The Effects of Latency and In-Game Perspective on Player Performance and Game Experience

DAVID HALBHUBER, University of Regensburg, Germany
PHILIPP SCHAUHUBER, University of Regensburg, Germany
VALENTIN SCHWIND, Frankfurt University of Applied Sciences, Germany
NIELS HENZE, University of Regensburg, Germany

Previous work shows that high latency, a prolonged delay between player in- and system output, negatively affects player experience and performance. However, previous work also comes to contrary conclusions about how the in-game perspective alters the latency sensitivity of video games. Currently, it is unclear if the in-game perspective independently modulates latency's effects. To investigate how a game's in-game perspective interacts with latency, we developed a shooting game incorporating three perspectives (First-Person-, Third-Person-, and Bird's-Eye-View). In a study, participants (N = 36) played with two levels of latency (low and high) and the three perspectives. We show that latency reduces performance and experience, independent of the perspective. Moreover, Bayesian analysis suggests that the in-game perspective does not interact with latency and does not affects performance or experience. We conclude that more robust means to categorize latency sensitivity of video games than the in-game perspective are required.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**; **Empirical studies in HCI**.

Additional Key Words and Phrases: Video Games, Latency, In-Game Perspective

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1 INTRODUCTION

In video games, latency, the delay between a player's action and the corresponding outcome, negatively impacts player performance and overall gaming experience [7, 13, 21]. This can have consequences for players, game developers, and publishers. In extreme cases, an unsatisfactory game experience can even result in the discontinuation of the game [12, 23, 38]. As a result, developers and researchers aim to minimize latency and its effects [28, 32, 61]. Previous work, for example, used methods such as *Geometrical Manipulation* [40] or *Time Warp* [8, 36] to adapt the gameworld to the gaming session's latency. In these methods, the current latency is directly integrated into the game loop to factor it in when calculating game events.

Adapting to latency directly in the game is one avenue to reduce its adverse impact. Other work takes different approaches and, for example, investigates how game characteristics, such as the

Authors' addresses: David Halbhuber, david.halbhuber@ur.de, University of Regensburg, Regensburg, Germany; Philipp Schauhuber, philipp.schauhuber@stud.uni-regensburg.de, University of Regensburg, Regensburg, Germany; Valentin Schwind, valentin.schwind@acm.org, Frankfurt University of Applied Sciences, Frankfurt, Germany; Niels Henze, niels.henze@ur.de, University of Regensburg, Regensburg, Germany.

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game's feedback frequency, the importance of player actions, or the required spatial accuracy when carrying out in-game actions, alter the game's latency sensibility [59]. That work zeros into game mechanics to establish which factors manipulate the effects of latency on a micro level. Similarly, previous work also aims to categorize latency sensitivity on a macro level using, for example, the game's pacing [60] or its genre [13]. On this note, Claypool and Claypool [13] argue that a game's genre and how the player perceives the game world are critical factors influencing the game's latency sensitivity. In their work, the authors highlight that different exemplary game genres, such as first-person shooters (FPS), role-playing games (RPG), and real-time strategy games (RTS), incorporate different in-game perspectives. Thus, the authors conclude that different video game genres have different thresholds before latency negatively affects performance and experience. However, while the in-game perspective certainly is part of how video game genres can be defined, video game genres are fluent. The perspective alone does not define the game's genre, as evidenced by FPS/RTS hybrids such as *Executive Assault 2* [49]. Genres differ in countless other aspects, such as pacing, narrative methods, and interaction techniques. Nevertheless, the in-game perspective plays a unique role in how the players perceive and experience the game. Whether it is a *First-Person View* (FPV), *Third-Person View* (TPV), or *Bird's-Eye View* (BEV), the perspective offers distinct visual and spatial information to the player. It affects how players perceive the game environment, navigate through it, and make strategic decisions. Moreover, the in-game perspective can influence the player's immersion, spatial awareness, and emotional engagement with the game [19, 52].

While the in-game perspective is a crucial element of how the game is perceived and played, it is unclear how the effects of latency are influenced by it. One reason for the small number of works investigating the in-game perspective as a modulator of latency is that most games only integrate one or two in-game perspectives. Therefore, using commercial video games, it is hard to consider the perspective's influence on latency perception in isolation.

Our work starts solving this problem by providing insight into how the in-game perspective alters the effects of latency on player performance and game experience. To achieve this, we developed a shooting video game that features the same core gameplay from three different perspectives. Using the game, we conducted a within-subjects study with 36 participants playing with three different perspectives (FPV, TPV, and BEV), and two levels of latency (low and high). Inferential analysis shows that players performed significantly worse when playing with a high latency independently of the used in-game perspective. The adverse effects of latency manifested in players hitting fewer targets and needing more time to shoot targets successfully. We also found that high latency significantly reduced perceived ease of control, progress feedback, and challenge appropriateness. Furthermore, high latency led to a reduced feeling of mastery, immersion, autonomy, and overall enjoyment. However, using Bayesian analysis, we found that our data support a model in which latency and perspective do not interact. We found evidence for a model demonstrating no true effect of the in-game perspective on player performance or game experience. Our findings are crucial to video game and latency researchers, as we demonstrate that the in-game perspective does not necessarily dictate the latency sensitivity of video games. This allows future research to investigate the interaction with other aspects of video games, such as their pacing or narrative methods and latency.

We enable other researchers to replicate and expand upon our work by providing all necessary resources. This includes the game, the source code, and all anonymous user data, which can be found in the accompanying *Open Sciences Framework* repository[1].

[1] https://osf.io/s3ekv/?view_only=009137199b904e23b36c33b0282a65b3

2 RELATED WORK

A growing body of work investigates latency, its effects on users, and means of preventing or compensating it. In this section, we first provide an overview of how latency in interactive systems arises and which adverse effects it causes. Then, we elucidate the effects of latency in video games on player performance and game experience. We continue by discussing video games' in-game perspectives and how these potentially alter and modulate the players' gaming experiences. Moreover, we highlight how previous work aimed to categorize latency sensitivity of video games using game-specific characteristics such as its in-game perspective. We conclude with a summary highlighting why the in-game perspective needs to be further researched when investigating the effects of latency in video games.

2.1 Latency in Human-Computer-Interaction

Assessing latency and its related effects has a robust foundation within Human-Computer Interaction research. For example, Card's [11] seminal Human-Processor Model (HPM) illustrates how users communicate with interactive systems in a continuous feedback loop. The users initiate the interaction by providing input to the system, for example, by clicking on a button in the user interface. The computer receives the input, processes it, and calculates an output that is provided to the user. Users may now respond to the provided output, potentially initiating another iteration of the feedback loop. Incorporating a high latency into the HPM prolongs the loop throughput time, thus resulting in diminished user performance. Although latency was not the primary focus of Card's work, he nonetheless established the basis for subsequent and current research into the study of latency and its impacts.

Latency in interactive systems is generally defined as the time interval between a user's action and its observable effect within a system [50]. In line with this definition, Wimmer et al. [65] posited that end-to-end latency is composed of three distinct partial latencies: (1) input latency, (2) processing latency, and (3) output latency. Input latency is the delay between a user's input and its receipt by the computer. Processing latency encompasses the duration between the receipt of the input and its processing and consequent transmission. It encompasses sub-latencies such as network latency or disk latency. Output latency represents the time between the completion of processing and the display of the effect to the user. These partial latencies have varying origins, with input and output latency primarily resulting from peripheral devices, such as keyboards, computer mice, and displays while processing latency comprises the communication between input and output and the system's processing performance.

