Interactive Video Game Live-Streaming

Master Thesis

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Abstract

Lately, user-generated video game live-streams have exploded in popularity and become a common source of entertainment. As a result, video game live-streaming has attracted increased attention as a research area. In recent years, there have been several studies focused on how to drive engagement and enhance the audience experience in gaming live-streams by applying different types of interaction mechanisms. However, there is of yet little research that investigates the usage of interaction mechanisms for directly influencing the game that is being streamed. Meanwhile, tools to implement such mechanisms are available, and some applications of this have already been demonstrated. There are strong indications that both viewers and streamers desire such interaction mechanisms. However, due to the nature of how today's streaming services operate and their limitations, designing these types of mechanisms comes with a number of challenges tied to stream delay, arbitrary number of viewers, and user interface design. As of today, there are not yet any established best practices on how to overcome these challenges while retaining an engaging audience experience. Therefore, the main goal of this research is to investigate how to achieve an engaging audience experience in scenarios where viewers of gaming live-streams can influence the game that is being played directly through an interface on the stream, with a large focus on the aforementioned challenges. To achieve this, I used an iterative approach, first performing a preliminary design exploration study, where I designed and implemented three different interaction mechanisms, and then a second evaluation study, where experts evaluated the mechanisms. The mechanism types were majority vote with discrete options, heatmaps, and interface around interactive items. All of these interaction mechanisms showed promising results, with varying potential for enhancing the viewer experience depending on their execution. Interface around interactive items seemed to be the mechanism that yielded the best results overall, with the highest chance of having a positive impact on the audience experience. The research suggests that interactions where viewers do not expect instant reactions can be highly effective for compensating for delays, and clear communication of the game state can be helpful. Exploiting the crowd mentality by creating situations where viewers are incentivized to work together towards a common goal can also be effective, both for accommodating for different audience sizes and for masking the delay. The user interface should be clear, understandable, and intuitive, with relevant feedback and instructions provided. Overall, interactive overlays seem to have the potential to significantly increase the viewer experience in gaming live-streams, especially if the interface is well-designed and does not detract from the gameplay.

Contents

1 Introduction

In recent years, the field of gaming, e-sports, and computer games in general have grown in importance and acceptance as an area of study. A primary cause for this is the ever-increasing number of individuals who engage with games in various manners, making gaming research increasingly important. People today generally have easy access to games, heavily due to the growth of smartphone ownership and mobile gaming [40].

For some individuals, gaming has become a full-time career, not just as professional gamers competing in e-sports tournaments, but also as online broadcasters (commonly referred to as "streamers") on live-streaming platforms [18]. Game live-streaming has grown in popularity to the point where a considerable number of people favor watching others play games on live-streams over playing themselves [3]. The most popular platforms for gaming live-streams today are Twitch, Facebook and YouTube. According to Streamlabs [27], Twitch dominated more than 70% of the game streaming market in the third quarter of 2021, with a total of 5.79 billion hours watched. During the same time period, Facebook and YouTube had 1.29 and 1.13 billion hours watched, respectively. The number of viewers and streamers on Twitch have increased immensely every year since its launch in 2011. In 2021, the platform had 2.78 million average concurrent viewers and 8.46 million monthly active streamers, compared to 539,000 and 1.7 million respectively in 2015, according to TwitchTracker [49].

These professional streamers monetize their presence on Twitch and in many cases build their own community around their Twitch channel. More research on viewer engagement is increasingly important, as streamers are heavily dependent on their viewership and their viewers' engagement with the stream. Hilvert-Bruce et al. [15] conducted one of the first studies on the drivers behind live-streaming viewer engagement. In their study they found that the most important predictors of Twitch viewer engagement were social motivations. More precisely, the researchers found social interaction and sense of community to be the most significant motivators for live-stream engagement. Therefore, they emphasize that engagement on live-streaming platforms such as Twitch depends considerably more on social motivations compared to more traditional mass media such as television. Similarly, various other studies have highlighted social interaction and sense of community as important motivators for live-stream engagement [14, 13, 37]. Thus, there may be a desire for audience experiences that go beyond just watching and instead are more participatory.

Lately, interactive live-streaming has attracted increased attention as a research area in the HCI community. There have been several studies focused on how to drive engagement and enhance the audience experience in gaming live-streams by applying different types of interaction mechanisms [35, 22, 3]. However, there has been little research that investigates the usage of interaction mechanisms for directly influencing the game that is being streamed, in such a way that the viewers essentially play the game together with the streamer. Some applications of this have already been demonstrated, and there are strong indications that both viewers and streamers desire such interaction mechanisms [36, 14].

When designing live-stream interaction mechanisms that directly influence gameplay, there are several challenges that need to be considered. Live-streaming today inherently comes with various limitations in regards to real-time interactivity with viewers [28, 19, 36]. Since gameplay-influencing live-stream interaction is a rather new phenomenon and research on the topic is scarce, there are not yet any established best practices on how to overcome these challenges. This research aims to investigate some potential key challenges and develop an understanding of how to overcome them. In this thesis, I will examine the following three challenges:

1) Delay and Desynchronization
First, due to the nature of how today's streaming services operate and their technological limitations, there is always an inevitable delay between the streamer and the viewers [28]. This delay can vary, depending on e.g., the platform and network capacity. What the streamer sees will inevitably appear somewhat later for the viewers, meaning the streamer and the viewers are never in perfect sync. Additionally, this delay might further vary between each individual viewer, depending on factors such as physical location, network capacity, and buffering. However, interactions performed by viewers that trigger something to happen in the game are typically processed immediately [19, 8].

Example case: Imagine a top-down multiplayer game where the players are fighting in an arena and the viewers of the live-stream have the ability to drop bombs into the arena at a location of their choice. You as a viewer attempt to drop a bomb at the position of a certain player in the game. If your view of the stream is e.g., two seconds delayed, the player you are targeting has likely already moved to a different position by the time the action is performed. When the action is performed the players will see the bomb being dropped more or less immediately, but the viewer will not see it on their screen before another two seconds. Consequently, for the viewer it will seem like there is a two seconds delay between performing the action and the action happening in the game, which could in turn result in different outcomes than the user expects.

2) Arbitrary Number of Viewers
The second challenge is the arbitrary (and varying) number of viewers, and thus number of potential interactors. When openly live-streaming to a public audience, there will always be an arbitrary amount of people watching the stream - and this number can vary significantly. There could be anywhere between 1-5 people watching to potentially tens of thousands. How does one design around this to ensure an enjoyable experience shared between all the viewers, as well as the player(s)?

Example case: Given the same game and live-stream experience as in the example case above, allowing each individual viewer to drop bombs into the arena might be perfectly feasible with e.g., 20 viewers. However, the experience might become messy with e.g., 10,000 viewers. Thousands of people simultaneously trying to drop bombs into the arena will likely make the experience very confusing and possibly unbearable for both the viewers and the players.

3) User Interface and Interaction Design
The last challenge and a vital part of achieving an engaging user experience, is having a suitable user interface for the relevant interactions, and ideally one that effectively assists in enabling the potential solutions to the above challenges.

1.1 Research Goals

The main goal of this research is to investigate how to achieve an engaging audience experience in scenarios where viewers of gaming live-streams can influence the game that is being played directly through an interface on the video stream. As part of this investigation, the main questions I aim to provide answers to are the following:

- How to compensate for delays and desynchronization?

- How to accommodate for an arbitrary number of viewers?

- How to present a suitable user interface?

2 Related Work

2.1 Live-Streaming in General

Live-streaming is not a new concept. It has existed on the internet for over 20 years already and even longer for television [38]. However, with recent improvements in internet bandwidth and new online services becoming available, live-streaming has become accessible for the average person, allowing anybody to stream whatever they want whenever they want. Today, various individuals and organizations use live-streaming as a way to broadcast their content to a broader audience [38].

Work by Hu et al. [16] attempted to understand why users continued to watch on live-streaming platforms, and discovered that self-identification with the streamer and viewing group increased the motivation to keep watching. A study by Haimson et al. [13] compared Facebook Live and Snapchat Live Stories to see what makes live events engaging. Immersion, immediacy, interaction and sociality were found to be important factors in people's willingness to watch live events.

2.2 Video Game Live-Streaming

Video games is a popular category on live-streaming services. With the growing gaming industry and increase of accessibility of live-streaming tools, user-generated video game live-streams have become a common source of entertainment [38]. Here, individuals, usually referred to as "streamers", broadcast themselves playing video games for a public audience to watch. Streamers typically talk over the game they are playing, often commenting on their performance. It is also common for streamers to display in-person webcam video of themselves and others they are playing with on top of their streamed game content to facilitate richer engagement [14].

A common feature among live-streaming platforms is a shared chat channel next to the video stream. Here, viewers of the live-stream can communicate with the streamer and the other viewers through chat. This makes consuming live-streams a social experience, as the streamer can react live to e.g., viewer questions or suggestions [37]. Depending on the platform, additional features are available to enhance viewers' interactive possibilities. For instance, Twitch offers streamers the option to add elements such as buttons to their stream that viewers can interact with (e.g., pressing a button plays a sound in the stream). Streamers can also employ third-party tools (e.g., chat bots) to extend the experience further [21].

Another common feature on live-streaming services such as Twitch is the ability to subscribe to a certain streamer. By paying a small fee (usually on a monthly basis) the viewer can unlock additional perks and benefits only available to subscribers, while supporting the given streamer financially. Typical benefits include, among others, removing ads, getting access to special chat commands, gaining the ability to re-watch previous broadcasts, and having the possibility to play with the streamer. Gaining a large number of subscribers is a recurrent goal among streamers and an important part of streaming professionally [25].

Hamilton et al. [14] investigated how the medium of live-streaming fosters participation and community. They found that live-streaming communities form around shared identities based on the content of streams and the shared experiences of viewers. Sjöblom et al. [37] investigated why people watch others play video games. They found that information seeking, tension release, social integrative, and affective motivations impacted the hours spent watching, as well as the amount of individual streamers watched. They also found that social integrative motivations are the primary predictors of subscription behaviour. Their study laid some groundwork for understanding the motivations to consume the medium of live-streaming in the context of video games. In a study on live-stream practices, Lu et al. [24] found evidence that both viewers and streamers desire mechanisms for interactions that are more substantial and consequential than chatting.

