Streamer's Hell – Investigating Audience Influence in Live-Streams Beyond the Game

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Fig. 1. Examples of two modifications in the streamer's study. Left: Background projection and lighting changes in the streamer's room are active. Right: The streamer's view on the free-to-play game "Slender: The Eight Pages" (developed by Mark J. Hadley), while a modification is active and is showing the streamer's stress level. The modification icon is shown in the top left and the stress level in the lower right.

In the context of game live-streams, we focus on whether audience influence options can be extended beyond the game, e.g., to the streamers' environment (e.g., controlling their room lighting), the streamers themselves (e.g., activating vibration feedback on their forearms) and the streamers' hardware and peripheral devices (e.g., switching key bindings). An online study (n=81) showed that viewers have mixed feelings and that the context matters, as only a few game genres are assessed as suitable for such an experience. In a lab-study six streamers experienced the idea while playing a horror game. They saw appeal in extending the influence space, but also again highlighted that context matters and customization options are necessary. The studies hint that although this interactivity is from a technical perspective independent of the content streamed, in practice it is not, as the perception is moderated by e.g., the game and why the streamer is playing it.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**; **Empirical studies in HCI**.

Additional Key Words and Phrases: Streamer-audience interaction, Twitch, Viewers' & Streamer's perception

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1 INTRODUCTION

In gaming live-streams, content creators ("streamers") typically show how they play digital or analog games. Twitch.tv[1] is an example of a platform dedicated to this live-streamed type of content. According to Twitch Tracker[2], Twitch had 1,116 billion minutes of watched content in 2021, 8.5 million channels streamed monthly and around 2.7 million average concurrent viewers, underlining its popularity. Live-streaming platforms, in contrast to videos on YouTube, allow direct (synchronous) interaction between viewer and streamer, through features such as real-time chat [9].

Integrating the audience into game live-streams is done by many streamers [9]. This can be as simple as streamers answering a question or acknowledging someone in the chat, or through more sophisticated functionality. Interactivity was shown to be an important factor in live-streams that is appreciated by viewers (e.g. [8, 13, 31]), and especially in the context of games live-streams, instances have appeared where viewers can have a direct impact on what is happening in the game. For example, in the commercial game ChoiceChamber[3], the audience receives periodic polls to alter game mechanics/elements, such as which enemies the streamer needs to overcome. Similar experience – called Audience Participation Games (APGs) – are also investigated from a scientific perspective (e.g., [6, 26], see next section). Considering these examples, the influence options are developed and tightly-coupled to each game. As streamers typically play several games and many of the often-streamed AAA titles[4] do not offer influence options and are closed-source, this limits audience influence options during a stream. Also, it raises questions about the viability in general, if every game would have to provide support for audience participation from a technical perspective.

Therefore, we shift our focus away from the question of how viewers can exert influence in *one streamed game* to the question of how viewers could exert influence *beyond the streamed game* and investigate interactive options that will work regardless of the game that is streamed and thus are usable independently. While the usage of polling systems [13] can be seen as one general method for this, the audience influence is indirect as the streamers offer voting options and are still free to decide whether to follow the majority. To mirror APGs, in which influence can be seen as direct, we were interested in interactivity with a direct impact, through empowering viewers to influence the streamers' environment (e.g., controlling their room lighting), the streamers themselves (e.g., activating vibration feedback on their forearms) and the streamers' hardware/peripheral devices (e.g., switching key bindings). We focus on the questions: (1) Do viewers want to have such audience influence options?; (2) Do streamers want to provide such options?; (3) Which options are promising from both the viewer's and streamer's perspective? To address these questions we did an online survey with viewers of game live-streams (n=81) and a lab study with local game streamers (n=6). This paper contributes answers to these three questions:

- For (1) – answers were found through the online survey – we presented three categories of modifications (environment/streamer/streamer's hardware; see above) and per category multiple options for exerting influence. Viewers of game streams could also add their own ideas that they would enjoy in streams. The results clearly showed that not every option per category is equally suitable. Especially those that interfere with the streamer (and thus

[1] https://www.twitch.tv, last accessed: 2022-07-19
[2] https://twitchtracker.com/statistics, last accessed: 2022-07-19
[3] https://www.choicechamber.com, last accessed: 2022-07-19
[4] https://twitchtracker.com/games, last accessed: 2022-07-19

the stream) too much are not seen as enjoyable from the viewer's perspective. For example, while a large majority of participants would not want to tickle the streamer via a device or to cause input delays for the streamer's hardware, they would enjoy changing the ambiance in the streamer's room (by changing lighting and projected images in the room, e.g., see Figure 1, left) or would like to enable views showing sensor information (e.g., the streamer's pulse). After all these options were presented, 56% of the viewers of game streams stated that they would be interested in exerting such kinds of influence, and given that for many the influence options even a higher percentage indicated that they would enjoy it (for the examples above: 70% for projection, 81% for the pulse), we determined that it is reasonable to investigate influence options beyond the game further. We also note that some influence options would also allow the audience to become co-creators of the stream, as they could react to sub-optimal circumstances (e.g., by adjusting the volume of the game sounds).

- For (2) – answers were found through the lab study – we followed the idea of providing a "best case" setting to assess the streamer's perspective. We implemented twelve influence options, set up a room with necessary equipment (e.g., a wall projector) and let content creators experience a horror game while periodically an influence option was activated. Streamers particularly liked the idea of allowing viewers to exert influence beyond the game and would provide this option to their viewers. They also found particularly enjoyable modifications in every category. Interestingly, perceptions varied between viewer and streamer ratings (e.g., swapping keyboard commands was rated as particularly enjoyable from the streamer's perspective, while viewers rated it only as somewhat enjoyable) and were also judged in respect to whether they would offer something interesting for the viewers (e.g., more information).
- For (3) – answers were found through both studies – this paper provides insights into various options to allow viewers to exert influence beyond the game. Not only can the ratings in the viewer and streamer study be considered for this, but also the free text answers viewers provided for additional ideas. While we saw differences in the perceptions of viewers and streamers (highlighting that considering both perspectives is reasonable in general), we found that there is indeed overlap in some of the influence options (i.e., viewers rated it as interesting, and streamers would enjoy it and would offer it in their streams). Such options should receive more focus in subsequent "in the wild" studies. In addition, contextual factors were seen as a factor moderating which influence options are reasonable, questioning whether "game-independent" influence options are possible at all. The streamers themselves, the stream type (e.g., competitive play or just-for-fun streaming), the game/genre played, and the game situation influence how influence options are perceived. While more research is necessary (as this was not the goal of the paper) to derive the specific impact of these factors, through the studies, this paper has already provided some hints towards suitability of different game genres. Furthermore, it became clear that in respect to the actual question of how to realize such a system in the wild, customization options needed to be provided to allow streamers to select which modifications they want to offer in their stream and which aggregation options should be used (i.e., who should be able to participate in the modification aggregation and to what extent), as one-size-fits-all solutions appear to be unreasonable. For the latter, this paper also contributes initial insights.