Contemporary research demonstrates a clear correlation between latency in interactive systems and a decline in user performance in various tasks. For example, Jota et al. [35] and Annett et al. [5] showed that user performance decreases when latency exceeds 25 ms. On the other hand, they did not observe any improvement for latency below 25 ms. Therefore, the authors concluded that the optimal latency value for users is 25 ms. Even though user performance does not improve below 25 ms latency, Ng et al. [55] found that users can perceive latency starting at 2 ms. This work highlights that users can detect even small latency and that the perception of latency is critical in interactive systems. Building on this knowledge, Ng et al. [54] conducted a follow-up study to investigate the ability of users to perceive differences between 1 ms and 2 ms latency in specific tasks. Their results showed that users could even perceive such minor differences in latency. In conclusion, the correlation between latency in interactive systems and user performance is well established, with a latency value of 25 ms being optimal for users. Additionally, users can detect small latency values, making reducing latency a critical aspect in designing and developing interactive systems.

2.2 Latency in Video Games

Latency also significantly impacts video gaming and its players. The adverse effects of latency manifest in various ways, such as a decrease in player scores, longer completion times for in-game tasks, or even failure to complete tasks at all [7, 16, 21]. Work by Claypool and Claypool [13] indicates that certain fast-paced shooting games are particularly susceptible to the effects of latency, as opposed to other game genres. The tolerance threshold for latency in these games and target selection in general has been estimated to be at 150 ms in some works [48], while others have reported a decrease in player performance starting at 100 ms latency [56]. Beyond performance degradation, latency negatively impacts video games' overall Quality of Experience (QoE). For example, Liu et al.[45] showed that a latency of 150 ms leads to a 25 % decrease in QoE. In related work, Liu et al.[44] found a linear decrease in QoE by 20 % as latency increases from 25 ms to 125 ms.

While QoE often is used to holistically assess the overall experience in a single variable [46], it does not allow for a finer graded analysis of gaming experience. Thus, previous work also aimed to capture the effects of latency on gaming experience using more in-depth approaches. Halbhuber et al. [28], for instance, showed that reducing latency in an FPS game from 180 ms to 60 ms increases the positive affect associated with the gaming session. Positive affect, in general, categorizes the positive feelings and emotions experienced while playing the game, the authors argue. Other work by Durnez et al. [20], investigating the effects of latency on game experience in a desktop-based exergame, found that latency decreases the experienced flow, with flow referring to a state of complete immersion, effortless concentration, and enjoyment [18]. The authors also found that increasing latency decreases the player's interest in the game and the enjoyment of playing it.

In summary, the effects of latency on gaming experience are substantial and multifaceted. The impaired responsiveness, compromised immersion, gameplay imbalances, and negative emotional and cognitive impacts collectively highlight the detrimental nature of latency in games. It is essential to acknowledge that latency and its effects on gaming experience is a complex problem that has not been entirely investigated. Hence, addressing this issue is paramount for creating truly immersive, fair, and engaging gaming experiences.

2.3 In-Game Perspective and its Interaction with Latency

Besides latency, other game characteristics, such as the in-game perspective, alter the players' experience. Video games typically feature three different in-game perspectives: (1) FPV, in which the player embodies the game character and perceives the world as if the player is the character, primarily used in fast-paced video games such as FPS games. (2) TPV, in which the camera angles outside (typically behind) the controllable character, and the player can see the character on the screen. The TPV perspective is common in action-adventure games such as *God of War* [63], or platform games such as *Trine* [24]. And lastly, (3) BEV (also called top-down view), in which the player sees the controllable character(s) from the perspective as if the player is looking down on the game world from above. This perspective gives the player a broad overview of the level or map. Hence, BEV is often used in strategy, city-building, and other games where players need a good overview of the game world. Figure 1 depicts three screenshots from current games showing the three different perspectives.

The in-game perspective can significantly alter a player's game experience and performance. Previous work, for example, highlighted that players are more immersed in gameplay when playing with FPV [19], even if the players typically preferred other in-game perspectives. Other work, by Gorisse et al. [27] showed that FPV enables more accurate interaction, while TPV increases the spatial awareness in virtual reality (VR) games. On a similar note, Monteiro et al. [52] investigated how the in-game perspective in VR games modulates the experienced level of cybersickness.

The authors found that using a TPV perspective decreases cybersickness. However, in line with Denisova and Cairns [19] they also found that players experience a higher level of immersion when playing in first-person.

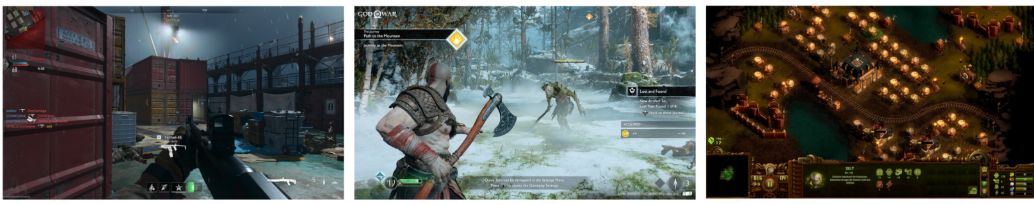

Fig. 1. Shows three in-game screenshots from different games using different player perspectives. Left depicts the first-person shooter game *Call of Duty: Modern Warfare 2* [3] in First-Person-View (FPV) in which the player embodies the character. The middle shows *God of War: Ragnarök* [63] using a Third-Person-View (TPV) with the camera angled behind the player character. The right shows the game *They are Billion* [26], which uses Bird's-Eye-View (BEV) to allow the players to navigate in the game.

While a large body of work investigates different aspects modulating the effects of latency in video games, such as its pacing and required player motions [41], the perceptual channel latency is perceived by [29, 32], or its mechanics [59] less is known about how the in-game perspective alters effects of latency. One reason for the need for more research investigating the in-game perspective as an isolated effector is that video games typically only feature one or two possible perspectives. For example, in *The Elder Scrolls Online* [9] - a massively multiplayer online role-playing game - players can seemingly transition between a first-person and a third-person perspective. However, currently, there are no games featuring all possible in-game perspectives. Hence, it is exceedingly hard to investigate the interaction between latency and in-game perspective in commercial video games in a controlled manner.

While there currently are no games featuring all possible in-game perspectives, previous work nevertheless tried to isolate its effects on latency. For example, Schmidt et al. [60] aimed to isolate the in-game perspective and the pacing of games to determine how both alter the effects of latency. In their work, the authors used three different games, *Grand Theft Auto*, *Project Cars*, and *Rayman* and added artificial latency to their test setup. Ultimately, the authors aimed to investigate the individual effects of latency on each game. The authors found that the in-game perspective did not alter the effects of latency in one of the tested games. However, since the authors used three different games, they cannot generalize their findings regarding the interaction between in-game perspective and latency. Schmidt et al.'s [60] findings contrast with previous work by Claypool and Claypool [13], which argues that the in-game perspective and in conclusion, the game's genre determines its latency sensitivity.

2.4 Summary

Previous research reveals that users can perceive latency down to 1 ms [54, 55]. Latency negatively impacts performance when it surpasses 25 ms [5, 35]. In video gaming, latency entails reduced players' scores, elongated completion times, or even task failures [7, 13, 21, 28, 29]. Moreover, the used in-game perspective can significantly alter game experience and performance [19, 27, 52]. However, previous work [13, 60] revealed contrary findings on how the in-game perspective alters the effects of latency. A generalizable conclusion is unattainable, given that previous work compared games from different genres with varying game mechanics and input methods. Thus, it is currently unknown how the in-game perspective interacts with latency and alters performance and experience.

3 GAME DEVELOPMENT

To investigate how the used in-game perspective alters the effects of latency on player performance and game experience, we developed a custom video game. We developed a shooting game since this type of game allows translating the core gameplay (shooting and tracking targets) to different perspectives without fundamentally altering the game mechanics. Furthermore, previous work showed that shooting games are particularly negatively affected by latency since these games require timely target tracking and selection to perform well [15]. After developing the game, we used it to measure the local latency of our test setup. Since we aspire to investigate the effects of latency, we need to account for local latency, which is inherently part of the computer setup due to polling and update rates of the used technical equipment such as the monitor, mouse, keyboard, and the workstation [65].