2.3 Interactive Video Game Live-Streaming

Audience participation has long been employed in theatre and other performing arts as a way to engage audiences [23], and it is increasingly being adopted into technological domains. Audience participation games, described as games that have a "mutually aware group of audience members who participate in a way that has a meaningful impact on the game", blurs the lines between players and spectators [36]. Many Twitch streamers use "home-brew" methods to enable audience participation (e.g., chat polls to decide what weapons they should use in-game or what game they should play next) [34], which further demonstrates the value of these types of mechanisms. Researchers in the HCI community have experimented with various tools for enabling audience participation, including tools that reveal streamers' biometrics to spectators [35], heads-up display elements (e.g., for spectators to vote or give hints) [22], expressive visual viewer input [6], and games where the audience plays a role in the game itself [8]. Lessel et al. [22] created an add-on to the video game Hearthstone that enables a new communication channel between streamers and their spectators, giving spectators a hands-on way to engage in the gameplay experience, and Fanzo et al. [8] created an audience-driven horror game that requires audience members to use the live chat to help guide the streamer through the game. Likewise, commercial game titles have attempted to incorporate audience participation. E.g., Choice Chamber allows spectators to vote on game events [36].

The following sections explore previous research on interaction mechanisms for video game live-streaming, as well as existing real-world applications. Here, a distinction is made between three different categories of live-stream interaction mechanisms:

1) Interactions unrelated to the game
These are interaction mechanisms that are used in gaming live-streams, but are not in any manner related to the game being played. These include mechanisms such as chat bots and buttons that e.g., play sounds in the stream when clicked.

2) Interactions related to the game
These are interaction mechanisms that are related to the game being played, but are not directly affecting its gameplay in any manner. These include mechanisms such as interfaces that allow viewers to vote or give hints, possibly affecting gameplay indirectly.

3) Interactions affecting gameplay
These are interaction mechanisms that directly affect the gameplay of the game that is being played. This category is further broken down into two sub-categories. The first one is for live-stream experiences where no real people are directly playing the game. Here, the viewers of the live-stream take on a shared role as the player. The second sub-category is for live-stream experiences where real people are playing the game, more like traditional games - but the viewers can influence the gameplay to a certain extent.

2.4 Interactions Unrelated to the Game

This section explores interaction mechanisms that are used in gaming live-streams, but are not in any manner related to the game being played. Commonly used in live-streams, especially on Twitch, are chat bots. When you initially start streaming, you are likely to have a small number of viewers and have an easy time moderating them. However, when your viewer counts increase, moderation might get more challenging. This is where chat bots are effective. They can be used to delegate certain tasks instead of manually having to do them yourself. Chat bots can e.g., read chat messages and react to certain pre-defined commands, or automatically remove unwanted messages from the chat [47]. Chat bots can be beneficial in enhancing the features in your chat while keeping it free of spam. According to Streamscharts [17] and Streamscheme [51], one of the most popular chat bots on Twitch is Nightbot [30]. For interactivity, Nightbot includes features such as mini-games, polling and song requests [30]. It also offers custom commands, spam protection, and message scheduling, among others.

Chat is not the only tool for viewer interaction that is supported by Twitch. Twitch also offers the possibility to add extensions to your live-stream. Extensions are interactive overlays and panels, that can be developed by third parties. One example of such an extension is Stream Avatars [29]: an interactive overlay that enables viewers to customize their own avatars that are then displayed as an overlay on the video stream. Viewers can control these avatars and knock other people's avatars off the screen if desired. This is essentially a separate meta-game overlaid on top of the existing video stream. While this technically is a type of interaction that directly affects "a" game, it is not affecting the primary game the streamer is playing. As of June 2022, the state of Stream Avatars' user reviews on Steam is categorized as "Overwhelmingly Positive", meaning at least 95% of its 1,245 user reviews are positive. Many of the reviews compliment the additional layers of interactivity it adds to the live-stream. One reviewer states: *"This app is amazing, there are so many possible interactions with viewers! When they trolling me I "punish" them by pinning their avatars in the middle of the screen, or building a "cage" and placing them inside. They love attention and they keep teasing me to "earn a honor" to be placed in the middle of the screen."* Another reviewer says: *"Does so much while also being so simple. Makes streams more interactive and fun. Worth every penny. Fantastic software."* This indicates that additional layers of interactivity are valued and desired by streamers and viewers.

2.5 Interactions Related to the Game

This section explores interaction mechanisms that are related to the game being played, but are not directly affecting its gameplay. One such example is the simulated marble racing game Marbles on Stream [32]. In this game, the gameplay itself is completely random, and neither players nor viewers can do anything to change the outcome. The goal is simply to race with marbles against your community peers, for a chance of coming out on top of the leaderboard. However, the game includes in-game features built specifically for live-stream integration. These include being able to assign a marble to each of the viewers in the audience, and the ability to upload and share maps on a global system for others to race on. This allows for a large number of viewers to participate and

does not require installing additional software to "play". However, there is limited player agency as this functions more like a "betting simulator" where the viewers get assigned random marbles in a race with a randomly generated outcome. Marbles on Stream's user reviews on Steam are as of June 2022 categorized as "Very Positive", with 85% of its 1,309 user reviews being positive. Numerous reviewers compliment the additional viewer engagement and interactivity it adds.

Minion Masters [2] is another game with a comparable live-stream interaction mechanism. Minion Masters is a player versus player arena game, with no interaction mechanisms that directly affect the gameplay. However, the viewers of the stream can opt to visually hop into the arena and become their own in-game "puff fan spectator". This lets them chat with other spectators, as well as use a range of emojis during duels, that are displayed in the game. Here, all viewer interactions are chat command based.

In 2017, Lessel et al. [22] presented a case study with a live-streaming tool for the virtual card game Hearthstone. The tool provides several new communication channels for viewer interaction. Viewers can give sophisticated feedback and hints on a dedicated web-page. These are shown to the streamer, in an aggregated fashion, directly in the game. Even though the viewers can not directly influence the gameplay, they can indirectly affect it by influencing the streamer's decisions. The results of the study indicate that new communication channels are appreciated. Direct video stream interaction and detailed rating of game decisions seem most promising.

Another recent example of a tool that uses in-game data to provide a richer audience experience is the Twitch extension Dota 2 Tooltips [42], which is a fan-made Twitch extension, released in April 2021, for streamers playing the game Dota 2. The extension enables viewers to display relevant in-game information as an overlay directly on the video stream by hovering over certain buttons and icons in the game's user interface. This can make it easier for viewers to understand the current state of the game, as they can receive relevant real-time information on demand, without having to use additional tools or websites, which in turn could make the audience experience more engaging.

2.6 Interactions Affecting Gameplay

The contents of this section are broken down into two sub-categories. The first one is for live-stream experiences where no real people are directly playing the game. Here, the viewers of the live-stream take on a shared role as the player. These experiences act more more like simulations where each individual viewer has a small say in the outcomes. The second sub-category is for live-stream experiences where real people are playing the game. These mostly act like traditional games where the players are the ones primarily in charge of the game's outcomes, but the viewers can influence the gameplay to a certain extent.

2.6.1 Affecting Gameplay in Simulation-Like Games

One of the most prominent examples of gameplay-affecting interaction mechanisms in the history of video game live-streaming is Twitch Plays Pokemon (TPP) [48]. TPP is a social experiment and channel on Twitch, consisting of a crowd-sourced attempt to play Game Freak's and Nintendo's Pokémon video games by parsing commands sent by users through the channel's chat box and mapping them to game controller inputs in order to advance in the game [20]. The experiment, which launched in February 2014, gave a global audience control of a game by practically turning the Twitch live chat into a game controller. The chaotic nature of having thousands of near-simultaneous inputs controlling the game has the potential to produce a joyous anarchy, driving a shared experience among viewers as they strive to achieve a common objective. TPP holds the Guinness World Record for having the most participants on a single player online video game, with 1,165,140 participants between 12th of February and 1st of March, 2014 [33]. During the same time period, TPP had more than 36 million views and a peak simultaneous participation of 121,000 [46]. This experiment implies that there is a significant desire for more hands-on live-stream interaction mechanisms that let viewers influence the outcome of the game, with a potential massive audience ready to be activated.

Another promising example is Rival Peak [10], an experimental competition reality show running on Facebook from December 2020 to March 2021. The show featured artificially intelligent virtual contestants whose fate was controlled by the viewing audience. Viewers were able to impact the

contestants and their environs in real-time via an interactive overlay on the live-stream to do things such as vote on tomorrow's weather, solve puzzles and help or hinder the AI characters in various decisions and projects. Audience interactions contributed points to each contestant's cumulative score, which in turn was used to determine the weekly elimination of a contestant [4]. Rival Peak's interactive live-stream had more than 100 million minutes watched, with viewers from more than 70 countries worldwide, and received more than 200 million engagements (reactions, comments, shares, and clicks) [4]. This experiment further implies a desire for interaction mechanisms that let viewers influence the outcome. In comparison to TPP, viewers could not control the virtual character's actions directly, but rather had a chance of influencing their choices indirectly through a voting system. Despite this, it still gained significant interest, comparable to TPP.

2.6.2 Affecting Gameplay in Games Played by Real People

In recent years, there have been several examples of games developed with integrated support for live-stream interaction. The first game designed from the ground-up to be played live on Twitch was Choice Chamber [1]. According to a 2014 blog post by Twitch: *"Choice Chamber is designed to be played while being streamed live to Twitch. As you broadcast the game on your channel, anyone watching can participate in the game simply by typing in the chat box. A series of polls ask viewers to vote on certain aspects that alter the game's progression in real-time, or viewers can trigger special events, friendly helpers, and even attack the boss themselves. Chatters can band together to help out the main player in getting far in the game, or they can work against the player and create a devilish challenge."* [26]. As of June 2022, the game's user reviews on Steam are categorized as "Very Positive", with 90% of its 122 user reviews being positive. In an article from 2015, Slashgear stated: *"It's one of the first, and quite possibly the best, example of really getting viewers involved in playing the game with the Twitch broadcaster."* [50]. The same year, Venturebeat also published a short article on the game, calling it "super-fun" [12].