Through these aspects, this paper contributes to the ongoing efforts to understand different forms of audience-streamer interactivity, sheds light on options regarding how viewers could be integrated in the streaming experience further and adds to the efforts for a more fine-grained understanding of the general notion that interactivity is an important part of live-streaming.

2 RELATED WORK

Interactivity in live-streams is important, as various approaches have already shown: Tang et al. [31] investigated mobile streaming apps and found that many of the activities are indeed interactive. Similarly, Haimson et al. [8] also found that interaction is one of the key components for making remote viewing engaging. Streamers are inclined to not only respond to chat comments but also to allow their viewers to alter how the stream proceeds. Wohn and Freemann interviewed streamers on Twitch.tv to learn how these streamers interact with their community [33]. Here, the interaction part was again highlighted to be a "core feature of streaming". Gros et al. [7] conducted a large-scale online survey and found that involvement of viewers is an important factor, although not every viewer apparently has the desire to get involved to the same extent. In addition, they randomly considered streams to observe what kind of interactions happen and found that various interactive options (e.g., acknowledging viewers, allowing viewers to make decisions, etc.) indeed occur in practice, between streamer and viewer, but also between the viewers themselves. Lessel et al. [13] also administered an online survey with a focus on the viewer's perception of features in game live-streams. Here, elements (some interactive, with varying impacts on the stream) were to be rated on how interesting they are. One of the results was that many of the top-rated features were interactive. In addition, it was found that many participants actually would not use the interactive options actively, but would still enjoy it if they were available in a stream and used by others. This also underlines that interactivity is useful for active and passive viewers alike. In addition, there are also indications that viewer types exist [1, 13, 25–27, 36], which might also impact how specific features are perceived [13, 25]. Thus, it is necessary to investigate interactive features to understand their properties to provide meaningful experiences to live-streaming. This is an ongoing effort [30] to which this paper contributes to as well.

Besides the two main stakeholders, i.e., streamers and viewers, several other stakeholders are relevant in live-streaming [32]: Game designers/game developers, who, for example, think about how to integrate the live-streaming ecosystem in their games (e.g., by allowing viewers to interact with game mechanics, see below) or platform vendors, who, for example, think about how they can provide a better experience for streamers and viewers, but also how to monetize this ecosystem. In this sense, advertisers and sponsors are also additional stakeholders. Another active stakeholder group are third-party developers, who create, for example, technology that streamers can use in their streams to provide new experiences, beyond what the platform offers. These stakeholders presumably have different requirements and prospects for interactivity based on their goals/intentions. To begin the exploration of audience influence beyond the streamed game, however, in this work, we focus our studies only on viewers and streamers, to understand whether these main actors are interested in providing/exerting such types of influence at all.

2.1 Forms of Interactivity in Live-Streams

Given that the viewer perception of "interactivity" already starts when streamers acknowledge viewers who are present in the stream [7, 13], the design space for interactive features can be considered as large [30]: for example, streamers can come up with interactive options based on existing features (e.g., they can encourage their viewers to create relevant art that is shown in the stream); streaming platforms might offer built-in features to enhance interactivity (e.g., the chat); or third-party options can be integrated (e.g., external polling tools). In this section, we will first briefly present research on interactive options that are tightly connected to the streamed game, and then cover interactivity beyond the game.

2.1.1 Interactivity Bound to the Streamed Game. Lessel et al. [16] added interactive features to live-streams of a digital trading card game: Viewers could open a dedicated web page in which the

stream was embedded and they were able to directly interact with it by drawing arrows signaling which game actions they would take. Additional hints could be given through other interactive elements on the web page, such as ratings of moves that the streamer made. All the hints were aggregated by the system and shown to the streamer while playing through overlays. In a study the authors found that the direct interaction is appreciated by streamer and viewers, and both groups reported that through these interactive options, influence was exerted. While the concepts might be usable for other games as well, the system was specifically created to work with the selected trading card game (e.g., by parsing a log file of the game). Matsuura and Kodama [17] created a side-scrolling platform game in which the chat messages of viewers became part of the gameplay. Message sentiment was analyzed and had different effects in the game. A study showed that increased feelings of participation. Although both examples use methods that work independent of the actual content (e.g., chat messages, aggregation systems), they are still in large part tightly connected to the game. Thus, a streamer would not be able to keep the same amount of influence options constantly throughout the stream, when playing different games.

Audience Participation Games [6, 26] (APGs) (as stated in the introduction) are another example for tightly connected interactivity. While the usage of polls (which are commonly used here) is something that is not bound to the specific game, the actual impact of the voting is connected to the games. Games such as "Twitch Plays Pokémon" (TPP) can also be seen as a special form of APGs, as there is no streamer controlling the gameplay: The audience itself is able to play the streamed game alone via the chat. In TPP viewers could control the game's avatar by entering chat commands, and at the peak, 121,000 people played the game simultaneously[5]. In the beginning every chat command was executed, leading to quite chaotic situations (which [23] showed to be one source of appeal for viewers); later an input aggregation mode was integrated so that only the most frequently entered commands in small time windows were executed. Similar ideas were investigated scientifically as well [12, 14, 15], where more interactive and motivational features were added in different game contexts (here Hedgewars, Pokémon, chess). For example, in [14], a virtual currency was introduced with which elements could be bought that would highlight one's own contribution in such contexts. In all these works more input aggregation modes were added to see how more sophisticated options would be used and how the audience would organize itself. Naturally, while input aggregation modes can be used as a scheme for other contexts, they were directly connected to the possible interactions of the underlying games.