3.1 Implementation

In the first step, we designed and developed the game world and the player avatar. Figure 2 shows the game world from a top-down tilted angle. The game world comprises one large main room (Figure 2, B) enclosed by two smaller rooms. The small left room (Figure 2, A) serves as the starting point for the player, in which the controllable avatar spawns. The small room on the right (2, C) acts as the endpoint for the gaming session.

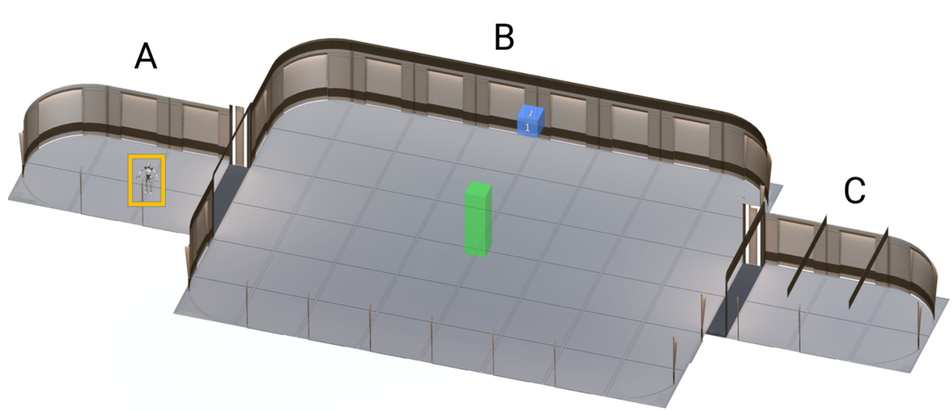

Fig. 2. Depicts the game world of our custom shooting game. In the room on the left (A), players start playing with their avatar (yellow box). In the middle room (B), the actual gameplay takes place. Players move their avatars to the starting point (green bar) to start the study. Players moved their avatars to the end room (C) when finished

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Next, we implemented three avatar controllers, one for each in-game perspective. Each controller allows the player to move the avatar and the avatar's viewport. Additionally, the controllers enable players to move a virtual weapon using the mouse and to shoot the weapon using a left mouse click. Avatar movement is controlled using the WASD keys (W = forward, A = left, S = backward, D = right). Rotational movement is controlled by using the mouse in FPV and TPV. In BEV, the rotational movement of the avatar follows the virtual weapon's cross-hair. Figure 3 depicts the player's view from FPV (left), TPV (middle), and BEV (right). Translating between FPV and TPV is quickly done. The viewport only needs to be slightly offset. However, translating avatar movement and behavior to BEV from FPV or TPV without fundamentally changing the presented amount of information or the game's interaction technique is non-trivial. BEV offers, per design, more information to the players. Players can see targets not only in front of them but in the whole game world. To prevent BEV from biasing our work by granting an advantage over other perspectives, we developed a custom occlusion map. This map is applied to the player's viewport when playing with BEV and limits the player's view to a cone in front of the avatar (see Figure 3). This approach mimics the viewport of FPV and TPV and is a common technique in tactical games such as *X:COM* [25] or *Divinity 2: Original Sins* [62]. Furthermore, changing the in-game perspective from FPV or TPV to BEV transforms the target selection task from a three-dimensional to a two-dimensional problem, effectively removing one dimension. This shift has notable implications for the player's interaction with the game environment and the challenges they face in selecting targets. In FPV, players typically navigate and interact with objects in a three-dimensional space, requiring them to account for depth, distance, and spatial relationships when selecting targets. On the other hand, with BEV, the game presents a flattened representation of the environment, where distance and depth are often conveyed through visual cues such as size, shading, or perspective. As a result, the target selection process becomes predominantly focused on the 2D plane. This reduction in complexity potentially makes target selection easier. Nevertheless, since players are stationary while shooting stationary targets in our game, and thus are not deeply interacting with the three-dimensional space, we argue that the actual differences between in-game perspectives are negligible.

Despite that, using BEV not only entails advantages. Since the player is situated above the game world and thus farther away from the actual gameplay, some tasks get more difficult. This is particularly the case in shooting games, in which the player is positioned further off from the targets, they are smaller and thus fundamentally harder to hit. However, since the whole game world's size is decreased, players require less real-world mouse movement to cover the same amount of in-game distance as in FPV or TPV. We anticipate that the increase in difficulty induced by the decreased target size and the decreased path length balance each other. This anticipation aligns with *Fitts' law* [22]. The law states that reducing the size of a target increases the time required to reach it in a 2D selection task while reducing the distance to the target decreases the movement time. Hence, the overall challenge in our game should be constant over all perspectives.

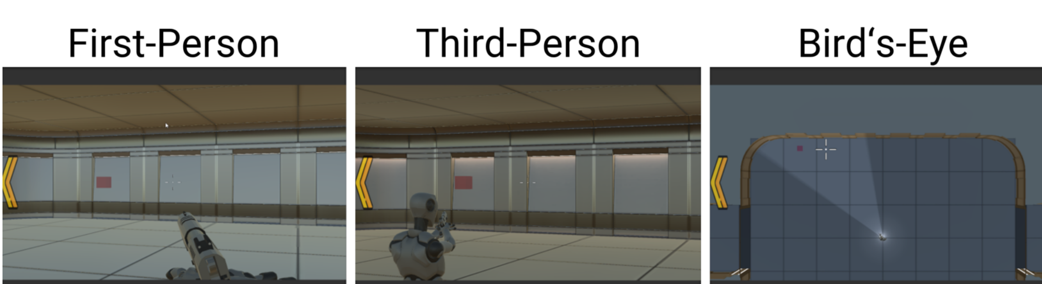


Fig. 3. Depicts three screenshots from our game. Each subfigure depicts the players' view from a different in-game perspective. Left shows the viewport in First-Person-View. The middle subfigure shows the Thrid-Person-View and the right depicts the view in Bird's-Eye-View. Additionally, each subfigure depicts a red target, which players had to shoot in the study. Furthermore, the right also depicts how we reduced the Birds-Eyes-View inherent advantage by using a cone-shaped occlusion map. Players using the Birds-Eye View could only see targets within the highlighted cone.

The player's objective in the game is to shoot a fixed number of targets. To start the main task of the game, the player has to move to the starting point. The green bar in Figure 2 highlights the starting area. Once the player reaches the starting area, the avatar can no longer be moved using the keyboard. However, players can still aim using the computer mouse. Stationary targets appear in a controlled but randomized order in a designated target area in front of the player. Our game features two types of targets: (1) Red targets, which the player needs to shoot as fast as possible, and (2) blue targets, which the player has to track by placing the weapon's cross-hair on it. The blue targets are always positioned right before the player's starting point (see green bar in Figure 2) and act as inter-trial fixation points. Players must actively move their mouse to find and shoot the appearing red targets. Players obtain points for successfully tracking and shooting targets. The faster players shoot or track the target after its appearance, the more points are awarded. However, players do not lose points for missing targets. While playing, we log all game events to a local database, such as successful hits, tracks, misses, and reaction times. We used *Unity 3D* (initial development with Version 2020.2.16f, updated to Version 2021.3.25f1) to develop the game.

3.2 Measuring Local Latency

We measured the game's local latency, comprised of the used hardware and the game's run-time, to determine precisely what latency players will face. For the measurement, we installed our game on a stationary workstation in our laboratory. The workstation (Intel i7, Nvidia GT970, 16 GB RAM) was attached to a monitor (24" FullHD @60Hz), a computer mouse (Razor Viper 8K), and headphones. The game ran in full-screen mode. Using a 240 fps camera (4,167 ms/frame, *GoPro Black 7*) and the procedure used by previous work [31, 34, 48], we captured both the system's mouse and the game screen. By manually comparing the physical mouse click with an in-game event (firing of the virtual weapon), we determined the local latency of our setup. We repeated this measurement 20 times. We found that our game has an average local latency of 11.46 frames (SD = 3.15 frames, n = 20), which translates to 47.75 ms (SD = 13.12 ms). This latency serves as the baseline latency of our game, and all subsequent latency values include this baseline without stating it explicitly.

