, 2013; Gupton, 2020; Javornik, 2016; Milgram et al., 1995). AR overlays the real world with computerized elements, or holograms, in which users can see the physical environment around them and the holograms through the use of devices such as Google Glass or smartphones (Derby et al., 2019). Unlike VR and AR, the reality-enhancing nature of MR allows users to manipulate interactive virtual elements superimposed over real-time and real-world environments.

Display platforms such as mobile devices and immersive headsets are some of the many popular video game devices. For instance, the Magic Leap 1 is an MR wearable spatial computer that brings the physical and digital worlds together. It is primarily known for its enterprise solutions, yet it serves various industries, including the video game (Magic Leap, 2021). The significant advantage of MR is the elimination of the border between the physical world and digital settings, giving users distinct experiences. When playing MR games, the systems enhance cognitive engagement through the concept of game immersion, involving physical movement as part of the gameplay (Brown & Cairns, 2004; Hu et al., 2016). Thus, blocking outside stimuli allows users to immerse themselves in the gameplay and impacts how real the game feels to users (Gaming Marketing Genie, 2020). For instance, chasing a virtual character across the room as it jumps in and out of the physical wall or being immersed in an underwater scene with fish swimming around the user influences perceptions of realism.

Another area that distinguishes MR is regarding the research into simulator sickness. Extensive studies have shown that VR simulator sickness can be very severe for some users. The major contributing factors include a field of view, refresh rate, scale, lag, and duration of usage (Dużmańska et al., 2018; Stoner et al., 2011). However, research on AR and MR has shown very low or moderate simulator sickness symptoms (Vovk et al., 2018; Vrellis et al., 2020). Even with the adverse side effects of VR and the low to moderate symptoms users experience with AR and MR, the uptake in immersive technologies has been swift in recent years (Carroll et al., 2019).

With all variables indicating that MR positively affects video game experience, how does the experience differ when played using a mixed reality headset instead of a traditional mobile device? While VR and AR games have received increasing attention across multiple disciplines and audiences, empirical examinations of MR games, particularly their impact on satisfaction and enjoyment, are limited.

Effects of Video Game Platform

Previous research has examined how video game platforms, specifically VR and traditional desktop, differ in the video game experience. A study exploring the impact of VR on gamer experience (Shelstad et al., 2017) found higher satisfaction when playing Defense Grid 2, a tower-defense strategy game, on the VR headset than on the traditional desktop. In particular, the results demonstrated that the participants found VR more engrossing, enjoyable, allowed more creative freedom, and offered better audio and visual aesthetics.

On the contrary, Yildirim et al. (2018) and Carroll et al. (2019) reported no difference across two VR devices and traditional desktop computers for their effects on video game satisfaction. The critical difference between these three studies was the

Table 1. A Short Description of GUESS Subscales (Phan et al., 2016).

Subscale	Description
Usability/Playability	The ease in which the game can be played with clear goals/objectives in mind and with minimal cognitive interferences or obstructions from the user interfaces and controls.
Narratives	The story aspects of the game (e.g., events and characters) and their abilities to capture the player's interest and shape the player's emotions.
Play Engrossment	The degree to which the game can hold the player's attention and interest.
Enjoyment	The amount of pleasure and delight that was perceived by the player as a result of playing the game.
Creative Freedom	The extent to which the game can foster the player's creativity and curiosity and allows the player to express his or her individuality while playing the game freely.
Audio Aesthetics	The different auditory aspects of the game (e.g., sound effects) and how much they enrich the gaming experience.
Personal Gratification	The motivational aspects of the game (e.g., challenge) that promote the player's sense of accomplishment and the desire to succeed and continue playing the game.
Social Connectivity	The degree to which the game facilitates the social connection between players through its tools and features.
Visual Aesthetics	The graphics of the game and how attractive they appeared to the player.

games used. Shelstad et al. (2017) used a tower-defense strategy game, Yildrim et al. (2018) used a first-person shooter game, while Carroll et al. (2019) used both a racing and a strategy game to examine how types of game could affect player satisfaction. This difference in findings could be due to the vast diversity of the games studied. A tower-defense game involves different mechanics, dynamics, aesthetics, and goals than a first-person shooter, strategy, or racing game. It is possible that some types of games may lend themselves better to an immersive platform than others.