In general, these approaches showed that various options exist to enable audience influence that are perceived positively. Whether similar positive effects could also be found if the changes are not tightly connected to the games the streamers are playing, but are applicable independent of the game, is something to which we contribute to.

2.1.2 Interactive Features Beyond the Game. A typical feature that is offered is the real-time chat which works independent of the streamed content. To date, it can be seen as the primary communication channel between viewers [16], but also between viewers and the streamer. Through suggestions given in the chat, streamers can change the course of the stream, and thus, it is not only an interactive medium, but also one that has influence capabilities. Work is done to improve the feature, e.g., how issues such as information overload can be targeted (e.g., by conversational chat circles [19] or structuring options [2, 16]) and how the text medium could be enriched (integrating annotated snapshots of the stream [34]). In addition, works such as [4, 5, 9, 20–22] revealed that the number of viewers using the medium has an impact on how this feature is used and that the way communication happens changes, e.g., Flores-Saviaga et al. [4] analyzed a large volume of chat messages and streamed video content and found five clusters of stream size with

[5]https://tinyurl.com/y2bl725o, last accessed: 2022-07-19

different characteristics. These findings show that interactive features are used differently, based on contextual factors. While understanding context factors is important, for us, it will be only a second step. We take a general viewpoint in this paper to understand extended audience interaction options beyond the game, before moving to understanding how context moderates the perception of it specifically (e.g., viewers should assume that they alone could decide to activate them). Nonetheless, results that already provide context insights are reported here as well.

[29] discusses several interactive features that integrate the audience in the context of game spectating, such as chat input, votes, betting with a virtual currency, donations, allowing viewers to directly participate in the games and allowing for viewer-created content. Some of the aspects can also be seen as independent of the actual game that is shown (such as donations that are always possible). Another related, commonly used feature in streams is overlays, for example, showing the latest follower, or the most recent donators and how much they have given. In the work of Robinson et al. [24] it was investigated how viewers perceive receiving "internal" information about the streamer during gameplay, i.e., heart rate, skin conductivity and the streamer's emotions, presented in the form of such a video overlay. In their study, this was found to impact the viewer engagement, enjoyment and connection to the streamer positively, but was also distracting to a certain extent. A question is whether overlays can be considered as being interactive. We take an inclusive view on this, as the information presented might spark discussion in the chat, and could alter how the stream proceeds, if the streamer comment on/discuss changes in the data as well.

The previously mentioned approaches focused on influence options that stay mainly in the streamed world (e.g., seeing overlays, chatting) and are not extended to, for example, physical aspects around the streamer (e.g., changing lighting conditions). In the above mentioned study of Lessel et al. [13], one of the features to rate was to manipulate the streamer's setup through, for example, swapping keys. This feature was perceived as particularly uninteresting from the viewer's perspective. Yonezawa and Tokuda [35] focused on music live-streams and provided a system that allowed audiences, through text messages, to control the cameras (zoom/pan/rotate and selecting different camera angles) in the musician's room during streams to alter the dramatic impact in the absence of dedicated staff to control these. In a four-weeks long experiment (over multiple sessions) with one of the authors being the streamer and with hundreds of viewers, they found that not everyone is an active user of the interactive options. In addition, they received many positive comments on the good quality of viewer decisions in respect to the camera handling and found that it was also used to (non-verbally) communicate with the streamer. They conclude that other aspects, such as smoke control or lighting changes, should be also investigated, and that even the camera controls could be extended further (e.g., controlling a drone with a camera attached).

The discussed features have in common, that they can be universally used across streamed content without additional efforts for developers/streamers. Although these features can have an impact on the game played (e.g., on its immersion), they are not directly connected to it (in contrast to the previously presented APGs for example). An example of an idea for coupling these worlds is reported in [32]: the donation tracker in the stream was set up to play a scary sound whenever a donation was incoming. The streamer decided to play a horror game to give viewers an additional incentive to donate, as frightening the streamer might also alter the stream's course.

As the presented work showed that it cannot be assumed that every feature works equally well, understanding the design space is important. This will also add to the ongoing efforts to understand interactivity in live-streaming in general, as questions such as "how much influence do viewers want to exert" are applicable independent of whether interactive features impact the streamed content or not. In this paper, we are mainly interested in direct means of influencing, i.e., applying changes to environment the streamer streams from, gadgets the streamers wear and manipulation options for the hardware the streamer is using, instead of focusing on digital solutions only (e.g.,

chat, polls), as these appear underrepresented in the current literature so far (thus, we add to the work of Yonezawa and Tokuda [35]). From a terminology point of view, in the following we call these audience influence options "modifications", based on the rationale that viewers literally modify something (e.g., switching on the light in a streamer's room).

3 GENERAL APPROACH

To explore this design space, the idea was to start broad by eliciting options from viewers, with a subset then being implemented and experienced (and rated again) by streamers. To this end, we started with assessing the viewer perspective. The idea behind this was to learn whether viewers actually want to be able to exert influence beyond the game and if so, through which means. Investigating this first appears to be a prerequisite as the work presented in the previous section showed mixed results. To assess this large design space, we expected that we would not only need to present examples, but that we would also need to give viewers the chance to provide their own ideas as well, towards a holistic picture. Method-wise, an online survey appeared reasonable for doing this, to avoid introducing a bias through specific realizations and to aim at a larger target group. Participants were asked to take a general viewpoint. We also aimed for keeping the idea granularity constant, i.e, as viewers would only be able to textually describe their ideas in such an approach, we would also present ours with only a small textual description, and we allowed viewers to systematically rate these. Details on the method and results are presented in Section 4.