In 2017, Fanzo et al. [8] presented the Twitch-based horror game What Lurks in the Dark, where the streamer takes on the role as a ghost hunter who is trapped inside of a house with an evil ghost. The streamer is tasked to explore the house and gather items required to banish the ghost, without being caught. However, the streamer can not see the ghost and is dependant on the guidance of their viewers. Meanwhile, in addition to seeing the game stream and Twitch chat, viewers can look at different cameras inside the house to locate the ghost. They can choose to communicate the ghost's location to the streamer, truthfully or not. Additionally, the viewers can collectively (through majority vote) control certain objects in the game. They can decide whether they want to help or hinder the streamer and plan their actions accordingly. What Lurks in the Dark explores themes such as viewer sympathy, the challenges of teamwork in online spaces, and the balance of power between streamer and audience. Fanzo et al. [8] point out the challenge of finding the balance where every audience member feels like their vote matters while still managing to keep the game balanced for the streamer. However, with the options provided for the viewers in this experiment, they "believe they are close to achieving a satisfactory balance" [8].

An upcoming game that comes with integrated support for live-stream interaction is In The Black, a multiplayer space shooter for PC. According to a 2020 article on Venturebeat [43], when live-streamed, viewers will have access to interactive game maps and player information cards containing statistics about the different players. On top of this viewers can place wagers on whether a player is going to kill or get killed, which are are then used to determine player bounties. Then if another player wins that bounty, both the player and the viewers responsible for the bounty get rewarded. This creates an interactive loop between the player objectives and the viewers, who have their own unique meta-game. In this game, all interactions are accessible through an overlay on top of the video stream. As the game has not been released yet, there are not any useful statistics available yet. However, this displays an interest in creating these types of experiences among game developers. It is also worth noting that the company behind the live-stream interaction technology used in this game, Genvid Technologies, raised 113 million dollars to fund the exploration and development of interactive video game live-streaming features [5]. This further displays a significant industry interest in this.

Other examples of games that support gameplay-affecting interactions include: "Dead Cells" [44], which lets viewers choose gameplay modifiers and which stats to upgrade when the player find scrolls in-game; "Warhammer: Verimintide 2" [9], which lets streamers connect multiple Twitch channels to a single in-game lobby, allowing votes from each channel's viewers to impact the game;

"Streets of Rogue" [7], which lets viewers decide the traits and rewards the streamer's character gets at the end of a level, as well as what disasters that should appear in the game; and "Black Future '88" [39], which lets viewers choose which perks and traits the streamer's character gets, as well as what curses, buffs, and upgrades to apply. Two common traits among all these examples are that viewer interactions are performed through chat commands and that voting systems are used to determine the final outcomes based on these interactions. All these games have received massive interest and significant amounts of positive reviews on Steam. However, even though all of these games support live-stream interactions, it is uncertain exactly how much this impacted their overall success.

2.7 Current Challenges With Gameplay-Affecting Interactions

As video game live-streaming has become popular, researchers have begun to identify interaction design challenges in regards to audience agency, time, and viewer-streamer relationships [11]. A primary challenge in participatory streaming experiences is how to give agency to multiple audience participants. Lu et al. [24] suggests that streamers and viewers both desire interactions that are more substantial and consequential than commenting, however it is difficult to do this without compromising the overall experience. In complement to agency, temporal challenges in live-streaming include delays and latency. Gameplay-influencing live-stream interaction is a rather new phenomenon and the aforementioned challenges seem to be just as present among the applications that have so far been demonstrated. However, there does not yet seem to be any established best practices on how to overcome or design around these challenges.

2.7.1 Delay and Desynchronization

Due to the nature of how today's streaming services operate and their technological limitations, there is always an inevitable delay between the streamer and the viewers [28]. This delay can vary, depending on e.g., the platform and network capacity. What the streamer sees on their screen will inevitably be displayed somewhat later for the viewers, meaning the streamer and the viewers are never in perfect sync. Additionally, this delay might further vary between each individual viewer, depending on factors such as their network capacity and physical location. In 2015, Twitch used to have between 12 and 30 seconds inevitable delay before adding any additional viewer-side delay, according to an article on Kotaku [19]. Similarly, Miller et al. [28] mentioned in 2017 that live streams often exhibit latencies of up to 20 to 30 seconds. This is due to the fact that most of today's live-streaming platforms uses HTTP-based adaptive streaming [28]. While this method ensures a high quality of experience, minimizing playback interruptions while maximizing video quality for the viewers, it also comes with the drawback of producing high latencies [28]. They also pointed out how this delay can be further extended by viewer network constraints. These inevitable delays can make real-time interactivity challenging. To add to this, even though the viewer's perspective of the stream is delayed, their input when interacting with the stream is still processed immediately [19, 8], which can further add to the challenge.

There have recently been some promising developments in this area. According to a blog post by Twitch from October 2021 [31], they have invented what they call low-latency HTTP live-streaming, which reduces the base platform delay down to 3 seconds. Even though this is a step in the right direction, making the issue much less significant, the delay still remains a challenge today when designing real-time interactivity between viewers and the streamer. Fully real-time interactions are still unachievable, meaning the current unavoidable delay needs to be designed around and can be a potential blocker for some types of interactions.

So far researchers and developers have mainly explored interaction mechanisms that are not heavily dependant on timing, and mechanisms that let viewers influence gameplay in real-time have generally been avoided. Most commonly seen have been the usage of voting systems, where the viewers only can influence what should happen, but not when it should happen. The aforementioned delay challenge could be one of the major reasons behind this. Fanzo et al. [8] mentioned that when designing "What Lurks in the Dark", they had to eliminate any "split second" types of mechanics due to the inevitable delay. Therefore they opted for a majority vote mechanism that allows the viewers to collectively control certain game elements at certain pre-determined timestamps. Games such as "Dead Cells" [44], "Streets of Rogue" [7], and "Black Future '88" [39] also opted for similar voting mechanisms.

2.7.2 Arbitrary Number of Viewers

A major challenge when designing participatory interaction mechanisms for large public broadcasts is the arbitrary (and varying) number of viewers, and thus number of potential participants. When live-streaming to a public audience, there will always be an arbitrary amount of people watching the stream - and this number can vary significantly depending on numerous factors. There could be anywhere between 1-5 people watching to potentially tens of thousands.

When playing and streaming a video game with a participating audience, the streamer typically has more capabilities in the game space than the audience. Additionally, power must be shared among multiple audience participants. With large number of participants, it is easy to imagine how each individual participant might feel insignificant. Seering et al. [36] mentioned how many audience participants value the ability to affect the outcome of the streamed game. Their central concern was how to give agency to multiple audience participants without compromising the experience for any of them. A common solution seen in various examples is the usage of voting mechanisms. However, Seering et al. [36] criticized such solutions for aggregating viewer inputs, hence reducing the sense of agency for each individual audience participant. Some researchers have touched upon the option of using a "fractal" design, where each audience participant has individual agency over a certain subset of the game's world or characters [11]. A similar issue might also arise here, where a given subset might not feel significant enough. Another way to give each individual participant more agency without sacrificing the overall participant experience could be to limit the agency to only a few selected audience members at a time. However, since a large number of people would likely not be able to participate, this might introduce a feeling of unfairness among the viewers, which can consequently reduce the audience experience as a whole.

Most applications seen so far have used voting mechanisms to compensate for large amounts of viewers. However, other types of interaction mechanisms have been demonstrated in for instance scenarios where viewer input does not make a significant impact on the gameplay, such as in the game Minion Masters [2], and in scenarios where the viewers act as the only "players", such as in Twitch Plays Pokemon [48]. In these scenarios, each viewer interaction causes a direct action inside the game space. In TPP, where there is no single main player who actively controls the game, the primary goal among participants becomes to collectively complete the game despite the chaos caused by the thousands of near-simultaneous inputs. However, there are many scenarios where employing similar mechanisms might completely ruin the experience. Imagine a game where the viewers controls an enemy character that is supposed to eliminate the streamer's character. If each viewer input causes an in-game action, like in TPP, it would likely be impossible for the viewers to coordinate their actions into anything useful in a timely manner, as indicated by the TPP experiment [20]. In this case, a more fitting solution could be to only give viewers agency over certain actions the enemy should take or which traits it should have, for instance using a voting system to determine the final outcomes - while letting the majority of the enemy's actions be controlled by the computer in a more traditional sense.

2.7.3 User Interface Design

A vital part of achieving an engaging user experience in any interactive system is having a suitable and intuitive user interface. This section discusses the user interface from the viewer's perspective in live-streams where the viewers can influence gameplay, as in how they interact with the game and what is presented to them on screen. This area as a whole is a rather new phenomenon and exploration in user interface design has thus been limited. The most commonly seen interaction method so far has been chat commands, as in parsing commands sent by viewers in the chat and mapping them to actions in the game. This is likely one of the easier interaction methods to implement, as Twitch and similar platforms already come with an integrated chat box, as well as APIs for reading and parsing chat messages [47]. However, Twitch recently started offering the possibility to add interactive overlays on top of the video stream [45]. These interactive overlays can be developed by third parties, and allow for viewer input to be sent directly to the game that is being streamed. There has not yet been much exploration in interaction methods using such overlays in scenarios where viewers can influence gameplay in games being played by real people. However, there has been some exploration in similar scenarios. E.g., the Dota 2 Tooltips extension lets viewers display relevant in-game information on demand as an overlay directly on the video stream [42]. By hovering over certain buttons and icons in the game's user interface as displayed on the stream, a contextual window containing relevant information pops up - similar to how it

would appear for someone playing the game. The same could be achieved using e.g., a chat bot. By typing a specific command, the bot could answer in the chat with relevant information. However, one can likely claim with high certainty that the on-stream solution is more intuitive, and that it could therefore yield a higher level of engagement compared to the chat-based method.