While VR is highly studied, there is a dearth of research investigating the effects of MR on video game satisfaction to date. Therefore, further investigation concerning the impact of MR on video game experience and satisfaction is imperative.

Measuring Video Game Experience

Evaluating MR games allows researchers, developers, and designers to better understand the interaction methods, engagement elements, and game mechanics that work well across game genres (Bonsignore et al., 2012; Shelstad et al., 2019). Aside from usability testing (Cornett, 2004), playtesting (Davis et al., 2005; Fulton, 2002) is a well-known method to evaluate post-play video games in a lab setting. It is typically conducted during the development stage and associated with a structured questionnaire used to gather data related to the quality of the game, preferences, and feedback from the player.

Table 2. Comparisons between *Angry Birds* on Magic Leap and Mobile.

	Magic Leap 1	Mobile Phone
Device Type	Headset device	Handheld mobile device
Interface Type	Interactive 3D elements	2D graphics
Structural Placement	Placed anywhere in the space	Always on the right of the screen
Navigation	Left and right virtual buttons, requiring pointing and clicking using the controller to change from one level to another	Map scene, requiring a horizontal scroll to reveal more and more levels
Field of View	First-person slingshot with 360 degrees views, encouraging the player to walk around it	Fixed angle on a device
Zooming In/ Out	Physically moving the body towards or away from the 3D elements	Pinch/Spread gesture
Slingshot Interactions	Line up the virtual slingshot, hold a button on the handheld controller, pull the controller back to aim, and lift the finger to launch the bird	Pull back the slingshot with a finger to aim and lift the finger off the screen to shoot

Several studies have used the Game User Experience Satisfaction Scale (GUESS) to investigate the effects of VR on video game satisfaction (Carroll et al., 2019; Shelstad et al., 2017; Yildirim et al., 2018; Yildirim, 2019) and have explored how the enjoyment scale (ENJOY) could be used to predict continuance and purchase intention in online games (Shelstad et al., 2020). Nevertheless, there is no research using new psychometrically validated scales, like GUESS and ENJOY, to evaluate the effects of MR on the video game experience.

GUESS-18. The Game User Experience Satisfaction Scale (GUESS) is a comprehensive measure consisting of 55-items within nine dimensions that evaluate game user satisfaction (Phan et al., 2016). Table 1 provides a brief description of each subscale. Development and validation of the GUESS were based on an assessment of over 1,300 participants and over 450 unique video games. The GUESS-18, an 18-item version of the GUESS, was created for quicker testing and research (Keebler et al., 2020). This shorter version of the GUESS allows designers and developers to use it in iterative game development and researchers to evaluate satisfaction multi-dimensionally quickly.

ENJOY. The Enjoyment scale (ENJOY) is a validated scale consisting of five dimensions that measure the enjoyment of an activity (Davidson, 2018). The ENJOY has 25 statements with five subscales, including pleasure, relatedness, competence, challenge/improvement, and engagement. The ENJOY scale was developed and validated based on the assessment of over 600 unique activities, for example, reading a book, exercising, playing video games, and watching television.

Method

Research Objective Statement

The current study investigates how MR impacts video game satisfaction, enjoyment, and user performance of first-time Magic Leap users. A repeated measures experimental design was used in this study. All participants were asked to play the *Angry Birds* game on two different platforms: a Magic Leap 1 and a mobile phone device (iPhone X). Table 2 provides the primary differences in gameplay between the two conditions. The order of the two devices was counterbalanced across participants. Institutional Review Boards approved this research, and each participant was informed of the purpose of the research prior to their participation.

Participants

A total of 20 participants (eleven males and nine females) with ages ranging from 18 to 23 ($M = 20.35$, $SD = 1.42$) took part in this study. Sixteen participants reported having prior experience playing the *Angry Birds* game via mobile device, but none were active players. Eleven participants had used a VR headset before, while only three had used an AR/MR headset or glasses. None reported prior experience with either the Magic Leap or the MR version of *Angry Birds*. None of the participants claimed any disability that would impact the gameplay.