As this study revealed that viewers can imagine certain forms of audience interaction beyond the game, we moved on to the streamer's perspective. Building on the findings of the first study (e.g., by using the horror genre, which was deemed as most reasonable by viewers), we were particularly interested in allowing streamers to experience the best rated and some of the most often suggested ideas in a "best case" setting on their own (e.g., using a fitting game, modification content and an offline "Let's Play" situation without a real audience, so as not to introduce a bias through, for example, trolling tendencies in the audience, and remaining in full control of the modifications). The rationale of using such a "best case" setting was to learn how streamers would assess the extended influence options by ruling out factors that might impact the experience negatively. Disliking the "best case" would already be a strong indicator not to follow this line further, and thus we deemed this as acceptable for a first exploration of the design space. Method-wise, while the first study only worked with textual descriptions of influence options (i.e., realization needed to be imagined), in a general setting, the second study complements this view with the usage of a prototype (i.e., the modifications could be experienced) in a laboratory setting in a specific setting. Details on the method and the results are presented in Section 5.

4 ONLINE STUDY: VIEWERS' PERCEPTION

In this first study, we focus on the viewers' perception.

4.1 Method

We set up an online survey in German and English and advertised it on Reddit (in *r/computerscience*, *r/SampleSize* and *r/Twitch*), Facebook and smaller game-streaming-related groups there. We clarified that it aimed at people who watch game live-streams at least a few times per year and integrated screening questions to ensure this requirement (see below). We also disclosed that *we want to find out whether they, as viewers, would like to have an influence on the stream or modify the streamer's input and output devices or a gadget they wear while streaming*. We assessed demographics and live-streaming consumption habits. Then, participants were prompted to come up with ideas for modifications. As a general starting point for their suggestions, we introduced three categories for which ideas could be provided:

Room *Imagine watching a video game live-stream and that you have the possibility to change something in the streamers' rooms, for example the lights or temperature.*

Streamer *Imagine watching a video game live-stream and that you have the possibility to modify something on the streamers themselves, or perform various measurements on them and display them in the stream. For example, they could wear a device that vibrates on their forearm, measures their pulse or simulates various flavors in their mouth.*

I/O *Imagine watching a video game live-stream and that you have the possibility to modify something on the input and output devices the streamers use. For example, you could swap two keys on the keyboard or play any sound over their headphones. For screen modifications, assume that you, as a viewer, would see both the distorted picture the streamers sees, as well as the original game output. This means that you are not directly affected by the modifications.*

Our rationale for *Room* modifications is that such modifications could also affect others who are in the same room (see Figure 1, left). For *Streamer* modifications the rationale is that new devices needed to be used and they would only affect the streamer and for *I/O* modifications that these only relate to existing devices that are already in use by the streamer. These are not formal definitions and we refrained from providing them to participants, as this might have complicated participation and restricted the idea generation too much. Thus, certain modifications might fall into multiple categories (e.g., generating ambient sound or music could be a *Room* or *I/O* modification, depending on the viewpoint). We saw this as acceptable, as this also increased the participants' freedom and helped to structure the online study. The explanations also provided hints towards features to explain the concepts. Finally, as the complete online study was already extensive, the usage of three categories needs to be seen as a trade-off between richness of possible ideas and participant effort, i.e., there might be more categories/modifications that do not fit into the three[6].

Each category was presented separately and participants were asked to take a general viewpoint (instead of thinking of a specific streamer), to assume that they alone would have the control over activating the modification, and that they should not consider whether a modification can be realized based on today's technology. For every category, participants had to first rate whether they would enjoy it (e.g., *I would, in general, enjoy modifying something in the streamer's room*) and they could provide free-text answers for the question *What would you like to be able to X*, with X instantiated for the three categories (e.g., *change on the streamer's input and output device*). Only then, participants were presented with our ideas for the category and needed to rate these (e.g., *I would enjoy changing the temperature*). Subsequently, we asked whether they could now imagine further modifications and to again rate their enjoyment of the category after having seen the examples. Then we asked questions on the modification suitability within game genres (based on the genres considered in [27]). Every genre was presented alongside game names taken from, e.g., top seller lists on Steam. Finally, questions were asked for how to realize the modifications in a live-streaming setting (e.g., how modifications should be activated by the viewers). In the survey we used statement-based questions on 6-point scales (labels: *strongly disagree, disagree, somewhat disagree, somewhat agree, agree, strongly agree*), and optional free-text-based questions. The former were analyzed by considering descriptive statistics and doing Student's t-tests [3]. The latter were analyzed with a thematic-based content analysis [10]. The study was approved by the Ethical Review Board of the Faculty of Mathematics and Computer Science at Saarland University (No. 18-1-3).

[6]We gave participants the chance to express further comments after having seen all categories, but no new ideas appeared.

Suggestions	#	Included
Control the lights (either brightness or color)	22	✓
Generate/control noises/sounds/music	22	(✓)
Modify objects in the room (toaster, chair/seating, objects' position, were concrete examples provided)	9	
Adapt images shown on, for example, the green screen	5	
Change the temperature in the room	4	✓
Change the walls/wall decorations	4	
Control a fan	3	✓
Change smell in the room	4	✓
Be able to fire a toy cannon (e.g. confetti, cuddly toys, balloons or cotton balls)	3	
In AR/VR games, add projections that are not part of the room	2	

Table 1. *Room* modification suggestions from participants that they would enjoy, the number of mentions and whether it was already included in later parts of the survey as well. In parentheses if only partially included.

4.2 Participants

91 participants completed the survey and we checked for careless responses [18]. We excluded participants who ...

- ... answered that they do not watch gaming live-streams (3 exclusions).
- ... filled out the questionnaire too fast (indicating that they might have rushed through it). The average time was 25.5 minutes (median 15.3). We excluded participants that completed it in less than 5 minutes (1 exclusion).
- ... had a standard deviation of 0 in their answers on questions shown on the same page. We had seven such thematic blocks and we excluded participants that showed this behavior on at least six scales (3 exclusions).
- ... provided free-text comments that indicated they did not take the survey seriously, e.g., one participant suggested killing the streamer using modifications. (3 exclusions).