4 INVESTIGATING THE INTERACTION OF LATENCY AND PERSPECTIVE IN VIDEO GAMES

We conducted a study using our game to investigate how different in-game perspectives and different levels of latency affect the game experience and player performance. In line with related work [28], we simulated different latency levels by using input buffering techniques within the game. Input buffering involves delaying the processing of user inputs for a specified duration, thereby mimicking the effect of local latency. In our study, we implemented two latency levels by introducing fixed delays in the processing of user inputs.

Specifically, we modified the game's code to incorporate a predetermined delay for each input (mouse and keyboard) received from the players. This delay was set to correspond to the desired latency level. By introducing delays in this way, we created a controlled environment that allowed us to investigate the effects of latency on gameplay performance and experience without introducing confounding factors.

4.1 Study Design

To control for perspective and latency, we utilized two independent variables (IVs) in a 2 x 3 within-design: (1) LATENCY, which corresponds to the latency participants are playing with. LATENCY has two levels: (I) *low* - which refers to 0 ms of artificially added latency and *high* - which represents playing with 150 ms of artificial latency. We chose the *high* latency in line with previous work, which shows varying thresholds of up to 150 - 180 ms [6, 48] for latency tolerance for video games in general and shooting games in particular. The second IV is (2) Perspective - which refers to the in-game perspective participants are playing with. Perspective has three levels: (I) First-Person-View (*FPV*), (II) Third-Person-View (*TPV*), and (III) Bird's-Eye-View (*BEV*).

To measure the players' performance and game experience, we used a set of dependent variables (DVs). In line with related work [28], we utilized *Reaction Time* and *Accuracy* to quantify the objective player performance. *Reaction Time* is the time required to hit a target. A lower *Reaction Time*, thus, corresponds to less time required for shooting the appearing target. *Accuracy* quantifies the participants' accuracy and is built by the ratio of total shots to successful shots. Therefore, a higher *Accuracy* refers to a higher level of precision.

We used the latest version of the 30-item *Player Experience Inventory* (PXI) [2] with its subscales: *Ease of Control*, *Progress Feedback*, *Audiovisual Appeal*, *Clarity of Goals*, *Challenge*, *Mastery*, *Curiosity*, *Immersion*, *Autonomy*, and *Meaning* to quantitatively evaluate the game experience. Furthermore, we added the recommended questions to asses player *Enjoyment* to the questionnaire. The instrument was administered according to original PXI work [2].

4.2 Apparatus and Procedure

For the study, we used the same system for which we determined the local latency of our game. The game was again executed in full-screen mode. The study was conducted in our laboratory, which was quiet and free of external disturbances.

Upon arrival, participants were greeted at our laboratory. Participants were not informed about the exact purpose of the study (investigating the interaction between latency and perspective) to prevent a bias induced by the anticipation of latency [30] but were told to test a novel game. They were informed about the study's procedure after giving informed consent and agreement to data collection. Each participant started the study with a short warm-up phase in our game. Following the warm-up, the actual study started, in which participants aimed to maximize their score by shooting targets. Participants were told they would receive additional compensation if they beat the game's high score to further incentivize them. However, all participants received the gift card, independently of if they beat the game's high score. Participants played six rounds, each with a unique combination of Latency and Perspective. Conditions were balanced using a Latin Square to avoid sequence effects. After each round, an in-game performance overview showcasing the game's high score and the participant's points obtained in the previous round was presented. Next, participants filled out the PXI and *Enjoyment* questionnaire, before the following condition started. Finally, the study was concluded with a debriefing, in which the participants were informed about the detailed purpose of the study. We estimated a total duration of one hour for the study, which was designed following the research ethics policy of our institution.

4.3 Task

In each of the six rounds, the participants started playing with one combination of Latency and Perspective. At the start of each round, the participants' avatars was situated in the starting area (see Figure 2, A). Participants could move freely for as long as they wished in the game world to accommodate themselves to the game controls and the new perspective. Then, participants started the actual task by moving the avatar to the center of the main room of the game world. After entering the starting position (green bar in Figure 2, B), the game restricted the avatar's movement. From this point forward, participants were not able to move the avatar but only to move the virtual weapon. After the avatar was locked in place, the first inter-trial target (blue) appeared. Participants had to position the cross-hair of their virtual weapon for 2 seconds on the blue target. We utilized the inter-trial target to ensure that each trial (shooting of a red target) started with the same preconditions independent of the in-game perspective. After 2 seconds, the blue target disappeared, and a stationary red target spawned with a randomized size at a random position within the designated spawn area. Spawn position and sizes for red targets for all rounds were randomized once and held constant over all participants. We manipulated red targets' sizes using *Unity*'s scaling component. The targets' sizes varied between 0.4 and 2.0 in reference to *Unity*'s standard *Cube* primitive [1]. Figure 4 depicts a blue inter-trial target and the spawn area for the targets in red. After shooting the red target, it disappeared, and the blue target in front of the avatar spawned again. This course of action was repeated 30 times (30 blue and 30 red targets). Upon completion, the participants were notified, and the avatar was free to move again. To end the round participant moved the avatar to the end zone (see Figure 2 C). This procedure was repeated for all six combinations of Latency and Perspective.

Fig. 4. Depicts an aerial view of the middle room of our game world. The avatar is situated at the bottom of the figure. In front of the avatar is a blue target, which the players had to track to spawn the next red target. The red targets spawned within the red area left and right of the blue target. The spawn area was not depicted in actual gameplay but is shown in this figure for clarification purposes only.

4.4 Participants

We recruited 36 participants (25 male, ten female, and one non-binary) using our institution's mailing list and social media. The participants' ages ranged from 19 to 35 years, with a mean age of 23.42 years (*SD* = 3.77 years). Thirty-two participants were right-handed, and four participants were left-handed. We allowed participants to choose which hand to use for controlling the mouse (right or left). All participants decided to use the right hand. Twelve participants said they play video games daily, eleven participants play video games weekly, four participants play a few times per month, and the remaining nine participants play less than a few times monthly. Thirty-one participants were students at our institution and received a half-credit point for their course of study. The other five participants had technical backgrounds (Computer Science, Engineering, and Software Development). All participants received an additional 5 € gift card as compensation.

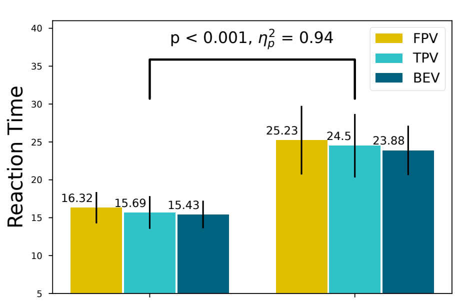
5 RESULTS

In the following, we report the analysis of all measures. Descriptive results can be found in the Appendix in Table **??** (performance measures), Table **??** (enjoyment measures), and Table **??** (PXI). All gathered data were tested for normality using Shapiro-Wilk tests (normal distribution assumed if $p > .05$). All measures violated Shapiro-Wilk's test for normality. Thus, we used a rank-aligned two-way RM-ART-ANOVA (non-parametric data) [66] for the inferential assessment of Latency and Perspective (Latency: *low* vs. *high*) x (Perspective: *FPV* vs. *TPV* vs. *BEV*) with repeated measures on both factors. We used an alpha level of .05 for all statistical tests (significance assumed if $p < .05$).

Bayes Factor BF_{10}			Interpretation
	>	100	Extreme evidence for H_1
30	-	100	Very strong evidence for H_1
10	-	30	Strong evidence for H_1
3	-	10	Moderate evidence for H_1
1	-	3	Anecdotal evidence for H_1
	1		No evidence
1/3	-	1	Anecdotal evidence for H_0
1/10	-	1/3	Moderate evidence for H_0
1/30	-	1/10	Strong evidence for H_0
1/100	-	1/30	Very strong evidence for H_0
	<	1/100	Extreme evidence for H_0

Table 1. Evidence categories for Bayes factors. Adjusted for BF_{10}, H_0, and H_1 from Andraszewicz et al. [4].