Materials

Video gaming platforms. This study used two different video game platforms, MR headset and mobile phone device (iPhone X). The Magic Leap 1 was the MR headset used in this study. It is a wearable spatial computer that combines the physical and digital worlds as one. While wearing it, the users can superimpose interactive 3D elements into their space and simultaneously view their physical surroundings. The device components include a heads-up display, light pack, and handheld controller. Its specifications include a 120Hz refresh rate, a high-resolution of 1280 x 960 pixels per eye, and its field of view is at 50-degree wide with a 76.9-degree diagonal (Magic Leap, 2021).

Angry Birds game. *Angry Birds* (Rovio Entertainment Corporation, 2021) is a famous strategy game developed by Rovio Entertainment. The purpose of the game is to destroy all the pigs on and inside the structure by launching a bird using a slingshot. Once the players eliminate all the pigs, the level is cleared. If the pigs remain after using all the birds given, the level is failed and can be attempted again.

Measures

Game user satisfaction. The GUESS-18 (Keebler et al., 2020) is a multidimensional measure of video game satisfaction, consisting of nine different subscales (Table 1) with eighteen statements, rated with a 7-point Likert scale (1 = Strongly Disagree to 7 = Strongly Agree). Because of the game's underdeveloped storytelling on Magic Leap and its nature that focused on the single-player experience, narrative and social connectivity dimensions of the GUESS-18 were eliminated from the data analysis. Consequently, 14 items from 7 dimensions were presented in a random order to each participant. This study calculated the remaining seven subscale scores by averaging the items within that scale. By summing the average of all subscales together, the total possible score of the overall GUESS-18 was 49. A higher score indicated a more satisfactory game user experience.

Enjoyment. The ENJOY (Davidson, 2018) originally measures enjoyment through five different subscales, consisting of twenty-five statements in total, rated with a 7-point Likert scale (1 = Strongly Disagree to 7 = Strongly Agree). Subscale scores are calculated by averaging the items in that scale. With the elimination of the relatedness subscale due to the game's essence, the sum of each of the four subscale's average scores gave the overall score with a total possible score of 28. The ENJOY comprises statements that include the words *the activity*, which was replaced by *playing Angry Birds* in this study.

Simulator Sickness Questionnaire (SSQ). The SSQ (Kennedy et al., 1993) is a 4-point Likert-scale questionnaire, *none* (0), *slight* (1), *moderate* (2), and *severe* (3), with three sub-factors, including nausea, oculomotor discomfort, and disorientation. A combined score from these items indicates the level of simulator sickness symptoms evoked by the immersive technologies (Lee et al., 2017). According to Bimberg et al. (2020), a simulator's total scores can be associated with *negligible* (< 5), *minimal* (5 – 10), *significant* (10 – 15), *concerning* (15 – 20) symptoms, and *bad* (> 20). Just as certain physical motions can cause motion sickness, for example, riding a roller coaster, the degree of conflict between visual motion and vestibular information while immersed in an MR environment can lead to simulator sickness, even in the absence of major body movements (Rebenitsch & Owen, 2016). Furthermore, this loathsome side-effect is often severe enough to cause the discontinuation of immersive technology use (Silva & Fernando, 2018). Because SSQ measures perceived simulator sickness symptoms in the context of MR, it was disregarded for the mobile device condition.

User performance. Performance was evaluated by averaging the number of stars received from all levels played on each display device. The stars awarded in the *Angry Birds* game represent how well a participant performed in each level. One star is awarded for simply completing the level — two stars for finishing the level with more than half of the obstacles destroyed. Finishing the level, using fewer birds than given,