The remaining sample (81 participants. Gender: female 18x; male 60x; 1x neither female nor male, but also wanted not to self-describe; not answered 2x. Age: <25 52x; 26–30 19x; 31–35 4x; 36–40 3x; >40 3x. Main nationalities: German 46x; American 8x; British 7x) is biased towards being young and male, what is in line with the demographics found on Twitch.tv[7], which are also biased towards young (55% are between 18 and 34) and male consumers (81.5% are male). Concerning the monthly consumption of game live-streams, 23 consumed up to three hours, 21 3–9, 15 9–18 and 22 more than 18 hours. They used mainly Twitch.tv (74) and YouTube (50). 20 also reported to stream as well.

4.3 Results

We first describe results in respect to the three modification categories, then on the general perception of the approach, and lastly, results on how this kind of integration might be realized in a live-stream from the viewers' perspective.

[7] https://muchneeded.com/twitch-statistics, last accessed: 2022-07-19

Change	M	SD	Mdn	AR	t
Project pictures of different environments onto the wall (e.g., forest, beach, hell)	4.2	1.5	5	70%	7.3
Generate ambient noises	4.1	1.7	5	61%	5.6
Adjust light brightness	4	1.5	4	64%	6.2
Adjust light color	3.9	1.5	4	59%	5.1
Make it windy/stormy (using fans)	3.4	1.8	3	45%	-
Generate smells	3.3	1.6	3	40%	-
Spray water on streamer	3	1.8	3	33%	-
Change the temperature	2.9	1.5	3	28%	-

Table 2. *Room* modification assessment (M=mean, SD=standard deviation, Mdn=median, AR=agreement rate (% of the sample that answered >3 on the six point scale) and whether the result was significantly different from the value 3 on the scale, as shown with a student's t-test with p<.05 (t-value shown only if significant).

4.3.1 Modification Perception. ***Room*** **modifications**: Before participants saw our *Room* modification examples, they provided mixed answers to the statement that they would enjoy modifying something in the streamer's room (mean M=3.7, standard deviation SD=1.4, median Mdn=4). 45 participants (56%) selected an answer >3 on the 6-point scale questions[8]. The same question was again asked after we showed our examples, but the values changed only slightly (M=3.8, SD=1.6, Mdn=4, AR=50 participants (62%)). For both questions, (marginally) more than half of the sample is in favor of the idea of having an impact on the streamer's room. 38 participants used the optional free-text field to provide various suggestions for what they would enjoy in the context of influencing something in the room (see Table 1). We included suggestions that were at least mentioned twice and indicate whether we had already included it in the list of modifications to be rated later. It shows that participants came up with various ideas, with the top three being able to control the lighting (potentially primed by the category introduction), generating sounds and modifying objects in the room. Table 2 shows how participants rated their enjoyment of our example modifications, presented afterward. Only four scored significantly above 3 (indicating that not every option is perceived as equally suitable), and again, controlling the lights and generating noise is rated positively. Interestingly, while only 56% (before)/62% (after) stated they would enjoy room modifications, we see that the agreement rate (70%) for the influence on the projected pictures is higher, **indicating that a proper modification selection could increase the overall perception of audience influence beyond the game**.

Of those who indicated that they would not like this modification category (i.e., who selected a score below 4), we received 30 answers in the free-text field for why they would not enjoy *Room* modifications. The prevailing theme mentioned here is that those viewers are more interested in the game and the streamers themselves and **do not want to interfere with either what the streamers present or their game performance (13x)**. Some (4x) also explicitly stated that for them the room is irrelevant and the idea is meaningless (4x). Other less frequently mentioned themes were privacy concerns, that it might be too distracting for viewers, that streamers know best how to present the environment, and that it enables too strong trolling tendencies in more popular streams.

[8]We will call this Agreement Rate, AR, subsequently.

Suggestions	#	Included
Measure and visualize streamer's pulse	27	✓
Measure and visualize streamer's eye tracking data	5	✓
Generate electric shocks/electronic muscle stimulation	5	✓
Change writing (e.g., via LED) or pictures on the streamer's clothes or the clothes themselves	4	
Measure and visualize streamer's blood pressure	3	
Measure and visualize streamer's respiratory rate	3	
Measure and visualize streamer's body temperature	3	✓
Measure and visualize streamer's button clicks and keystrokes	3	
Control the voice pitch of the streamer	3	
Measure and visualize streamer's stress level	2	✓
Generate an arbitrary taste in the streamer's mouth	2	✓
Manipulate the streamer's point of view	2	
Measure and visualize streamer's brain waves	2	
Handicap the streamer, e.g. tie the streamer's hands together	2	

Table 3. *Streamer* modification suggestions (see caption of Table 1).

Change	M	SD	Mdn	Ag	t
Measure and visualize streamer's pulse	4.4	1.6	5	81%	7.9
Measure and visualize streamer's stress level	4.2	1.6	4	77%	6.7
Measure and visualize streamer's emotions	4.0	1.6	4	70%	5.5
Measure and visualize streamer's eye tracking data	4.0	1.6	4	67%	5.6
Measure and visualize streamer's body temperature	3.4	1.5	4	52%	2.3
Control vibration feedback on the streamer's body	3.2	1.7	3	42%	-
Tickle the streamer	2.7	1.7	2	26%	-1.8
Control hot/cold pads on the streamer's body	2.5	1.5	2	21%	-2.9
Give the streamer light electric shocks	2.4	1.7	2	21%	-3
Generate an arbitrary taste in the streamer's mouth	2.4	1.5	2	17%	-3.4
Blindfold the streamer	2.2	1.5	2	16%	-5

Table 4. *Streamer* modification assessment (see caption of Table 2).

***Streamer* modifications**: The assessment before seeing examples appeared slightly better (M=4, SD=1.4, Mdn=4) than the *Room* modifications, with AR=53 participants (65%). Suggestions of what participants would enjoy for this category are shown in Table 3 (provided by 31 participants). The most often mentioned aspects mainly cover (activating) sensors. This is congruent to Table 4, as from the elements that we presented, the best-rated ones are all sensors and the actuators are mainly rated significantly below three. In addition, we had statement-based questions on this specifically: Participants rated the enjoyment of seeing sensor output of measurements from the streamer better than changing something on the streamer during the stream (M=4, SD=1.4, Mdn=4, AR=63 participants (78%) vs. M=3.2, SD=1.8, Mdn=3, AR=35 participants (43%)). In sum, it is obvious that **sensor *Streamer* modifications are perceived better than actuators**.