Since classical null hypothesis testing only reveals differences between distributions - ANOVA either accepts or rejects a hypothesis - it can not reveal if an insignificant difference indicates a similarity between the investigated distribution. Thus, we conducted a Bayesian analysis to investigate the similarity in the data of our conditions. Rather than just rejecting a hypothesis, a Bayesian ANOVA calculates the probability that the acceptance of the null hypothesis (no differences in distribution) is correct [17, 64]. Contrary to classical null hypothesis testing, thus, Bayesian inference calculates probabilities for both: H_0 and H_1. For Bayesian analysis, we used the *R*-package [57] *BayesFactor* [53]. Bayes factors [37, 39] are formulated as BF_{10}, which indicates how much more likely a model that supports H_1 over H_0 is. Bayes factors are interpreted in line with Andraszewicz et al.s' postulation [4], which categorizes continuous Bayes factors into discrete levels of evidence. Table 1 depicts the used Bayes factor evidence categories. To increase readability, we structure the following sections by independent instead of dependent variables.



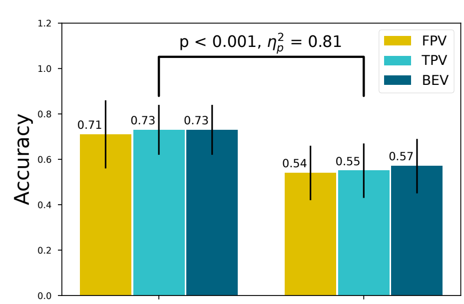


Fig. 5. Depicts mean *Reaction Time* (left) and *Accuracy* (right) values grouped by Latency. Both subfigures provide p-values and effect size for the within Latency comparison. Error bars depict the standard error. Participants shoot targets significantly faster (*low*: 15.817 s (*SD* = 12.157 s), *high*: 24.541 s (*SD* = 24.205 s)) and with a significantly higher precision (*low*: 0.729 (*SD* = 0.128), *high*: 0.561 (*SD* = 0.125)) when playing with the *low* level of Latency.

5.1 Inferential Analysis

5.1.1 Latency. ART-ANOVA revealed a significant main effect of LATENCY on *Reaction Time* ($F(1{,}35) = 643.775$, $p < 0.001$, $\eta_p^2 = 0.94$) and on *Accuracy* ($F(1{,}35) = 144.660$, $p < 0.001$, $\eta_p^2 = 0.81$). Figure 5 depicts mean *Reaction Time* (left) and *Accuracy* (right) values for both levels of LATENCY. When playing with *low* LATENCY compared to playing with *high* LATENCY participants were significantly faster (*low*: 15.817 s (*SD* = 12.157 s), *high*: 24.541 s (*SD* = 24.205 s)) and more accurate (*low*: 0.729 (*SD* = 0.128), *high*: 0.561 (*SD* = 0.125)).

ART-ANOVA also found significant effects of LATENCY on *Ease of Control* ($F(1{,}35) = 25.555$, $p < 0.001$, $\eta_p^2 = 0.42$), *Progress Feedback* ($F(1{,}35) = 11.534$, $p = 0.0017$, $\eta_p^2 = 0.24$), *Challenge* ($F(1{,}35) = 24.328$, $p < 0.001$, $\eta_p^2 = 0.41$), *Mastery* ($F(1{,}35) = 49.639$, $p < 0.001$, $\eta_p^2 = 0.58$), *Curiosity* ($F(1{,}35) = 5.904$, $p = 0.0203$, $\eta_p^2 = 0.14$), *Immersion* ($F(1{,}35) = 8.709$, $p = 0.0056$, $\eta_p^2 = 0.19$), *Autonomy* ($F(1{,}35) = 5.973$, $p = 0.0197$, $\eta_p^2 = 0.14$), *Enjoyment* ($F(1{,}35) = 30.143$, $p < 0.001$, $\eta_p^2 = 0.46$), and no significant effect on *Audiovisual Appeal* ($F(1{,}35) = 2.667$, $p = 0.1113$, $\eta_p^2 = 0.07$), *Clarity of Goals* ($F(1{,}35) = 0.950$, $p = 0.3362$, $\eta_p^2 = 0.02$) or *Meaning* ($F(1{,}35) = 2.071$, $p = 0.1589$, $\eta_p^2 = 0.05$). Participants had a higher feeling of control and progress feedback, rated the challenge of the game as more appropriate, were stronger immersed, derived a stronger feeling of mastery, curiosity, and autonomy, and overall had more fun when playing with *low* LATENCY than playing with *high* LATENCY. Figure 6 and Figure 7 depict all significant differences grouped by level of LATENCY.

5.1.2 Perspective. ART-ANOVA found no significant effect of PERSPECTIVE on *Reaction Time* ($F(2{,}70) = 1.881$, $p = 0.1600$, $\eta_p^2 = 0.05$) or *Accuracy* ($F(2{,}70) = 0.629$, $p = 0.5359$, $\eta_p^2 = 0.01$). Furthermore, ART-ANOVA also found no significant effect on *Ease of Control* ($F(2{,}70) = 0.228$, $p = 0.7959$, $\eta_p^2 < 0.01$), *Progress Feedback* ($F(2{,}70) = 0.084$, $p = 0.9194$, $\eta_p^2 < 0.01$), *Audiovisual Appeal* ($F(2{,}70) = 0.095$, $p = 0.9089$, $\eta_p^2 < 0.01$), *Clarity of Goals* ($F(2{,}70) = 0.037$, $p = 0.9633$, $\eta_p^2 < 0.01$), *Challenge* ($F(2{,}70) = 0.718$, $p = 0.4908$, $\eta_p^2 = 0.02$), *Mastery* ($F(2{,}70) = 0.172$, $p = 0.8419$, $\eta_p^2 < 0.01$), *Curiosity* ($F(2{,}70) = 1.230$, $p = 0.2982$, $\eta_p^2 = 0.03$), *Immersion* ($F(2{,}70) = 1.312$, $p = 0.2757$, $\eta_p^2 = 0.03$), *Autonomy* ($F(2{,}70) = 1.101$, $p = 0.3381$, $\eta_p^2 = 0.03$), *Meaning* ($F(2{,}70) = 1.300$, $p = 0.2788$, $\eta_p^2 = 0.03$), and *Enjoyment* ($F(2{,}70) = 0.463$, $p = 0.6310$, $\eta_p^2 = 0.01$).

5.1.3 Latency x Perspective. ART-ANOVA found no significant interaction effect of LATENCY x PERSPECTIVE on *Reaction Time* ($F(2{,}70) = 0.105$, $p = 0.9003$, $\eta_p^2 < 0.01$) or *Accuracy* ($F(2{,}70) = 0.103$, $p = 0.9017$, $\eta_p^2 < 0.01$). Furthermore, ART-ANOVA also found no significant effect on *Ease of Control* ($F(2{,}70) = 0.162$, $p = 0.8503$, $\eta_p^2 < 0.01$), *Progress Feedback* ($F(2{,}70) = 0.558$, $p = 0.5748$, $\eta_p^2 = 0.01$), *Audiovisual Appeal* ($F(2{,}70) = 0.589$, $p = 0.5573$, $\eta_p^2 = 0.01$), *Clarity of Goals* ($F(2{,}70) = 1.582$, $p = 0.2128$, $\eta_p^2 = 0.04$), *Challenge* ($F(2{,}70) = 0.020$, $p = 0.9801$, $\eta_p^2 < 0.01$), *Mastery* ($F(2{,}70) = 1.538$, $p = 0.2218$, $\eta_p^2 = 0.04$), *Curiosity* ($F(2{,}70) = 0.078$, $p = 0.9245$, $\eta_p^2 < 0.01$), *Immersion* ($F(2{,}70) = 1.570$, $p = 0.2151$, $\eta_p^2 = 0.04$), *Autonomy* ($F(2{,}70) = 0.3365$, $p = 0.7153$, $\eta_p^2 < 0.01$), *Meaning* ($F(2{,}70) = 0.6705$, $p = 0.5146$, $\eta_p^2 = 0.01$), and *Enjoyment* ($F(2{,}70) = 0.648$, $p = 0.5259$, $\eta_p^2 = 0.01$).