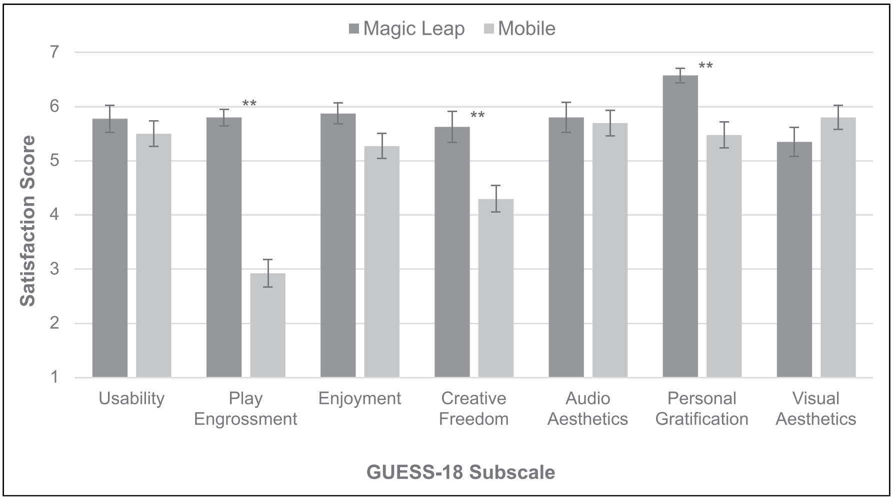

Figure 1. Comparison of the satisfaction scores for GUESS-18 subscales. *Note.* ** $p < .001$. Subscales of the GUESS-18 scale (7 = more satisfying, 1 = less satisfying).

and causing more damage to the structure will lead to three stars, the maximum stars awarded. The difficulty of obtaining three stars increases as users progress through levels.

Procedure

Participants were recruited either from a university online research participation system or from word of mouth. Upon completion of the consent form, participants filled out a demographic questionnaire. Next, they received a pre-assigned device, either the Magic Leap or an iPhone X, for their first round. If given the Magic Leap, they put on the device, adjusted the fit until it remained securely on their head, and were instructed to review the controller's user guide. They completed a tutorial for the *Angry Birds* game on the given device and spent 20 minutes playing it starting from the first level with audio on for both devices. When the remaining time reached zero seconds, participants were asked to stop the game and complete the survey depending on the device given. After completing the first round, participants subsequently completed the second round using the other device with the same tasks, followed by the survey. The survey for both rounds included the GUESS-18 and ENJOY, but the SSQ followed the Magic Leap round only. The study took approximately 60 minutes to complete. Participants, along with the researcher, followed the university's COVID-19 safety precautions and wore masks throughout the study.

Table 3. Overall GUESS-18 and Subscale Scores for Magic Leap and Mobile.

Subscale	Magic Leap 1		Mobile		t	Cohen's d
	M	(SD)	M	(SD)		
Usability	5.78	(1.13)	5.50	(1.05)	1.18	0.25
Play Engrossment	5.80	(0.68)	2.93	(1.14)	8.92**	3.07
Enjoyment	5.88	(0.86)	5.28	(1.03)	1.98	0.63
Creative Freedom	5.63	(1.29)	4.30	(1.11)	4.21**	1.11
Audio Aesthetics	5.80	(1.26)	5.70	(1.04)	0.56	0.09
Personal Gratification	6.58	(0.61)	5.48	(1.08)	3.93**	1.25
Video Aesthetics	5.35	(1.19)	5.80	(0.98)	-1.66	0.41
Overall Satisfaction	40.80	(4.76)	34.98	(4.57)	4.58**	1.25

Note. ** $p < .001$ (two-tailed).

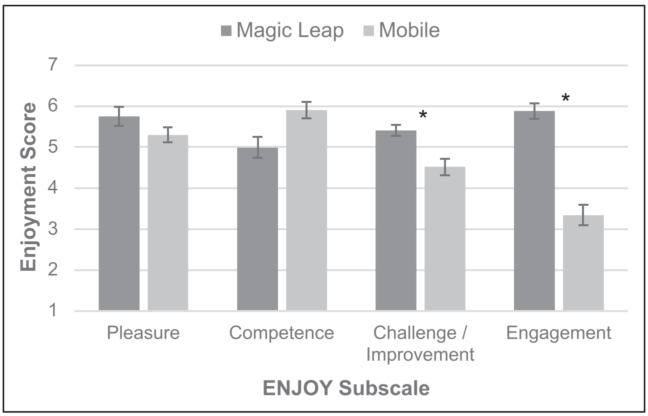

Figure 2. Comparison of the enjoyment scores for ENJOY subscales. *Note*. * $p < .0025$. Subscales of the ENJOY scale (7 = more enjoyable, 1 = less enjoyable).