Suggestions	#	Included
Generate/control noises/sounds/music	22	(✓)
Swap keyboard keys	15	✓
Change the volume of the game sounds (up to the point of muting them)	8	✓
Invert the mouse direction	8	
Impact the controls of the game (no concrete examples were provided)	5	
Change the colors of the screen's content	4	✓
Turn off the screen for a couple of seconds	3	
Swap mouse keys	3	✓
Adjust the screen's brightness	3	
Change the mouse sensitivity	2	
Change the game's visual quality	2	✓
Move the streamer's camera	2	
Take over the chat	2	
Change monitor options (no concrete examples were provided)	2	✓

Table 5. *I/O* modification suggestions (see caption of Table 1).

21 participants provided free-text answers for why they would not enjoy *Streamer* modifications. The prevailing theme here is that the role of a streamer is highlighted as **an autonomous being and not a "puppet"** (6x), that they see issues with **privacy and personal rights** (4x) and that **"it goes too far"** (4x). Less often mentioned themes (only mentioned by one or two participants) were that it is "useless" and provides "unnecessary information"; some fear that it hinders the streamer and the experience, that it does not add to it and that there are health risks.

Taken together, the results show that *Streamer* modifications are **not in general considered reasonable**: *Active* modifications through viewer-controllable actuators are not perceived well, likely as they interfere with the actual "performance" of the streamer. For *passive* modifications through sensors that viewers can enable or disable, the perception changes significantly, likely as it provides additional insights during the "performance" without impacting it.

***I/O* modifications**: Together with the actuator *Streamer* modifications, the enjoyment answers (before and after) received the worst ratings (M=3.4, SD=1.7, Mdn=4, AR=41 participants (51%)/M=3.6, SD=1.8, Mdn=4, AR=42 participants (52%)). Concerning suggestions (see Table 5), sound-controlling aspects were mentioned often, potentially, because viewers could also use it to improve the streaming experience (e.g., adapting game sound if too loud compared to the streamer, or improving immersion by activating horror sounds in horror games). From the ratings in Table 6, we see that only a few of our suggestions were rated positively, especially considering the AR of 52% for the top-rated feature, indicating that this category **might be the least relevant one**.

23 participants provided free-text answers for why they would not enjoy this. The prevailing theme here is that they do not want to impact the streamer's skill and thereby **harm the viewing experience** (14x). Other themes were that it is annoying, that viewers do not want to have control over the streamer and that trolling might be an issue. Given the suggestions and the ratings, we see that there is a chance that the sole purpose of many *I/O* modifications is to interfere with the streamer's performance, which was also rated negatively in the *Streamer* modifications. Nonetheless, the results also show that certain viewers might find this appealing, but it needs to be kept in mind that for all the categories, no questions regarding the usage frequency were asked.

Change	M	SD	Mdn	Ag	t
Swap any two keys on the keyboard	3.6	1.9	4	52%	2.8
Swap left and right mouse keys	3.5	1.8	4	52%	2.6
Re-color the screen (e.g., only black and white)	3.5	1.7	3	46%	2.4
Play different effects on the screen	3.4	1.5	4	52%	2.4
Play any sound	3.3	1.7	3	47%	-
Rotate screen content	3.3	1.7	3	41%	-
Flip screen content horizontally	3.2	1.8	3	42%	-
Mute one or all audio channels	3.1	1.7	3	41%	-
Turn the screen upside-down	3.1	1.8	3	36%	-
Pixelate the screen	3.1	1.7	3	36%	-
Swap left and right audio output channel	3	1.7	3	36%	-
Change the screen's contrast	2.9	1.7	3	36%	-
Distort the sound	2.9	1.6	3	35%	-
Cause input delays (e.g., clicks arrive after one second)	2.8	1.6	3	30%	-

Table 6. *I/O* modification assessment (see caption of Table 2).

4.3.2 General Perception. It can be seen that **modification instances are not equally suitable**, but in every modification category, at least a few instances were also rated positively. Participants were asked, after having seen all the options, whether they would like to influence the streamer through modifications *in general*, to which half the sample agreed (M=3.5, SD=1.7, Mdn=4, AR=45 participants (56%)). Considering that certain individual modifications were rated higher, it is likely that the range of examples that were rated below 3 might have had an impact on this.

Context factors impact the perception as certain modifications suit certain streamers better than others (M=4.7, SD=1.3, Mdn=5, AR=70 participants (86%)). This fits with the free-text answers above that modifications are judged as problematic in streams that are consumed by viewers because they want to see the streamers' skill set. Through an free-text field, participants could explain why modifications are more reasonable for certain streamers. 46 participants provided an answer and two prevailing themes could be identified, namely, **the streamer and the stream type they are producing** (36x) and **the game itself** (15x). For the first theme, many participants clarified that the selection of the individual modifications might be guided not only by a streamer's personality/preferences and available streaming setup (e.g., streamers using a green screen would not want lighting changes through modifications), but also the type of stream they are producing (e.g., competitive vs. entertainment-only). The following quotes[9] exemplify these aspects: *There are streamers that rely on the fact that they offer entertainment. That makes sense. But there are others where the stream has a more serious component. There it doesn't make much sense.* or *Each streamer has a different character and streams the same games in a different way. Therefore, not every modification can be used in the same way for every streamer.*

The second theme was related to the game/genre streamed. Some modifications support immersion and are thus more suitable for games that rely on immersion (e.g., horror games), while other games, which are more skill-driven (e.g., shooter), would make modifications unreasonable, as exemplified through the following quotes: *It also depends on the games the streamer plays, because*

[9]German quotes were translated accordingly.