Using an on-screen overlay also allows for certain mechanics that are not feasible using chat commands. E.g., in Rival Peak, viewers can interact with the virtual characters by directly clicking on them on the video stream [4, 41]. Such overlays allow for some interesting mechanics, which can potentially enable more immersive and engaging audience experiences. Since the viewer can interact in the same screen-space as the streamer, it allows for direct interaction with the game world through the live-stream. Stream overlays also make it possible to display visual cues on top of the video stream that are e.g., only visible to the viewers and not the streamer, or only visible to certain viewers. This can potentially make for some interesting interface and interaction designs. However, a natural drawback of using such overlays is the additional design and development time it requires, in comparison to using e.g., the readily available chat box. Voting systems, which have been the preferred interaction mechanisms so far, do not particularly require a visual user interface to serve its purpose. The feedback and user reviews of existing games with such mechanisms indicate that voting through chat is feasible and intuitive enough for participants to get a satisfactory experience out of it. This, together with the additional effort required to design overlays, could explain why most applications so far have resorted to chat commands. As this field gets more explored and new interaction mechanisms are introduced, research on how to achieve satisfactory interface and interaction designs is getting increasingly relevant.

2.8 Conclusion

Video game live-streaming is becoming increasingly popular, and in parallel the desire for richer live-stream interaction mechanisms is growing. In recent years, there have been several studies focused on driving engagement and enhancing the audience experience in gaming live-streams by applying different types of interaction mechanisms. However, just a small portion of these studies have explored interaction mechanisms for directly influencing the game that is being streamed. Meanwhile, some applications of this have already been demonstrated, and there are indications that both viewers and streamers desire such interaction mechanisms. Therefore, I will explore this subdomain further and investigate how to achieve an engaging audience experience in scenarios where viewers can influence the game that is being live-streamed.

Due to the nature of how today's streaming services operate and their limitations, designing these types of mechanisms comes with a number of challenges tied to stream delay, arbitrary number of viewers, and user interface design. As of today, there are not yet any established best practices on how to overcome these challenges. Investigating these aspects will therefore be of high importance for this research.

3 Methodology

The main goal of this research is to investigate how to achieve an engaging audience experience in scenarios where viewers of gaming live-streams can influence gameplay through live-stream inputs, with main focus on the following challenges:

- How to compensate for delays and desynchronization?

- How to accommodate for an arbitrary number of viewers?

- How to present a suitable user interface?

I provided answers to these questions by conducting an iterative approach, where I first conducted a preliminary design exploration study. Here I received feedback and suggestions from experts in the field of game development. Based on the expert feedback, I designed and implemented prototypes for three different interaction mechanisms that were supposed to overcome the aforementioned challenges while providing an enjoyable audience experience. Then I conducted a second study: an evaluation study, where experts evaluated the suggested mechanisms after testing the prototypes in a simulated environment.

4 Study 1: Design Exploration

The goal for this study was to design and implement prototypes of a set of different interaction mechanisms that will later be evaluated. While doing so the challenges regarding delay, arbitrary numbers of viewers and user interface were in focus. I aimed to make them as engaging as possible. At the same time, I aimed to create mechanisms that minimize the negative effects tied to delays and arbitrary numbers of viewers, and give them suitable user interfaces fit for their individual purposes. These interaction mechanisms would in a later study be tested and evaluated by experts. From this implications and limitations will be discussed.

Even though the exact interaction mechanisms to evaluate would be decided during this study, there were already some types of mechanisms that came as natural choices and were likely to be included. E.g., voting, being the most common mechanism seen in applications so far, would likely be part of it. Another type of interaction previously mentioned in this paper is "fractal" design, where each audience participant has individual agency over a certain subset of the game's world or characters. A mechanism similar to this would potentially also be part of this. In addition to evaluating more established mechanisms, this research aimed to go a bit beyond what has previously been explored, and experiment with some novel implementations where varying levels of agency are given to viewers.

4.1 Method

In order to test and evaluate live-stream interaction mechanisms I needed a platform, or a game, to do so for. I decided to design and implement these mechanisms as a Twitch extension for the multiplayer arena brawler game Rules of Robots, and use that as the testing platform for this research. This is a game currently in alpha-phase and in development by the game studio Sharp Raccoon. I already have access to its source code and am allowed to use it as I desire, and can therefore implement the in-game actions required for the live-stream interaction mechanisms in a rather straight forward manner, without having to do any sort of modding or unethical altering of game code. Rules of Robots has simple and functional gameplay, and even though it is still in early development, it has been user-tested and received positive feedback, in addition to winning a couple of awards. This means I can say with at least some certainty that this game will suffice for creating realistic scenarios when performing the tests, despite being in an unfinished state.

For context and better understanding of the study, shortly told, Rules of Robots is a top-down 2-4 player arena brawler game where you play as robots trying to eliminate each other, using different weapons that spawn across the map. The last person remaining wins the round, and the first person who wins a set amount of rounds wins the entire match. Players can also create their own maps with their own customized game rules, that can then be played by themselves and others.

It is important to note that, due to the studies performed in this research being limited to one specific game, the given results and implications might not perfectly represent similar scenarios in other types of games. That being said, the mechanisms used in this research are designed and implemented with generalizability in mind. This is also taken into consideration when evaluating and discussing the results.

To decide on the types of interaction mechanisms to implement and their designs, I conducted semi-structured one-on-one interviews with experts with relevant experience in the field of game development. The goal of these interviews was to discuss possible interaction mechanisms and land on a few different ones that, with supported reasoning, were supposed to overcome the aforementioned challenges while providing an enjoyable audience experience. At the same time I aimed to land on mechanisms that tackle these challenges differently and engage in significantly different ways.

I invited four participants for this study. These were people with expertise in the area of game development and user experience design. I had two participants from an indie game studio with proven track record of receiving good reviews from their users: one UX and game design lead with several years of professional experience, and one media and marketing manager with several years of experience with online media content. The third participant was a game designer from a AAA game studio, with an education within game design and several years of experience working

in the game industry. The fourth and last participant was a game developer with several years of experience working for multiple game studios. These participants, considering their relevant experience with game and UX design, should be able to provide reasoned input on this.

When conducting the interviews, the procedure went as following: I gave them an introduction to the research project, and told them about the goals of this research and what I aim to get out of these interviews, namely a set of live-stream interaction mechanisms that will later be tested and evaluated, with focus on the challenges posed in the research questions. Here I also showed them gameplay videos of the game the interaction mechanisms are being implemented for, to make it easier for the interviewees to come up with specific mechanisms rather than keeping everything abstract. To give them some ideas for different mechanisms, I gave them some examples of "high-level" categories of existing interaction mechanisms, namely majority vote, fractal design, direct real-time interaction, and giving certain viewers authority. To get the most out of these interviews I wanted to keep the question part semi-structured and opt for a discussion-type format. I wanted to set it up for the participants to speak and provide their own original reasoned suggestions as much as possible. Therefore I prepared a few relevant questions to serve as discussion starters. Then I let the discussion flow from there. The questions I prepared were the following:

- Have you previously heard of or watched any gaming live-streams with gameplay-influencing viewer interaction?
  - **If yes:** Are there any interaction mechanisms you found particularly interesting?
  - **If no:** When hearing about this now, are there any gameplay-influencing interactions mechanisms you imagine could be interesting to see?
    - Could these be applied to different scenarios or other games? How?
      - Any way you imagine these working in Rules of Robots?
- I already mentioned majority vote, fractal design, and giving certain viewers authority/control as examples of high-level interaction mechanisms. Do you know of or can think of any other interesting high-level interaction mechanisms (in a general sense, without considering a specific game)?
  - Are there any ways you could see these high-level mechanisms be applied to Rules of Robots?
    - From a UI/UX perspective, could you imagine any practical ways of applying these interaction mechanisms? E.g., through chat, contextual buttons on the screen, or some other type of interface?
- Do you see any potential issues with [mention ideas that we have discussed] in scenarios with arbitrary viewer counts? For example, would any of these only work with a certain number of viewers, or could there be ways to generalize them for any viewer count?
- What about potential stream/input delays? Is timing a vital factor for any of these ideas/mechanisms? Would any of these only work in a fully real-time environment?
- Any other ideas for how to apply gameplay-influencing interaction mechanisms to Rules of Robots, outside of what we've already discussed?
- Any new ideas that have popped into your head during this discussion? Could be related to Rules of Robots, or not.

4.2 Analysis and Results

Throughout the interviews, various interesting types of mechanisms were suggested. I wrote all of them down and sorted them into a few main "high-level" categories. To land on a set of mechanisms to implement from these, I defined a relevant design space. Since it has previously been established that the level of enjoyment and engagement often relies on each individual viewer's feeling of agency,

I opted for a design space with democracy and anarchy as the opposing dimensions. It is fair to assume that in an democratic environment where each person has a minor say in the final outcome, each individual person's feeling of agency is probably on the lower end, and in addition it negatively scales with the amount of people involved. In contrast to this, in an anarchistic environment there is likely to be more freedom and thus control given to each individual person. After categorizing the mechanisms I looked at how likely they are to be democratic versus anarchistic and defined their place in the design space thereafter. To get some variety I aimed to opt for one mechanism type that is high on democracy, one that is high on anarchy and one that is something in-between. To help make the decisions, I also discussed implied pros and cons based on the interview discussions. The different categories found were the following:

Majority vote with discrete options
Voting is the most common mechanism seen in applications so far, and different voting systems were common suggestions among the participants. This type of system seems to be a logical choice for developers/designers. Given its limited nature, it is a rather safe option. Because it entails limited options with controllable outcomes from a developer perspective, there is not much room for negatively impacting the existing gameplay and viewer experience by something unexpected happening. A typical drawback with such systems is the lack of agency. Again, considering that it is limited by nature, the viewers' impact is by extent limited, which can make viewers feel more constrained and less influential.

A suggestion that kept coming up to mitigate the agency challenge was to split viewers into x number of groups and have each group control a different subpart of the game. There would still be a majority vote within each group for making decisions regarding their subpart. This would not solve the problem, just decrease the pool of people you are voting against, possibly making each vote feel a little more influential. However, above a certain amount of viewers, this would still be insignificant.