5.2 Bayesian Analysis

Previous inferential tests consistently did not reveal any significant effects of PERSPECTIVE or the interaction between LATENCY and PERSPECTIVE on either the performance or experience measures. Thus, we used a Bayesian two-way RM-ANOVA to further asses the influence of PERSPECTIVE.

5.2.1 Latency. We found extreme evidence [4] in support of a model that postulates that LATENCY has a effect (acception of H_1) on *Reaction Time* ($BF_{10} > 100$, *error* $\pm$ 0.55 %, $R^2 = 0.699$) and a effect on *Accuracy* ($BF_{10} > 100$, *error* $\pm$ 0.55 %, $R^2 = 0.575$).

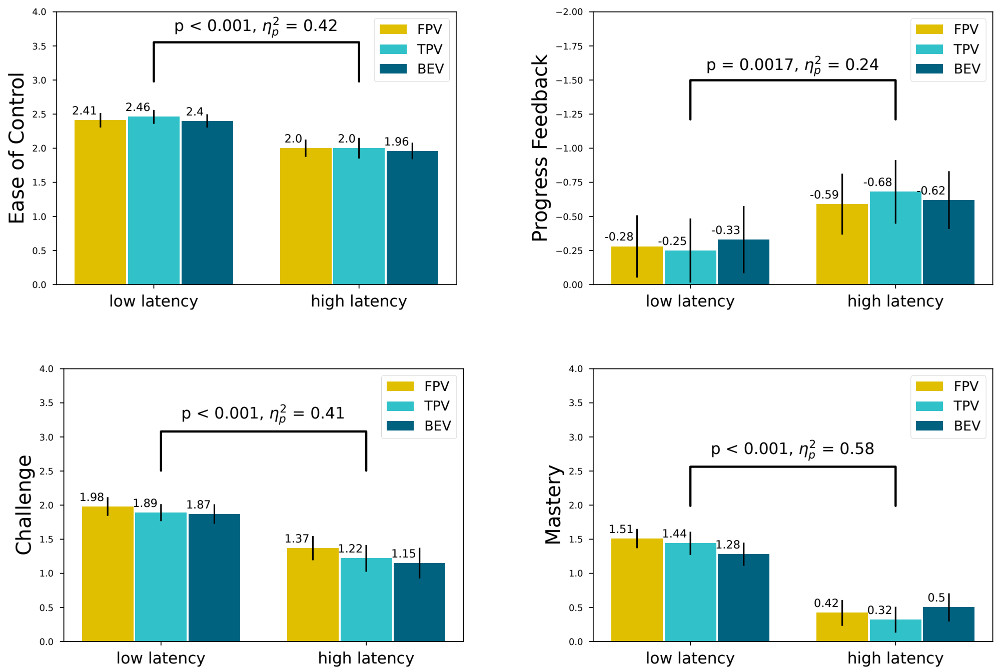


Fig. 6. Depicts mean values of the subscale *Ease of Control*, *Progress Feedback* (negative Y-scale), *Challenge*, and *Mastery* of the *Player Experience Inventory* [2] grouped by Latency. The subfigures also provide p-values and effect sizes for the within Latency comparison. Error bars show the standard error. On average, participants had a higher feeling of control and a stronger sense of how they were doing in the game. Additionally, they derived a greater sense of mastery when playing the game with *low* Latency. Furthermore, participants felt that the game was significantly less of an appropriate challenge when playing with *high* Latency.

Investigating the effects of Latency on player experience, we found evidence for a model that accepts H_1 and postulates a effect of Latency on *Ease of Control* (BF_{10} > 100, *error* ± 0.54 %, R^2 = 0.419), *Challenge* (BF_{10} > 100, *error* ± 1.09 %, R^2 = 0.622), *Mastery* (BF_{10} > 100, *error* ± 0.48 %, R^2 = 0.534), *Immersion* (BF_{10} = 96.889, *error* ± 0.46 %, R^2 = 0.595), *Enjoyment* (BF_{10} > 100, *error* ± 0.52 %, R^2 = 0.680), and *Progress Feedback* (BF_{10} > 100, *error* ± 0.43 %, R^2 = 0.798). Furthermore, we found strong evidence that Latency has a effect on *Autonomy* (BF_{10} = 20.935, *error* ± 0.4 %, R^2 = 0.721), on *Clarity of Goals* (BF_{10} = 19.462, *error* ± 0.68 %, R^2 = 0.852), and on *Curiosity* (BF_{10} = 19.086, *error* ±0.39 %, R^2 = 0.757). Lastly, we found anecdotal evidence in support of no effect of Latency (acception of H_0) on *Audiovisual Appeal* (BF_{10} = 0.520, *error* ± 1.04 %, R^2 = 0.514) and *Meaning* (BF_{10} = 0.224, *error* ± 0.59 %, R^2 = 0.672).

5.2.2 Perspective. We found evidence in support of a model that postulates no effect (accepting H_0) of Perspective on *Reaction Time* (BF_{10} = 0.087, *error* ± 0.58 %, R^2 = 0.699) and no effect on *Accuracy* (BF_{10} = 0.081, *error* ± 0.28 %, R^2 = 0.575).

Investigate the effects of Perspective on player experience, we found up to very strong evidence for a model that accepts H_0 and postulates no effect of Perspective on *Ease of Control* (BF_{10} = 0.052, *error* ± 0.98 %, R^2 = 0.419), *Challenge* (BF_{10} = 0.100, *error* ± 0.46 %, R^2 = 0.622), *Mastery* (BF_{10} = 0.055, *error* ± 0.38 %, R^2 = 0.534), *Enjoyment* (BF_{10} = 0.069, *error* ± 0.34 %, R^2 = 0.680), *Progress*

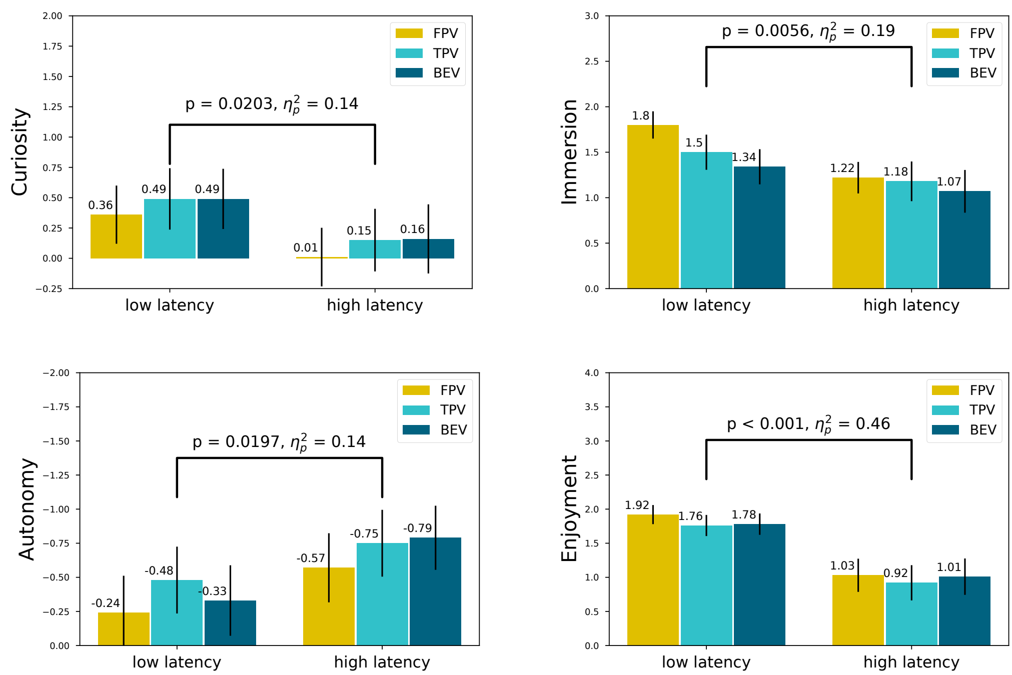


Fig. 7. Depicts mean values of the subscale *Curiosity*, *Immersion*, and *Autonomy* (negative Y-scale) of the *Player Experience Inventory* [2] and the mean values of the *Enjoyment* dimension grouped by Latency. The subfigures also provide p-values and effect sizes for the within Latency comparison. Error bars show the standard error. On average, participants were more curious about the game, were stronger immersed in the game, had a higher feeling of autonomy, and had a more joyful experience when playing with *low* Latency.