Genre	MP?	M	SD	Mdn	Ag
Survival horror games without weapons (e.g., Amnesia, Slender: The Eight Pages)	No	4.6	1.5	5	78%
Survival horror games with weapons (e.g., Dead Space, Resident Evil, The Evil Within)	No	4.5	1.5	5	77%
First-person shooters (e.g., Doom, Half Life, Wolfenstein)	No	4.0	1.7	4	61%
Action adventures (e.g., GTA, Tomb Raider)	No	3.9	1.6	4	65%
Beat 'em Ups (e.g., Mortal Combat, Street Fighter)	No	3.7	1.6	4	54%
Sandbox games (e.g., Garry's Mod, Minecraft)	No	3.7	1.7	4	54%
Platformer/Jump 'n' Runs (e.g., Crash Bandicoot, Super Mario)	No	3.7	1.6	4	54%
Roleplaying games (e.g., Skyrim, The Witcher)	No	3.6	1.6	4	56%
Racing games (e.g., Need for Speed, Project Cars)	No	3.4	1.7	3	48%
Rhythm games (e.g., Guitar Hero, Just Dance, Rockband)	No	3.4	1.6	3	47%
Sports games (e.g., FIFA, NBA, NHL)	No	3.1	1.5	3	34%
Real-time strategy games (e.g., Age of Empires, Company of Heroes)	No	3.1	1.6	3	38%
Round-based strategy games (e.g., Sid Meier's Civilization)	No	2.9	1.6	3	32%
First-person shooters (e.g., Counter-Strike, Overwatch, Player's Unknown Battleground)	Yes	3.8	1.8	4	58%
Multiplayer Online Battle Arena (MOBA) (e.g., Dota 2, League of Legends)	Yes	3.5	1.7	3	49%
Massively Multiplayer Online Role Playing Games (e.g., Guild Wars, World of Warcraft)	Yes	3.2	1.7	3	38%
Real-time strategy games (e.g., Company of Heroes, Starcraft)	Yes	2.9	1.6	3	36%
Sports games (e.g., FIFA, NBA, NHL)	Yes	2.9	1.6	3	31%
Round-based strategy games (e.g., Sid Meier's Civilization)	Yes	2.9	1.6	3	30%
Trading card games (e.g., Hearthstone, Magic: The Gathering Online)	Yes	2.8	1.6	3	27%

Table 7. How suitable the modifications are for a given game genre and whether corresponding games are played alone or with others ("no" in the column "MP?" ("multiplayer?") means that participants should imagine playing it in single-player mode).

the modifications fit some games better than others. or *It depends on the intent. For horror games, it would be awesome to see the heart rate. For competitive games, it would be silly to distract the streamer.*

Table 7 shows genres and whether participants should assume the game is played in a single-player or multiplayer fashion. The table also supports the finding above – that the game type is indeed an influencing factor for the modifications – as the genre itself, and whether it is played alone or with others, impacts the perception: Considering the involvement of multiple players, only one context – first-person shooters – was perceived as suitable by more than half of the participants. The sample also disagreed with the statement that modifications should be allowed in competitive settings (M=2.6, SD=1.6, Mdn=2, AG=21 participants (26%)), i.e., first-person shooters played in an eSports fashion would, again, be unreasonable. For games played in single-player mode, the situation looks different, as eight of 13 categories in the table were perceived as suitable by more than 50% of the participants. Here, the horror genre seems particularly fitting. This can either be explained by the immersion aspect (e.g., viewers activating the appropriate noises) or even the aspect of being able to scare the streamer further, through the modifications.

4.3.3 How to Realize. While assessing a modification, participants were to assume that they could enable it on their own. As this is an idealized situation, we closed the questionnaire with questions regarding how such an approach should be realized practically. Before they were primed with any of our options, we asked them to state how they would realize such a system. We received 58 answers; many of the resulting themes were only mentioned once and will be omitted here due to space reasons. The prevailing theme found was to use a voting system (26x). Here, some participants also explicitly mentioned that polls should be available for dedicated time frames and should be periodically re-occurring. Another theme (9x) was that particular subgroups (such as subscribers, donators, regulars or moderators) should be treated differently and either their votes should count more in polls, or that only those groups should take part in the choice of which modification should become active. A dedicated theme for donation was found as well (6x): Modifications should be bound to donations, i.e., paying money should allow the donor to activate modifications, and with higher donations, they would have access to modifications with a more substantial impact. It was also suggested (6x) that a virtual currency in the stream should be available (e.g., gained through watching) and with it, bidding on modification rights should occur in certain time frames, either with the highest bidder having a chance to be in control of the modifications, or with bids activating certain modifications if a bidding threshold is reached. Another idea (8x) was that one random viewer could be automatically picked, who then would have control over the modifications. From the answers to our statement-based questions, we again saw a non-uniform tendency: Only 57% of the participants think that every viewer should be able to take part in modification polls (M=3.6, SD=1.7, Mdn=4) and 72% (M=4, SD=1.5, Mdn=4) think that channel subscribers or regulars should have a larger impact in these. Based on the free-text answers that trolling might be an issue for the modifications, this could even be an explanation for both results. Taken together, this shows that ideas range around the desire to **collect the opinion of all viewers** (e.g., open polls), **subgroups** (e.g., subscribers only) **or empowering individuals** (e.g., those that donated), with a clear tendency to empower subgroups. A small majority thinks that there should be a minimum amount of votes that must be reached as a threshold to activate a modification, not just a plurality vote (M=4, SD=1.4, Mdn=4, AR=49 participants (60%)) and that when a modification is used it should have a cooldown before it can be voted on again (M=4, SD=1.4, Mdn=4, AR=55 participants (68%)). 72% (M=4.1, SD=1.6, Mdn=4) want only one modification active at a time and the length of its activation should be in relation to what the modification is actually doing (M=4.4, SD=1.3, Mdn=4, AR=69 participants (85%)).