Statistical Analysis

Paired-samples t-tests (t) were conducted to examine the differences in user satisfaction, enjoyment, and user performance when participants played the game on each device. Bonferroni corrections (.0025) were used to correct the family-wise error rate. Analysis summaries include descriptive statistics of mean (M) and standard deviation (SD) for each condition, probability value (p) for statistical significance, and Cohen's d (d) for effect size. Correlations were calculated using Pearson correlation (r). The data analysis tools used included IBM SPSS Statistics 27 and the Microsoft Excel version 16.5 for macOS.

Results

Satisfaction (GUESS-18)

There was a significant difference in the overall satisfaction scores between the Magic Leap (M = 40.80, SD = 4.76) and the mobile device (M = 34.98, SD = 4.57) conditions, $t(19) = 4.58$, $p < .001$; $d = 1.25$. The total possible score was 49.

Further analysis of the GUESS-18 subscales revealed significantly higher perceptions of play engrossment, creative freedom, and personal gratification when played on the Magic Leap (Figure 1). No significant differences were found for usability, enjoyment, audio aesthetics, and visual aesthetics (Table 3).

Enjoyment (ENJOY)

A statistically significant difference was found between the overall enjoyment scores, $t(19) = 3.66$, $p = .002$; $d = 1.13$. With the total possible score of 28, the overall ENJOY score was significantly higher when using the Magic Leap (M = 22.03, SD = 2.39) than the mobile device (M = 19.07, SD = 2.84).

As seen in Figure 2, the ENJOY subscales indicated significantly higher ratings in challenge/improvement, $t(19) = 3.71$, $p = .001$; $d = 1.17$, and engagement, $t(19) = 9.12$, $p < .001$; $d = 2.60$, when playing the Magic Leap version. However, no differences in pleasure, $t(19) = 1.66$, $p = .113$; $d = 0.48$, or competence, $t(19) = -3.23$, $p = .004$; $d = 0.89$, were found.

Simulator Sickness Questionnaire (SSQ)

A one-way within-subjects analysis of variance (ANOVA) used F-test (F) to compare the effect of the Magic Leap on SSQ sub-factors. No significant differences were found among the SSQ sub-factors, $F(2, 57) = 1.72$, $p = .188$. However, the SSQ total score (M = 12.90, SD = 12.52) is associated with significant symptoms (10-15). While the scores for oculomotor discomfort (M = 17.06, SD = 16.29) and disorientation (M = 18.10, SD = 19.21) are considered concerning, nausea (M = 9.54, SD = 11.16) is considered minimal (5 – 10) and the lowest among the sub-factors (Bimberg et al., 2020).

User Performance

There was a significant difference in the performance scores for Magic Leap (M = 2.52, SD = 0.29) and mobile device (M = 2.94, SD = 0.09) conditions with universally higher scores on the mobile device, $t(19) = -6.68$, $p < .001$; $d = 1.94$. Correlation analyses between user performance, satisfaction, and enjoyment showed no significant relationships.

Discussion

Game User Satisfaction

The results demonstrated that MR resulted in higher overall satisfaction for the strategy game played with a large effect size (Cohen, 1988). Participants (all first-time users of the MR version) rated playing *Angry Birds* on the MR headset more satisfying than playing the same game on a mobile device. Notably, they found it to be engaging, fostering their creativity, and promoting their desire to succeed more than on a mobile device. The immersion of MR may have caused the participants to lose awareness of the wearable device, time spent, and their surroundings. This sensation is associated with flow, which is achieved when participants felt as if they were directly interfacing with real elements in the game world (Carroll et al., 2019), increasing the play engrossment in MR. In addition, MR encouraged creative freedom and physical movement within the user's space, whereas traditional mobile experiences limit users merely to a screen. For example, participants could place the game anywhere and freely strategize ways to maneuver the slingshot and defeat each level, whether it involved sitting, standing, or walking closer to or further away from the virtual building blocks; these possible actions are beyond the mobile gameplay. With the creative freedom perceived, the possible strategy was indefinite, enriching their desire to continue playing the game. MR completely changes human-computer interaction through immersive experiences that it offers (Parekh et al., 2020).