Some specific gameplay ideas were suggested, such as at certain intervals voting for which player should get a buff (e.g., extra life or speed boost), or voting for a game state change, like changing game mode, game rules, game mechanics or attributes. This could essentially be applied to anything that is normally decided randomly in the game. Instead of having the game decide the outcome, it can be outsourced to the live-stream viewers.

Design space position: low anarchy / high democracy

Fractal design
The idea here is that each audience participant has individual agency over a certain subset of the game's world or characters. While this could be interesting with a low number of viewers, it would scale poorly with larger numbers of viewers. The game would require an independent interactive element for each viewer involved, which would mean with a lot of viewers and a lot of different interactable elements, the game could either quickly get too cluttered or chaotic, or each viewer would need to have very little independent impact - which in turn could significantly decrease the sense of agency. One way to give each interactor more agency would of course be to limit the possibility to interact to only a certain number of viewers at a time. The drawback of this is that it would completely remove agency for everyone who is not selected, and depending on the amount of viewers, one would potentially have to wait for a long time to get to participate. On a general basis, there does not seem to be a logical clean way to implement this in a way that scales well with an arbitrary number of viewers. This could of course differ depending on the specific game involved, but in a general sense, this type of interaction mechanism does not seem to be suited for an arbitrary number of viewers.

Design space position: (low-)medium anarchy / high democracy

Independent direct real-time interaction
The idea here is that you straight up bind commands or stream inputs to certain in-game actions. Each viewer would be able to interact independently and the action would be executed immediately (though of course with a slight inevitable delay). By nature, this type of mechanism would likely be challenging to keep under control, meaning unexpected situations that would negatively affect the experience could appear. One obvious drawback here is the inevitable live-stream delay. When dealing with real-time interactions, people most likely expect their action to happen instantly.

When this does not happen due to the delay, confusing, unpredictable or annoying situations might possibly arise, which in turn could decrease the viewer experience.

Design space position: high anarchy / low democracy

Interface around interactive items on the map
In many ways this concept could also be considered a subcategory of independent direct real-time interaction. The principle here is that you have an interface (e.g., arrows, buttons or sliders) around or next to interactive elements in the game. Interacting with this would directly add a small change to the given element.

For example, if the game has something that moves or rotates, the viewer could have an interface with arrows around it. If you click a certain direction, the given object will move or rotate in that direction, or alternatively click either direction to increase/decrease its speed. To quote one of the interview participants: *"You could be like, actually I want this to move the other way, so you spam it, and it slows down and eventually starts turning the other way."* The same participant also added: *"If something in the game is doing something, you could just add a button on the screen to give it a small change. This thing moves, okay, here is a 'change how it moves' button. And then let people just spam it, making it a fight within the community basically a toggle war or a rope pulling competition."* Another possible way to apply this mechanism is to have a progress bar or a slider that fills up the more people click it, and when it fills up completely, something happens. If you have for example a static item in the game with a shooting mechanic, a shot could be fired each time the progress bar reaches the top. One participant comments: *"In a competetive multiplayer game, if you divide the audience into groups, for each player, you could have a power meter that goes up the more people spam it, so it literally turns into a war between the players about who has the biggest fans (or haters) among the audience. If enough people spam it, the player will get a boost or a de-buff or something. In general, you could just find mechanics where the viewers in one group can chant with each other, add up and become part of something bigger, where it feels like what they are doing is reflected in what other people are doing. Setting up for community wars like this could possibly add a lot of engagement."*

Intuitively, this type of interaction mechanism would give viewers a high sense of agency, as every interaction has a literal direct impact. This would also likely scale well with any number of viewers. With a low number of viewers, people would likely feel agency because of the large contribution one can make when the group is small and there is less fighting against each other. On the other hand, with larger number of viewers, the community would be likely to "form teams" that are working together towards certain goals, possibly several teams competing against each other. In this situation, people would likely feel an influence, as well as sense of community, due to being part of a crowd with a shared goal. You end up getting a sort of crowd mentality, which can be powerful. One seemingly clear drawback of such a system is the inevitable live-stream delay, for the same reason as the previous category. The delay might create confusing and unpredictable situations for the viewers, when they expect the action to take place immediately after interacting.

Design space position: high anarchy / low democracy

Heatmaps
When dealing with a ton of information and a ton of people, doing some sort of a heatmap intuitively seems like one of the better options. This is a very general idea as well - the idea of creating heatmaps and letting the game decide how to use them. For example, instead of a viewer choosing "I am going to drop a bomb at this location now" (which with many interactors involved could quickly clutter the game and ruin the experience), the game would have certain heatmap spaces. Each viewer would be able to select a spot on the heatmap where they want the bomb to drop, and then the game can either take an average spot from the heatmap or the hottest spot, and drop the bomb there. This is like an automated majority vote. It is a vote with a lot higher granularity. Instead of having discrete options, you would have continuous options, likely giving a higher sense of agency.

Design space position: medium anarchy / medium democracy

Latest input decides the action
The principle here is simple. Say if you have a countdown that everyone can see. Then viewers

have to spam the input they desire, and the one (or few) that is last in the list when the countdown is finished gets their action executed. One could also limit how often people can click, so that it becomes about timing it the best. Intuitively, this does not seem to be the most engaging type of mechanic. As this could set up for contests between the viewers, there is some possible engagement value from that. However, as only a small number of viewers would get to influence at a time, the overall sense of agency would likely be rather small.

Design space position: medium anarchy / medium democracy

General notes
In regards to user interface design, independent of the interaction mechanism, the general consensus among the participants is that using chat commands will usually be too primitive. The preferred option for any mechanism is having a visual interface on the screen with intuitive buttons and visuals for all interactions. A common agreement is that it is important to display to the viewers that their action made an impact. When using chat, it is easy to miss what your action actually did.

4.3 Prototype Designs

The selected types of interaction mechanisms to implement ended up being the following:

Majority vote with discrete options
This type of mechanism is mostly on the democratic side.

Heatmaps
This type of mechanism is somewhere in-between democratic and anarchistic.

Interface around interactive items
This type of mechanism is mostly on the anarchistic side.

The following sections describe how these types of mechanisms were applied to Rules of Robots, and how I went about designing each mechanism and their interface. It is important to note here that the focus when designing the interfaces is mainly on functionality and usability, rather than looks. This is supposed to be on a prototype-level and not fully represent a potential finished product.

4.3.1 Majority Vote With Discrete Options

This mechanism was designed in a rather straight forward manner and could easily be generalized. A natural way to go about this would be to find or make something in the game that viewers should be able to change at certain intervals or conditions. Since Rules of Robots is heavily a game about changing rules, and is also a game with rounds, I opted to give the viewers the option, between each round, to vote for a game rule to be added. Every time there are three options, and each viewer can vote on one of them. A counter for how many people have voted on each rule is always present. The interface design can be seen in Figure 1.

Figure 1: Screenshot from Rules of Robots displaying panel with voting options (February 2023).

The panel with buttons for voting will only be visible to the viewers and not the players. The panel will appear a few seconds into the round and stay there until the round is finished. Then the top voted rule is added before the next round. Every time a round finishes, a pop-up window displays the rule that will be added, as seen in Figure 2.

Figure 2: Screenshot from Rules of Robots displaying vote decision pop-up for players (February 2023).

The assumption here is that this type of interaction mechanism will work well with any number of viewers. No amount of viewers should add any more chaos to this, so it will scale quite well in that regard. However, the feeling of agency will likely be quite low overall, and quickly get lower the more viewers that are interacting, as each individual vote will disappear more into the masses. Though, this one will probably not be much affected by delay. So game design wise, this will probably work quite well, but the entertainment value will not be the highest. However, this could likely work well together with other mechanisms, more as a simple side mechanic that you may or may not decide to use. At the very least it will add some extra interactivity to the live-stream without adding much additional clutter for the players and the viewers. Given its limited nature,

it is a rather safe option, without much room for negatively impacting the existing gameplay and viewer experience by something unexpected happening.

4.3.2 Heatmaps

The design of this idea is heavily based on suggestions from the interviews, namely having a bomb drop every x seconds at a location defined by a heatmap. This is a very general idea that could be applied to various other games as well - the concept of having heatmaps and letting the game decide how to use them. In this specific implementation, the arena in the game has a grid, where each viewer can select a spot where they want the bomb to drop. The more people that select a spot, the hotter the spot gets. The game then takes the geometric mean location of all the selected spots and drops the bomb there. This repeats every 10 seconds. I opted to use a geometric mean for the drop location instead of the hottest spot. The idea here is that no matter the outcome, each individual click will still have a slight impact, possibly increasing the sense of agency. The interface design can be seen in Figure 3 and 4.

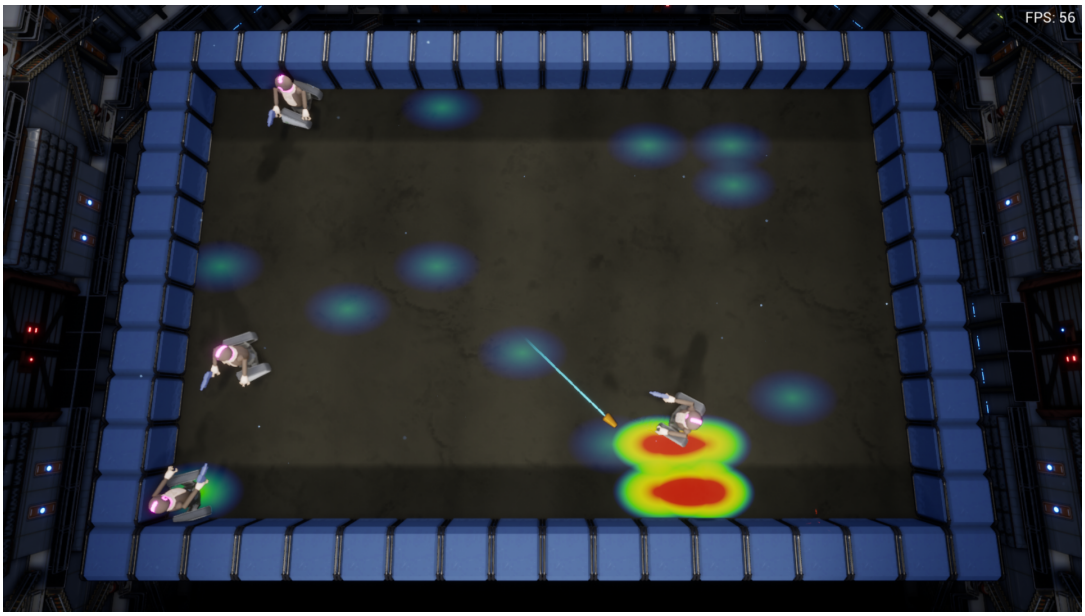

Figure 3: Screenshot from Rules of Robots displaying heatmap without grid (February 2023).