Feedback (BF_{10} = 0.051, *error* ± 0.46 %, R^2 = 0.798), *Audiovisual Appeal* (BF_{10} = 0.068, *error* ± 0.38 %, R^2 = 0.514), *Clarify of Goals* (BF_{10} = 0.056, *error* ± 0.29 %, R^2 = 0.852), and *Curiosity* (BF_{10} = 0.093, *error* ± 0.68 %, R^2 = 0.757). Furthermore, we found moderate evidence in favor of H_0, for *Autonomy* (BF_{10} = 0.151, *error* ± 0.32 %, R^2 = 0.721) and *Meaning* (BF_{10} = 0.109, *error* ± 0.42 %, R^2 = 0.672), and anecdotal evidence for no effect on *Immersion* (BF_{10} = 0.557, *error* ± 0.36 %, R^2 = 0.595).

5.2.3 Latency x Perspective. Investigating the interaction between Latency and Perspective, we found strong evidence in support of a model that postulates that Perspective X Latency has no effect (accepting H_0) on *Reaction Time* (BF_{01} = 0.089, *error* ± 1.22 %, R^2 = 0.699) and no effect on *Accuracy* (BF_{10} = 0.089, *error* ± 2.37 %, R^2 = 0.575).

Investigating the effects of Latency x Player on player experience, we found strong evidence for a model that accepts H_0 and postulates no interaction effect of Latency X Perspective on *Ease of Control* (BF_{10} = 0.085, *error* ± 4.2 %, R^2 = 0.419), *Audiovisual Appeal* (BF_{10} = 0.092, *error* ± 2.29 %, R^2 = 0.514), *Enjoyment* (BF_{10} = 0.093, *error* ± 1.17 %, R^2 = 0.680), *Curiosity* (BF_{10} = 0.085, *error* ± 1.62 %, R^2 = 0.757), and *Challenge* (BF_{10} = 0.100, *error* ± 2.79 %, R^2 = 0.622). Furthermore, we found moderate evidence of no interaction effect on *Progress Feedback* (BF_{10} = 0.104, *error* ± 1.28 %, R^2 = 0.798), *Autonomy* (BF_{10} = 0.106, *error* ± 1.69 %, R^2 = 0.721), *Meaning* (BF_{10} = 0.167, *error* ± 1.93 %, R^2 = 0.672), *Immersion* (BF_{10} = 0.187, *error* ± 1.88 %, R^2 = 0.595), *Mastery* (BF_{10} = 0.196, *error* ± 1.59 %, R^2 = 0.534) and *Clarity of Rules* (BF_{10} = 0.197, *error* ± 1.78 %, R^2 = 0.852).

6 DISCUSSION

Inferential analysis shows that latency in our game significantly reduces player performance and game experience. Using a Bayesian analysis, we strengthen our findings. We found up to extreme evidence for a model that implies a effect of latency on player performance (all BF_{10} > 100) and a effect of latency on most subscales of the PXI and the enjoyment of the game (all BF_{10} > 19.086). However, we also found anecdotal evidence that latency does not affect the audiovisual appeal of the game (BF_{10} = 0.520) and the level of meaning derived from playing it (BF_{10} = 0.224). Furthermore, via inferential analysis, we found that the in-game perspective does not significantly alter performance or experience. Using a Bayesian approach, we found that the in-game perspective may not manipulate the gaming experience (0.051 < BF_{10} < 0.557). We found a similar effect of the interaction between latency and the in-game perspective. Our inferential analysis showed no significant interaction. Additionally, we found up-to strong evidence (0.085 < BF_{10} < 0.197) that supports a model with no effect of the interaction on gaming experience.

In the following, we first discuss our results regarding player performance. We then shed light on how latency and in-game perspective alter the functional components (ease of control, progress feedback, audiovisual appeal, clarity of goals, and challenge) of the *Player Experience Inventory* (PXI). Subsequently, we explore the implications of our findings regarding the psychosocial consequences (mastery, curiosity, immersion, autonomy, and meaning) of the PXI and the enjoyment of the game itself [2]. We continue by showcasing the implications of our findings for latency and video game research. Lastly, we conclude this section with a discussion about our work's limitations and possible future work.

6.1 Player Performance

Our work shows that players were less accurate and required more time to shoot the in-game targets when playing with high latency. The temporal asynchronicity between player input and the latency-induced game reaction led to a performance decay. These findings are in line with previous work, which showed that latency negatively affects game performance [7, 14, 28] and accuracy in particular [42, 44]. However, while a large body of work investigates the effects of latency in different games, the in-game perspective has been largely neglected. Previous work typically investigated the effects of latency in a single game [7, 28], and thus a single perspective, or only related the effects of latency in different video games to each other [14]. One notable exception is the work by Schmidt et al. [60]. Similarly to our findings, the authors found that the in-game perspective in one game did not change the effects of latency. However, given that the authors also used three games from different genres, their work cannot produce a generalized conclusion on the interaction of latency and in-game perspective. Our work, in contrast, extends upon previous work and demonstrates that the in-game perspective in a single game does not alter the players' performance potential or the actual in-game performance.

6.2 Functional Consequences

We found that latency significantly and negatively impacts three of the five constructs targeted at the functional components of the PXI (ease of control, progress feedback, and challenge). These constructs generally describe how the immediate gaming experience is altered as a direct result of game elements and design choices. Hence, our work shows that introducing latency to the game directly influences how players experience the game on a functional level. This is generally in line with previous work, which shows that latency leads to a decreased gaming experience. However, previous work often treats gaming experience as a single dimension [42, 44] or used instruments that are not well-suited for a comprehensive comparison with the PXI [28, 58]. Hence, our work builds on previous findings and extends it by an assessment of how latency manipulates game experience using the validated PXI-scale.

Our results show that players rated the game with significantly higher ease of control and a higher level of progress feedback when playing with low latency. Conversely, this means players had a significantly harder time performing targeted in-game action and judging if the performed action was good or bad when playing with high latency [2]. Thus, playing with high latency leads to a less intuitive input-out paradigm. Latency increases the loop-throughput time in Card's [11] HPM and leads to increased asynchronicity between in- and output. Ultimately, this increased asynchronicity in the interaction decreases the ease of control. Furthermore, since the game's response, for example, the visual feedback when a target was successfully hit, was delayed, players did not know how well they were performing in the game, decreasing the level of perceived progress feedback.