However, it is noteworthy that usability, enjoyment, audio aesthetics, and visual aesthetics subscales were not significant between the two conditions. The similarities of the game's user interface and the similar level of *fun* on both platforms buttress the non-significant usability and enjoyment scores shown. In addition, positional glitches and performance issues within the MR version might have altered the spatial audio and graphical aesthetics and resulted in less favorable ratings despite being more satisfying and engaging overall, whereas the mobile version provided responsive, high-quality 2D graphics. For example, loading issues at the start of a level slowed down the animation, the 3D slingshot was occasionally upside down, and there was sometimes a noticeable delay in the spatial audio effects, specifically when completing a level.

Enjoyment

These results suggested that being challenged and improving skills while playing an MR game led to increased engagement and enjoyment than playing on a mobile. Although participants felt slightly more capable when playing on mobile than the MR version of the game due to their familiarity with the system, the differences were not high enough to be significant. Interestingly, both platforms offered similar pleasure for the play.

Simulator Sickness

Overall simulator sickness scores were associated with significant symptoms, and the most concerning included oculomotor discomfort and disorientation. Some participants reported having difficulty concentrating and experienced headaches and/or eye strain after using Magic Leap. Yet, SSQ scores neither exhibited any correlation with satisfaction, $r(18) = -.19$, $p = .282$, enjoyment, $r(18) = -.17$, $p = .295$, nor performance, $r(18) = -.24$, $p = .227$. These scores are higher than other researchers have observed (Vrellis et al., 2020); however, participants spent twice the amount of time using the Magic Leap and for a different task. More research is needed to understand what factors in an MR game contribute to the various simulator sickness dimensions (i.e., time, amount of head/body movement, spatial audio, and interactive tasks required).

User Performance

User performance was better on the mobile device than on the MR device, which could be due to the familiarity of the mobile device and mobile gaming, in general. Even though no participants were active *Angry Birds* players, most were familiar with other mobile games' general gameplay and controls.

Limitations

There are some limitations to this study that are worth mentioning. First, the novelty effect of MR might have exaggerated the results. As mentioned, all participants were first-time users of the MR headset and MR *Angry Birds* version. Participants could have reported higher-than-usual satisfaction and enjoyment on some constructs, given the freshness of the technology. That said, not all aspects of satisfaction and enjoyment were significantly different, indicating that novelty could not account for the overall difference.

Second, this study required participants to wear a face mask during their sessions due to the COVID-19 regulations. It is possible that without a mask, the satisfaction and enjoyment results may have been higher, especially when using the MR headset.

Finally, while participants reported higher satisfaction and enjoyment when playing the game on an MR wearable device, we cannot generalize to other MR games or other genres (Carroll et al., 2019; Yildirim et al., 2018). Some games will always be ill-suited to play in the MR system, such as games that may take multiple hours to play or are highly collaborative. It would benefit the literature to study how MR impacts video game experience in different game types.

Future Research

Future research should examine how mixed reality technology affects other video games and genres. For example, researchers could require participants to play a number of different MR games from multiple genres, which would eventually neutralize the novelty of using an MR headset. They could then ask participants to play a new MR game and a mobile equivalent before completing a set of questionnaires similar to those presented in this article. In addition, future research should investigate the video game experience across games with different levels of competitiveness, the game usability factor between disabled and non-disabled users, the involvement of physical movement during the play, and the effects of spatial audio on the gameplay experience.

Conclusion

MR provides unique video game experiences that are unobtainable from other types of technology. The users' ability to interact with virtual elements in the real world and real-time has shown promising potential. Despite the growing interest and use in immersive technologies in the video game industry, scientific knowledge concerning the impact of MR on the video game experience is limited as opposed to AR and VR. This article approached the largely unexplored topic of MR in the video game industry by evaluating the impact of MR on video game satisfaction, enjoyment, and user performance, compared to a mobile device. The results are valuable for future design and development as the MR video gaming applications advance in a highly competitive industry. This study demonstrates a practical application of the GUESS-18 and ENJOY to investigate different aspects of the video game experience across two display conditions. These scales are helpful to designers and developers when designing gameplay components in MR and evaluating video game experience in its development stages due to their multiple dimensions. With this context, the study corroborates that playing a video game in mixed reality has the potential to enhance the user experience of game players despite the possibility of simulator sickness and worse performance than traditional mobile environments. This article scratches the surface of the video game experience in MR gameplay; more research is indispensable to underpin these results and understand the more profound effects of this technology as it scales.

Funding Statements

The authors received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

The authors declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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