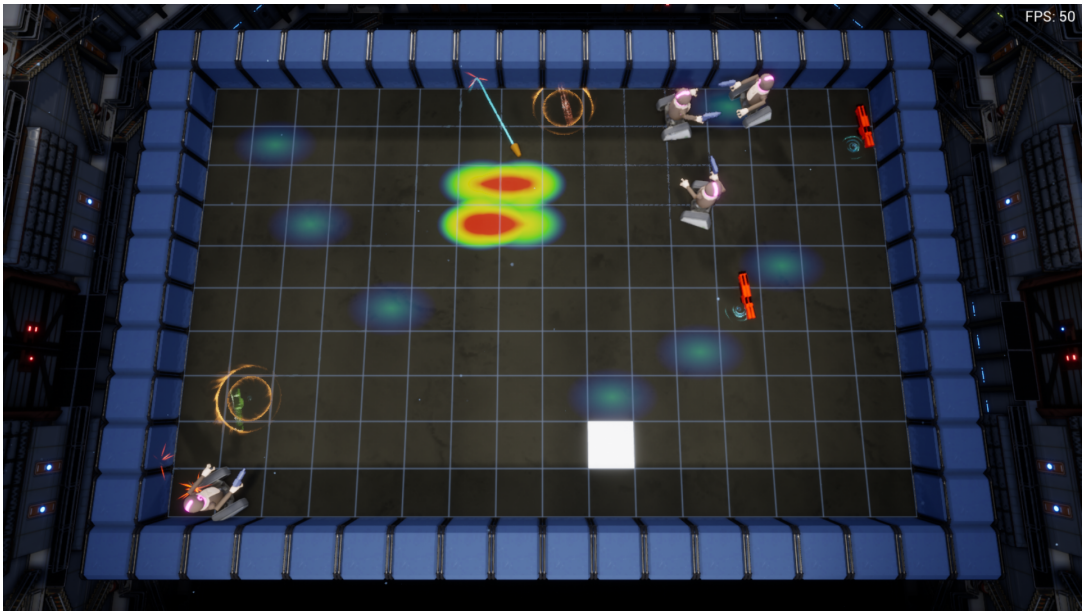

Figure 4: Screenshot from Rules of Robots displaying heatmap with grid (February 2023).

Figure 3 displays how it looks when not actively interacting. When the viewer hovers over the arena, a grid appears, as displayed in Figure 4. The currently hovered grid slot is displayed as a white square. When clicking that spot will be selected and locked in. Each time a viewer selects a spot, a blue dot gets added to the heatmap. As more viewers select the same spot, the hotter it will get and the more red it will turn, clearly displaying the hot-spot(s).

The heatmap and its interface will only be visible to the live-stream viewers. From the player's perspective there will just be a bomb dropping at a seemingly random location every 10 seconds. The idea here is that the game will be less cluttered for the players this way, and the viewers will have full control over where the bomb drops, without players knowing, meaning they can easier target certain locations or players without them being able to prepare for it. Every 10 seconds the heatmap will disappear for a moment and the bomb will be dropped. An indicator for where the bomb will drop will show up for a slight moment before the bomb drops, also for the players to see. This will be visualized as in Figure 5.

Figure 5: Screenshot from Rules of Robots displaying a bomb being dropped from the heatmap (February 2023).

4.3.3 Interface Around Interactive Items

This is a type of mechanism that intuitively should work quite well overall. The design of this is heavily inspired by the suggestions from the interviews. As one of the participants indicated with their statement "if something in the game is doing something, you could just add a button on the screen to give it a small change", one could essentially just add an interface to any possibly interactive element in the game. Interacting with this would then directly add a small change to the given element, depending on its specific mechanic. The user interface design for this can be seen in Figure 6.

Figure 6: Screenshot from Rules of Robots displaying interfaces around interactive items (February 2023).

The interaction interfaces will only be visible to the live-stream viewers. The numbers displayed in Figure 6 are not part of the interface and are only there to show which interaction elements belong to which game elements.

This game already had a few existing game elements fit for this purpose. Instead of having a random number generator decide the outcome for certain elements, I outsource the decisions to the viewers of the live-stream. All the gameplay elements this is applied to are physical objects that are placed within the arena. The included elements are the following:

1: Spikes
The interface for this is a two-directional progress bar, where viewers can click to either increase or decrease the progress. While the progress is below 50%, the spikes stay down, and while above 50%, the spikes stay up. If a player gets hit by the spikes, they are eliminated.

2: Light
The interface for this is a two-directional progress bar, similar to the spikes. The progress directly defines the light value of the given light source. If the progress is 0%, it emits no light at all, and if it is at 100%, it emits the maximum amount of light.

3: Turret
The interface for this is a one-directional progress bar, where the only option is to click to increase the progress (or do nothing). As soon as the progress bar reaches the top, a shot is fired, and the bar resets.

4: Exploding cube
The interface for this is a one-directional progress bar, similar to the turret. As soon as the progress bar reaches the top, the cube makes an explosion, eliminating anyone that is close to it, and the bar resets.

5: Moving "roomba"
The interface for this consists of four arrow buttons pointing left, right, up and down. This one is, unlike the others, placed in the corner of the screen instead of next to the relevant object. That is because this is a moving object, and spam clicking it would be challenging during movement. Each arrow click directly makes the "roomba" move a slight bit in the given direction.

4.4 Implementation of Prototypes

In order to test the prototypes in a fully realistic scenario, it would be optimal to conduct a trial run with thousands of viewers on Twitch. However, the challenges involved in setting up such a large-scale test have led to the decision to simulate the viewers instead. Initially, the prototype was intended to be an extension on Twitch, but since a simulation will be used, there is no added benefit to testing it on Twitch. Instead, the entire prototype is created in-engine, and the viewer interaction interface is added as an overlay to the game. This approach will enable experts to test the same interface and setup as if it was on Twitch, just without the chat feature, which would be trivial anyway given the absence of other real viewers.

As part of the simulation, a delay similar to that on Twitch is incorporated, to create a more realistic testing environment, and to make it possible to evaluate how well the mechanisms perform with live-stream delay. Additionally, each interaction mechanism will be tested with both a small and large audience. To achieve this, the simulation will simulate 50 and 1000 viewers, respectively. By testing the prototypes in this way, it will be possible to gain a better understanding of how they perform with varying audience sizes.

While conducting a large-scale test on Twitch may not be feasible, the simulation approach will provide valuable insights into how the interaction mechanisms would perform in realistic scenarios. By creating a realistic testing environment, it should be possible to evaluate the prototypes in a way that reflects their potential performance in the real world.

Given that the focus of this research is on the viewer experience and the interface presented to the viewers, and not in any way the player experience, to ensure that the tests provide consistent and comparable results for the interaction mechanisms and their interfaces, the prototypes will be tested with bots playing the game. The tester acts as a viewer in a fully simulated environment representing a Twitch live-stream scenario, with four players playing the game and other viewers interacting along.

5 Study 2: Evaluation

The goal for this study was to evaluate the suggested interaction mechanisms from the previous study, with the help of experts.

5.1 Method

The suggested mechanisms were evaluated by conducting a qualitative evaluation, where I had experts test the prototypes, and afterwards evaluate the mechanisms through open-ended one-on-one interviews. The participants I invited for this study were the same experts I conducted the preliminary interviews with, with one additional person. The last person is actively streaming on Twitch, and could therefore provide useful insight, given their relevant experience. The procedure for the evaluations went as following:

I selected 6 different conditions to test, two for each type of interaction mechanism - one with a small audience and one with a large audience. I used a Latin square generator to mix up the orders in which the conditions are tested. For clarification, the conditions are the following:

- A: Majority vote with discrete options (small audience)
- B: Majority vote with discrete options (large audience)
- C: Heatmaps (small audience)
- D: Heatmaps (Large audience)
- E: Interface around interactive items (small audience)
- F: Interface around interactive items (large audience)

For each condition, the participant got five minutes to try it out, followed by five minutes of questions and evaluation. At the very end, I gave them the option to come with general comments or suggestions. The questions I asked were the following:

- How clear/understandable are the available options/tasks?

- How well do you think the interface serves its purpose?
- How is the interface in terms of user experience? *(Does it feel satisfying to use? How clear/obvious is it what the different interactive elements do?)*
- Suggestions for improvements for the interface? Alternative way(s) to do this?
- How is the mechanism in terms of user experience? *(How entertaining/fun is it? Does interacting add to the viewer experience, or would the entertainment value be similar by just letting other people interact while you just watch?)*
- How much do you feel that you have agency/influence over the situation? *(Do you feel like your choices affect the outcome or do you feel "overshadowed" by the other viewers' actions?)*
- *How much do you notice the delay?*
- (If noticeable) Do you feel like the delay affects your overall experience? If so, in what way? *(Does it make things confusing? Is it annoying? Does it affect the feeling of agency?)*
- Did you feel the presence of or connection to other people, or that you were part of something "bigger"?
- Do you see any potential issues/challenges that people in general could experience with this? *(Especially regarding delay, viewer count and interface)*
- Any other comments or general suggestions for improvements?