Our analysis also reveals that players rated the game's challenge significantly less appropriate when playing with a higher level of latency. This is in line with previous work, which also shows that latency influences the perception of a game's challenge bidirectionally. Halbhuber et al. [31], for example, showed that switching between latency levels leads to a reduced feeling of challenge compared to a constant level of latency. Previous work, however, does not provide conclusive evidence of how latency alters the perception of challenge. While most works suggest that latency increases challenge by decreasing the interaction's responsiveness [48], some work also concludes that it reduces challenge as a byproduct of reducing the game's flow [31]. We argue that it is a combination of both. While it is evident that the game becomes harder by delaying action feedback (such as target hit registration), latency also alters how the players perceive the game's challenge. When playing with high latency, the immediate response is missing. Players would not receive confirmation if their actions were successful right after the action. This possibly leads to a feeling of unfairness. Subsequently, this feeling of unfairness and the increased difficulty caused by input-output asynchronicity leads to a reduced level of challenge appropriateness. Previous work, arguing that playing with a higher latency puts players at unfair disadvantages over other players playing with lower latency, or the game itself, indicates that this is a reasonable conclusion [10, 33, 67].

Lastly, using an inferential analysis, we found no significant influence of the in-game perspective on the functional components of the PXI. Additionally, a Bayesian ANOVA, strengthens the inferential results and suggests no effect of the in-game perspective on functional components. Changing the in-game perspective did not immediately change the gaming experience on a functional level. This is in strong contrast to previous work, which showed that how the player is situated in the game world, i.e., the players' in-game perspective, dictates what level of latency is acceptable for the gaming session [13]. Based on our data, we propose that latency thresholds are not definable by categorizing games using their in-game perspective. Different aspects, such as the game's pacing [60], the importance of player actions, or the required spatial accuracy when carrying out in-game actions [59] alter how latency affects the functional components of the gaming session. Our results suggest that the in-game perspective as a standalone variable does not affect latency nor interact with it. Thus, previous findings that showed an effect of in-game perspective more likely originated from testing different games and game mechanics.

6.3 Psychosocial Consequences and Enjoyment

Our work also reveals a significant impact of latency on the psychosocial consequences of the gaming experience as well as on the overall enjoyment of the gaming session. The psychosocial consequences of the PXI describes second-order emotions experienced by the players as a result of playing the game. We found that latency decreased four of the five constructs in the psychosocial consequences dimensions (mastery, curiosity, immersion, and autonomy) and the game's overall enjoyment.

These results highlight the importance of reducing latency in video games as it directly affects the players' emotional experience. Latency significantly impacts the players' feelings of control, excitement, and engagement while playing the game. A lower latency results in a more seamless and enjoyable gaming session, allowing players to fully immerse themselves in the virtual world and feel a sense of mastery and autonomy. On the other hand, a high latency negatively impacts the players' psychosocial consequences and overall enjoyment of the game. This is in line with previous work, which showed that increasing latency decreases players' perceived effectiveness, their experienced fun [47], and increases their frustration [48]. Furthermore, we found no significant effects on the psychosocial consequences of the game experience induced by the in-game perspective or by the interaction of latency and in-game perspective. Again, a Bayesian approach revealed evidence for a model which supports no effect of the in-game perspective. Thus, the Bayesian analysis suggests that altering the in-game perspective of the game does not alter the players' psychosocial consequences induced by playing the game.

6.4 Implications of our Findings

This work's findings have implications for researchers and game developers. The implications of our work are twofold: Firstly, we show that the used perspective in our game does not alter the player's performance or gaming experience. Game developers can leverage this insight to design games that prioritize gaming experience across different in-game perspectives. Since the perspective does not significantly affect latency's impact, developers can allocate resources and potentially implement strategies to reduce latency and enhance overall gameplay, regardless of the chosen perspective. This knowledge allows for more flexible and inclusive game design decisions, accommodating a wider range of player preferences without compromising performance. Furthermore, the knowledge that in-game perspective does not significantly impact latency effects simplifies the development process. Developers can allocate their resources more efficiently without the need for perspective-specific optimizations. This streamlined approach can lead to reduced development time and costs, enabling teams to focus on other critical aspects of game design and performance improvement. Secondly, our work also replicates and builds upon previous work investigating the effects of latency on player performance and gaming experience [16, 31, 45, 48]. However, our work goes one step further and shows that latency always has negative consequences and is not imperatively dependent on the player's perspective of the game world. Furthermore, our work suggests that findings regarding latency from one in-game perspective are transferable to other in-game perspectives. This reduces the need to validate the effects of latency found in one study using one particular in-game perspective in additional studies with different perspectives. These results highlights the potential for researchers to shift their focus from the in-game perspective as a primary factor affecting latency's impact. Instead, they can explore other aspects, such as network conditions, game mechanics, player characteristics, or environmental factors that may have a more significant influence. By broadening the scope of investigation, researchers can gain a deeper understanding of the complex dynamics of latency and identify additional mitigating factors.

6.5 Limitations and Future Work

While our work demonstrates that in-game perspective does not alter player performance and game experience in our game and that latency and in-game perspective do not interact, our work still has limitations. In the following, we discuss these limitations and present new avenues to investigate the interaction between latency and in-game perspective.

One limitation of our work is the used game. We developed our own game to translate fundamental game mechanics to different in-game perspectives without changing the core gameplay. Our results, predominantly the Bayesian analysis, supports the assumption that we achieved this without changing the game experience. However, our game neither has an elaborate story nor requires a comprehensive input strategy. Hence, one needs to be cautious about generalizing to the ever-increasing landscape of video games with its countless types of games and genres. Nevertheless, our work provides the next step toward a better understanding of latency and the factors influencing its impact. Future work should build on our work and try to further parameterize different components that influence the effects of latency in video games.

Furthermore, it is crucial to acknowledge the limitation imposed by our study's participant sample and sample size. Firstly, our sample primarily consisted of university students. While focusing on university students allowed for an accessible and homogenous recruitment and data collection, it also limits our work's generalizability. Secondly, the sample size of 36 participants presents inherent limitations in terms of statistical power and precision. Despite previous work showing that a relatively small number of participants is sufficient to detect the effects of latency (MacKenzie and Ware: n = 8 [51], Long and Gutwin: n = 18 and n = 20 [48], Liu et al.: n = 25 [43]), the limited number of tested participants in our study may hinder the ability to detect subtle and small effects. Hence, future work should investigate the interaction between latency and the in-game perspective with a larger sample. Additionally, future research endeavors should aim to diversify the participants pool to include individuals from different age groups, educational backgrounds, and cultural contexts to strengthen the generalizability and robustness of our findings.

Another limitation of our work relates to our findings regarding the psychosocial consequences induced by the gaming session. While our data show that in-game perspective does not alter the psychosocial consequences of the players induced by playing our game, this finding does not generalize to the broader field of digital media, such as story-driven games or videos. Cinematography, for example, shows that different camera angles, light setups, and scenery evoke different emotions in viewers or players. To further investigate the psychosocial consequences manipulated by the in-game perspective, future work should craft a video game that focuses on a compelling narrative targeted at creating highly engaging gaming sessions. Similarly to our work, this custom game could be translated to different in-game perspectives and used in a study to inform about the effects of the perspective.

7 CONCLUSION

This paper presents a study with 36 participants playing a custom shooting game with two levels of latency and three different in-game perspectives. We found that latency significantly decreases player performance and gaming experience. Further, we did not find a significant effect of the in-game perspective or the interaction between latency and the in-game perspective on our measures. We continue by analyzing the gathered data using a Bayesian approach which supports the assumption that neither the in-game perspective nor the interaction with latency influences game experience and performance. We discuss and conclude, thus, that the in-game perspective does not necessarily dictate the effects of latency in video games. Our work is a crucial step towards a better understanding of latency, how video game players perceive it, and how other factors manipulate its effects in video games. Finally, we conclude that the in-game perspective, as a standalone characteristic, is not a fruitful metric to define a game's latency sensitivity. Previous approaches to categorizing latency sensitivity by video game genre or in-game perspective may neglect in-game factors that fundamentally alter the effects of latency. Ultimately, our findings allow future latency research to exclude the in-game perspective and to shift its focus to exploring other game characteristics that may alter the effects of latency in video games. By identifying other factors that influence latency sensitivity in video games, researchers can develop a more nuanced understanding of how game design affects player experience, which can help game developers design games that are more enjoyable and engaging for players.

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