5.2 Analysis, Results and Implications

After completing the interviews, I used a thematic analysis to analyze the data. Thematic analysis is a widely used qualitative method for analyzing data that involves identifying patterns, themes, and meaning in textual data. First, I transcribed the interviews and organized the responses. Then, I coded the data and identified overarching themes. From these themes I examined implications for how the three tested interaction mechanisms are perceived. I analyzed the responses of each interaction mechanism separately, before considering general implications and takeaways. When performing the analysis, I kept the main focus on the elements relevant for the research goal and research questions. Therefore, for each interaction mechanism, to help identify themes relevant for this research, I started by grouping the various codes into the following main categories:

- User interface design
- Impact of delay
- Sense of agency
- Sense of community/connection
- Entertainment value

5.2.1 Majority Vote With Discrete Options

The main themes revealed in this analysis were the following:

- User interface design is clear and effective
- Viewer experience is not affected by delay
- Sense of agency was low to medium
- Works well with varying audience sizes
- Medium entertainment value, adds a little bit to the viewer experience

The analysis revealed that the user interface design was clear and effective. All participants indicated that the interface was understood quickly, and that it served its purpose well. There were some suggestions for improvements, such as changing the timing of when to let viewers interact and adding more feedback to show which option you have voted for, but nothing that would fundamentally change how it works. This interaction mechanism also seem to solve the delay problem. Participants generally stated that the delay was unnoticeable, mostly due to the

mechanism not being dependent on viewers timing their actions. One participant said: *"I did not notice the delay at all, and I don't think I would have cared if I did, because it is just a timed vote."* The sense of agency was generally rated as low to medium, indicating that viewers do not feel a substantial impact on the outcome, but some participants reported still having some sense of agency due to the 1/3 chance of their choice being selected. Different audience sizes did not seem to make a significant difference in the viewer experience, indicating that it is effective in live-streaming environments with varying audience sizes. Participants reported feeling a clear presence of others, possibly contributing to the sense of community and connection among viewers. The entertainment value was rated as medium, adding some value to the viewer experience, but not a significant amount. Overall, the analysis indicates that this type of majority vote system is a safe and effective addition to gaming live-streams, adding a little bit to the viewer experience, and can easily be incorporated into different types of games.

5.2.2 Heatmaps

The main themes revealed in this analysis were the following:

- User interface design is clear and effective
- Viewer experience is not affected by delay
- Sense of agency was low
- Works well with varying audience sizes
- Low entertainment value, does not add to the viewer experience the way it is currently executed
- The concept possibly has a lot of potential, if executed differently

The analysis revealed that the user interface was clear and effective. Participants reported that the interface was easily understood, and one participant commented on its nice and clear visual feedback. This interaction mechanism also seem to solve the delay problem. Participants either stated that the delay was unnoticeable or that it was noticeable, but did not significantly affect the viewer experience. Similar to the majority vote mechanism, this also seems to mostly be due to the mechanism not being dependent on viewers timing their actions. The sense of agency was overall rated as low, meaning viewers do not feel a substantial impact on the outcome. Different audience sizes did not seem to make a significant difference in the viewer experience, indicating that it is effective in situations with varying audience sizes. Participants reported feeling a clear presence of others, possibly contributing to the sense of community among viewers. One participant commented: *"I felt the presence of other people. However, knowing that it is a simulation destroys the illusion a bit, but in a real situation I imagine I would feel the presence of other people quite a lot. You could really see a lot of people interacting."* The entertainment value was rated as low, indicating this does not add much to the viewer experience, at least not the way it is currently executed. Several participants said that they see a lot of potential with this concept. However, for it to be effective, it would need to be executed differently, mainly with focus on improving the sense of agency and entertainment value. One participant, who came with some suggestions for improvements, said: *"I would have removed the grid and just let people click where they want. I would make it possible to spam. Maybe have a falloff system where for example your five latest clicks are the ones that matter. You don't get the crowd mentality unless you let people over time figure out what they want. Right now you just choose once and it is pretty arbitrary where the bomb lands. I think you should also change it so the indication of where the bomb drops always is shown, so you can until the last moment see where it will land and feel like you take part in influencing the position. This could also in some situations create the feeling that you are chasing certain players, which could make for some entertaining outcomes and reactions from the streamer(s). In general you want more "cult feeling". This heatmap system could also possibly be used for other things, such as spikes. Having spikes come up from the floor when a spot reaches a certain heat."* Similarly, another participant commented: *"I think it would be a lot better if you could change your vote, because then it could turn into a community thing. Viewers could unite and collaborate, for example to go after a specific player. When you have a heatmap that just gradually heats up over time, it will be easy for players to dodge it, which is uninteresting, but if you have the option to rearrange it, for example right before the timer runs out, you could use that to trick players. Given some slight changes, I think this mechanism could definitely add to the viewer experience as a whole. So there is definitely some potential."* This highlights the possible importance of key aspects, such as sense of agency and sense of community, to enhance viewer engagement and enjoyment.

5.2.3 Interface Around Interactive Items

The main themes revealed in this analysis were the following: - User interface design is generally clear and effective, but could use some improvements
- Viewer experience is not affected by delay
- Sense of agency was medium to high
- Works well with varying audience sizes
- High entertainment value, adds to the viewer experience

The analysis revealed that the user interface was mostly clear and effective, but could use some improvements. Participants generally stated that they would like more feedback when interacting. One participant stated that the user interface might take the focus away from the game. One participant mentioned: *"The buttons need to be bigger. You get a sniper-vision, you do not really get to follow what else is going on in the game when focusing on interacting."* Participants also mentioned the need for some instructions. One participant commented that it was not very clear what each interactive element did. This could possibly be solved by providing some simple instructions. This interaction mechanism seem to solve the delay problem rather well, but not perfectly. Participants either stated that the delay was unnoticeable or that it was noticeable, but did not significantly affect the viewer experience, similar to the heatmap mechanism. The analysis indicates that this could partly be due to viewers not expecting any immediate action after interacting. No matter when you decide to interact, the progress bars still need to fill up to the top for anything to happen. Since your influence per click is rather small, you do not really notice whether or not it is your interaction that made an impact in the ocean of viewers interacting. On the other hand, if you spam click, you can see the bar rapidly going up after a couple of seconds, making the delay noticeable in those situations. However, you you can always watch the progress and see when it reaches the top, so it is still always clear when an action will take place, making it less confusing for the interactor, despite the delay. One participant also mentioned: *"when you click ten thousand times you do not notice if it was your previous click or this click that made something happen."* There was one participant who said that the delay negatively affected the experience, but it was far from a deal-breaker. The sense of agency was rated as medium to high, meaning viewers feel a substantial impact on the outcome. A reoccurring theme among the participants' responses was that they prefer when every interaction/click actively does something. One participant also highlights the possible significance of fostering a crowd mentality among the viewers. The participant commented: *"Since everything is quite random here in the simulation, you could be stubborn enough to always get what you wanted if you wanted to, so in that way yes, I feel like I have influence. However, in a real situation there could often be some incentive for others to fight against you. In a real Twitch situation I feel like it would probably be either rope pulling or the group agreeing to go for certain things together, and you take part in it and therefore feel influence because you are contributing as part of something bigger working towards a common goal."* Participants mostly reported feeling a clear presence of others, possibly contributing to the sense of community among viewers. However, this was not a uniform opinion in all cases, as one participant said they did not really feel the presence of others too much when testing the version with only 50 viewers. Though they mentioned that this would probably be different in a real Twitch situation, as you are more likely to get a crowd mentality, thus feeling as though you are part of something bigger. Different audience sizes did not seem to make a significant difference in the viewer experience, indicating that this mechanism works well with both small and large audience sizes. Some participants mentioned small and large audience sizes provide different types of viewer experiences, although they are both just as entertaining. You might feel more direct influence with a smaller audience, but there is more chaos caused by a large audience, which seems to contribute positively to the viewer experience. Overall the entertainment value is rated as high, and it seems like this mechanism can have a significant positive impact on the viewer experience.

5.2.4 Implications Regarding the Research Goals

Regarding delay compensation, the findings suggest that having interactions that are not dependent on timing, such as those that do not require instant reactions, can be effective. Additionally, ensuring that information and the state of the game are conveyed clearly can reduce confusion and thus mitigate the negative impact of delays.

To accommodate for an arbitrary number of viewers, one strategy is to make sure each interaction has a high chance of making an impact. As implied by this research, this can be done by for

example limiting the available options, so that no matter what you choose to do, you have a high chance of having your intended action happening, or by making sure each interaction directly makes a difference, even if the effect is small. Fostering and exploiting the crowd mentality also seems to be an effective strategy, and can be achieved by setting up for situations where viewers are incentivized to work together towards a common goal. This makes it so that even if each individual contribution is small, you still feel an influence, due to being part of something bigger working towards a common goal. So if the group you are part of succeeds, you as an individual also feel success.

In terms of presenting a suitable user interface, the tested interactive overlays were all found to work quite well for their purposes. Participants generally stated that they were clear, understandable and intuitive. The times participants stated the contrary, they indicated that the confusion caused by this negatively affected their experience. It was stated several times that having some sort of instructions and ensuring the interactions have relevant feedback are important factors. Overall, the concept of such live-stream interaction overlays seem to work well, as long as the interface is understandable and intuitive, and does not take too much focus away from the game itself.

6 Discussion

6.1 Summary of Findings

This research has analyzed three different types of live-stream interaction mechanisms and evaluated their effectiveness in terms of user interface design, viewer experience, sense of agency, arbitrary audience sizes, and entertainment value. In the majority vote system with discrete options, the user interface was reported to be clear and effective, and the delay was unnoticeable due to the mechanism not being dependent on viewers timing their actions. The sense of agency was rated as low to medium, and the entertainment value was rated as medium. Heatmaps were found to have a clear and effective user interface and solved the delay problem. However, the sense of agency was low, and the entertainment value was also low, but there was a large potential for improvement with changes to the mechanism's execution. The interface around interactive items had a clear and effective user interface and solved the delay problem. The sense of agency was rated as medium to high, and the entertainment value was high. Different audience sizes did not seem to significantly affect the viewer experience in any of the three mechanisms. Overall, these interaction mechanisms can be incorporated into different types of games and have varying potential for enhancing viewer engagement and enjoyment depending on their execution.

The research suggests that in order to compensate for delays in interactive live-streams, interactions where viewers do not expect instant reactions are highly effective. Additionally, clear communication of the game state can be helpful. To accommodate for an arbitrary number of viewers, ensuring that each interaction has a high chance of making an impact and exploiting the crowd mentality by creating situations where viewers are incentivized to work together towards a common goal can be effective strategies. Utilizing the crowd mentality can also be helpful for masking the delay. The user interface should be clear, understandable, and intuitive with relevant feedback and instructions provided to avoid confusion and negative impact on the viewer experience. Overall, the concept of interactive overlays can work well and can significantly increase the viewer experience in gaming live-streams, given that the interface is designed well and does not take too much focus away from the game.

6.2 Limitations

The research has several limitations that should be taken into consideration. First, the testing and evaluation were based on one specific game, which may limit the generalizability of the findings to other types of games. Additionally, the sample size of participants was relatively small, which may limit the validity and reliability of the results. Furthermore, the implications of the study were based solely on qualitative evaluation, without any quantitative data to support the findings. The research also utilized simulations instead of real scenarios, which do not fully capture the complexities and nuances of actual live-streaming situations, possibly limiting the transferability of the findings. Furthermore, the study only explored a small number of mechanisms for interactive overlays and did not cover a wide range of possibilities. Lastly, the study focused on prototype-level implementations, and more research may be needed to determine the feasibility and effectiveness of implementing these findings in real-life scenarios.

6.3 Future Work

There are several potential directions for future work. First, testing similar interaction mechanism with different types of games could be useful in order to assess the generalizability of the findings. Secondly, a large-scale test on Twitch or other live-streaming platforms would provide a more realistic scenario, and thus more robust data and insights into the effectiveness of the interactive overlays on a real audience. Additionally, including a quantitative evaluation could provide more objective data to support the qualitative findings. Exploring other types of mechanisms beyond the limited set tested in the current study could help to identify additional effective strategies for engaging viewers. Finally, improving the execution and implementing the mechanisms beyond a prototype-level could be beneficial for more accurate and better results.

If I should suggest one of the tested interaction mechanisms for further exploration, I would suggest the interface around interactable items. This is the mechanism that yielded the best results overall, being the mechanism with the highest reported entertainment value and highest chance of positively affecting the audience experience. I would suggest further developing this beyond a prototype-level and refining the implementation, making sure all interaction elements have supporting visual (and possibly audial) feedback and relevant instructions. To account for viewers who do not particularly want to interact, I would also suggest having the option for the viewers to hide the interface or an opt-in mechanism before being presented with the interactive interface. For the sake of generalizability, both from a development perspective and for the viewer experience, I would suggest implementing and testing this type of mechanism for one or more different games. Most importantly I would suggest testing the mechanism in real live-streaming scenarios with various small and large audience numbers, for more accurate insights into the effectiveness of the mechanism on a real audience.

7 Conclusion

In this research, I investigated how to achieve an engaging and enjoyable audience experience in scenarios where viewers of gaming live-streams can influence the game that is being played through an interface on the stream. When designing live-stream interaction mechanisms that directly influence gameplay, there are several challenges that need to be considered. Live-streaming today inherently comes with various limitations in regards to real-time interactivity with viewers. Since gameplay-influencing live-stream interaction is a rather new phenomenon and research on the topic is scarce, there are not yet any established best practices on how to overcome these challenges. This research aimed to investigate some potential key challenges and develop an understanding of how to overcome them. To achieve this, I performed an iterative approach, where I first conducted a preliminary design exploration study. Here, I received feedback and suggestions from experts in the field of game development. Based on the expert feedback, I designed and implemented prototypes for three different interaction mechanisms that were supposed to overcome the given challenges while providing an enjoyable audience experience. Then I conducted a second study: an evaluation study, where experts evaluated the suggested mechanisms after testing the prototypes in a simulated environment. The type of interaction mechanisms that were selected to be tested and evaluated were: majority vote with discrete options, heatmaps, and interface around interactive items. All of these interaction mechanisms showed promising results, with varying potential for enhancing the viewer experience depending on their execution. Interface around interactive items seemed to be the mechanism that yielded the best results overall, with the highest chance of having a positive impact on the audience experience. The research suggests that interactions where viewers do not expect instant reactions can be highly effective for compensating for delays in interactive live-streams, and clear communication of the game state can be helpful. Exploiting the crowd mentality by creating situations where viewers are incentivized to work together towards a common goal can also be effective, both for accommodating for different audience sizes and for masking the delay. The user interface should be clear, understandable, and intuitive, with relevant feedback and instructions provided. Overall, interactive overlays have the potential to significantly increase the viewer experience in gaming live-streams, especially if the interface is well-designed and does not detract from the gameplay.

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Appendices

A Ethics and Privacy Quick Scan

Response Summary:

Section 1. Research projects involving human participants

P1. Does your project involve human participants? This includes for example use of observation, (online) surveys, interviews, tests, focus groups, and workshops where human participants provide information or data to inform the research. If you are only using existing data sets or publicly available data (e.g. from Twitter, Reddit) without directly recruiting participants, please answer no.

· Yes

Recruitment

P2. Does your project involve participants younger than 18 years of age?

· No

P3. Does your project involve participants with learning or communication difficulties of a severity that may impact their ability to provide informed consent?

· No

P4. Is your project likely to involve participants engaging in illegal activities?

· No

P5. Does your project involve patients?

· No

P6. Does your project involve participants belonging to a vulnerable group, other than those listed above?

· No

P8. Does your project involve participants with whom you have, or are likely to have, a working or professional relationship: for instance, staff or students of the university, professional colleagues, or clients?

· Yes

P9. Is it made clear to potential participants that not participating will in no way impact them (e.g. it will not directly impact their grade in a class)?

· Yes

Informed consent

PC1. Do you have set procedures that you will use for obtaining informed consent from all participants, including (where appropriate) parental consent for children or consent from legally authorized representatives? (See suggestions for information sheets and consent forms on the website.)

· Yes

PC2. Will you tell participants that their participation is voluntary?

· Yes

PC3. Will you obtain explicit consent for participation?

· Yes

PC4. Will you obtain explicit consent for any sensor readings, eye tracking, photos, audio, and/or video recordings?

· Yes

PC5. Will you tell participants that they may withdraw from the research at any time and for any reason?

· Yes

PC6. Will you give potential participants time to consider participation?

· Yes

PC7. Will you provide participants with an opportunity to ask questions about the research before consenting to take part (e.g. by providing your contact details)?

· Yes

PC8. Does your project involve concealment or deliberate misleading of participants?

· No

Section 2. Data protection, handling, and storage

The General Data Protection Regulation imposes several obligations for the use of **personal data** (defined as any information relating to an identified or identifiable living person) or including the use of personal data in research.

D1. Are you gathering or using personal data (defined as any information relating to an identified or identifiable living person)?

· No

Section 3. Research that may cause harm

Research may cause harm to participants, researchers, the university, or society. This includes when technology has dual-use, and you investigate an innocent use, but your results could be used by others in a harmful way. If you are unsure regarding possible harm to the university or society, please discuss your concerns with the Research Support Office.

H1. Does your project give rise to a realistic risk to the national security of any country?

· No

H2. Does your project give rise to a realistic risk of aiding human rights abuses in any country?

· No

H3. Does your project (and its data) give rise to a realistic risk of damaging the University's reputation? (E.g., bad press coverage, public protest.)

· No

H4. Does your project (and in particular its data) give rise to an increased risk of attack (cyber- or otherwise) against the University? (E.g., from pressure groups.)

· No

H5. Is the data likely to contain material that is indecent, offensive, defamatory, threatening, discriminatory, or extremist?

· No

H6. Does your project give rise to a realistic risk of harm to the researchers?

· No

H7. Is there a realistic risk of any participant experiencing physical or psychological harm or discomfort?

· No

H8. Is there a realistic risk of any participant experiencing a detriment to their interests as a result of participation?

· No

H9. Is there a realistic risk of other types of negative externalities?

· No

Section 4. Conflicts of interest

C1. Is there any potential conflict of interest (e.g. between research funder and researchers or participants and researchers) that may potentially affect the research outcome or the dissemination of research findings?

· No

C2. Is there a direct hierarchical relationship between researchers and participants?

· No

Section 5. Your information.

This last section collects data about you and your project so that we can register that you completed the Ethics and Privacy Quick Scan, sent you (and your supervisor/course coordinator) a summary of what you filled out, and follow up where a fuller ethics review and/or privacy assessment is needed. For details of our legal basis for using personal data and the rights you have over your data please see the University's privacy information. Please see the guidance on the ICS Ethics and Privacy website on what happens on submission.

Z0. Which is your main department?

· Information and Computing Science

Z1. Your full name:

Trym Lie Rannem

Z2. Your email address:

t.l.rannem@students.uu.nl

Z3. In what context will you conduct this research?

· As a student for my master thesis, supervised by::

Julian Frommel

Z5. Master programme for which you are doing the thesis

· Game and Media Technology

Z6. Email of the course coordinator or supervisor (so that we can inform them that you filled this out and provide them with a summary):

j.frommel@uu.nl

Z7. Email of the moderator (as provided by the coordinator of your thesis project):

gmt-ethics@uu.nl

Z8. Title of the research project/study for which you filled out this Quick Scan:

Interactive Video Game Live-Streaming

Z9. Summary of what you intend to investigate and how you will investigate this (200 words max):

The main goal of this research is to investigate how to achieve an engaging audience experience in scenarios where viewers of gaming live-streams can influence the game that is being played directly through an interface on the video stream, with a large focus on challenges tied to stream delay, arbitrary number of viewers, and user interface design

I plan to propose and implement a set of different interaction mechanisms for influencing gameplay through live-stream inputs. When doing so I will attempt to make them as engaging as possible, with suitable user interfaces, while minimizing the negative effects of the aforementioned challenges. To decide on the exact types of interaction mechanisms and their designs, I plan to interview experts and relevant people from the industry, and gain their input on the matter. After implementation, I will also perform interviews and present the proposed solutions as part of the evaluation process.

Z10. In case you encountered warnings in the survey, does supervisor already have ethical approval for a research line that fully covers your project?

· Not applicable

Scoring

- Privacy: 0
- Ethics: 0