4.4 General Takeaways and Limitations

From the results we derive the following takeaways for this study: [information in brackets denotes on what bases we derived them]

- **Game-independent viewer integration is, in general, perceived positively**: In each of the presented categories, participants came up with ideas they would enjoy seeing in a stream, and at least some of our presented instances were perceived positively by the majority of participants. Thus, we conclude that – in general – investigating viewer integration beyond the game is a reasonable endeavor to pursue. [Above 3 scores in Tables 2, 4, 6; suggestions in Tables 1, 3, 5; answers on the general perception of exerting influence (see Section 4.3.2)]
- **Not just for fun**: Understanding the exact parameters that lead to viewer acceptance seems to be a worthwhile next step. This should not only be done from the perspective of enjoyment, as viewer integration could also be a factor for improving the viewing experience: Making the audience a kind of co-creator in the stream would allow them, for example, to mitigate bad streaming setup configurations (e.g., adjusting the loudness levels of the game and

microphone) or allow them to activate stress-level indicators in intense situations. Allowing the audience to co-create here would result in a better stream experience for them and is thus an aspect that should be considered in upcoming studies as well. [Suggestions in Tables 1, 3, 5]

- **Non-interference with the streamer**: We presented several options for the three modification categories and learned that there are clear differences in their perception. The by far best rated type was *Streamer*-sensor modifications. These are particularly non-invasive, i.e., they do not impact the stream experience negatively. This, on the other hand, was something that was seen across the categories: Many participants feared that certain options would interfere with the streaming experience too much, especially if trolls were present in the audience. Certainly, this aspect explains the sample's tendency to use polls and empower dedicated subgroups, such as regulars, when it comes to realizing this form of audience integration. The negative perception of some of the related features in the feature acceptance study of Lessel et al. [13] can thus be set in relation to this aspect as well. [Tables 2, 4, 6; corresponding discussion for the different categories in Section 4.3.1; answers to the questions of how to realize such an approach (see Section 4.3.3)]
- **Context matters**: The results of the study showed that context factors moderate acceptance. We identified the streamer, the game genre, the type of stream and the intent why the game is presented (skill and competition vs. entertainment) as factors. Considering the motivation of this paper, we were interested in interactivity that, from a technical perspective, is not bound to the game and could thus be used independent of it. The study revealed that there is no game independence. Thus, it seems that there are different "stages" that are considered, when deciding whether or not a specific modification is considered as reasonable: The modification itself is judged ("*Would I like this?*"), then whether it fits with the game ("*Does it make sense in the content/game shown?*") and then whether the stream's context is appropriate ("*Does it make sense for the current stream situation?*"). [Section 4.3.2; Table 7]

Concerning study limitations, participants could only imagine the modifications and needed to take a general viewpoint, instead of focusing on a specific streamer and game. This was done on purpose so as not to introduce a context bias, which was wise if one considers that the streamer, the game and the stream type were revealed to be context factors. It will be an opportunity for future work to better understand the impact of these attributes. Second, the sample was small, which needs to be seen in the light of an already long survey, with many optional free text fields, with no compensation or giveaways. However, for gaining a first overview on this topic, we deem the sample size as acceptable. Similarly, although age and gender distribution of the sample was in line with the Twitch demographics, many participants were German, which might have had an effect of on the results. It would be interesting to complement the study with participants mainly of another nationality, to investigate potential differences in this respect. Third, to structure the extensive questionnaire, we introduced three modification categories as a starting point for participants' idea generation. As stated in the method section, these categories had no sharp boundaries, and we do not want to claim that these are the only possible categories. Thus, there might be further ideas, belonging to other categories, that were not elicited from participants with this approach. Fourth, we did not enforce statements from a streamer perspective – participants were to take the point of view of consumers of game live-streams. It would be worthwhile to re-run such an extensive questionnaire for streamers only as well.

5 LAB STUDY: STREAMER'S PERCEPTION

This study aimed at streamers. To mitigate the first limitation of the previous study, we developed a prototype that allowed them to experience modifications that were perceived well by viewers while producing typical game content.

5.1 Game and Modifications

As the online study revealed context factors, we designed the study to represent a "best case" setting: If streamers would already dislike such a setting, it would become clear that the overall idea is not viable.

Game: The best rated game genre before was survival horror without weapons. We picked the free-to-play game "Slender: The Eight Pages"[10] (developed by Mark J. Hadley) as an instance of this genre. In this game, the player needs to collect eight journal pages in a forest at night. While the forest and the placement of points of interest (e.g., a truck or oil tanks) is always the same, the location of the pages is randomly decided per game run. The player navigates through the forest in a first-person view and the player's avatar is able to run for a short time before it is exhausted. In addition, the player has a flashlight; its power decreases over time if used too extensively. The game's challenge is the "Slenderman", an enemy who hunts the player. The only possibility to avoid getting caught (and thus avoid losing the game) is to run away from this enemy and collect all the pages quickly. This becomes harder, as with more collected pages, the enemy approaches faster and at a certain point is even able to teleport over long distances. Immersion-wise, the game offers unnerving background noises and a fog in the forest grows thicker over time, making it harder to spot whether Slenderman is nearby. If the enemy is particularly near, the screen also starts to crackle and increasingly louder static noises can be heard.

Modifications: We set up and implemented twelve modifications (see Table 8). To achieve the "best case" setting, we picked mainly those modifications that received high acceptance scores in the previous study, added a modification to allow for changes of the background music (as this was one of the most often provided suggestions that was not explicitly included in our ratings) and added a modification for vibration feedback, to include the best rated *Streamer* actuator modification. Although this is not necessarily part of a "best case" setting, we aimed to get a holistic picture for this category. Where possible, we instantiated modifications (M1, M4–M6) with appropriate content, to match the game setting (i.e., suitable image, sound, etc.). Active modifications, besides their inherent changes, were also indicated with a small icon in the top left of the streamer's screen. For this, we used the Overwolf[11] system, which allows to overlay games in full screen mode with own visual content. Figure 1 shows M1 (left) and M11 (right).

5.2 Method

The hardware and room setup (e.g., the light strips and projector) led to a lab study with local participants. The requirement was that they already had experience with producing game streams and "Let's Plays" [28]. To increase the external validity, every participant was told that they should imagine that they would now record an offline "Let's Play" for their viewers, and that they were free to take it with them to provide it to their real viewers afterward[12]. This was done to strengthen the "real use case" and as an incentive for participating. In contrast to the later use case, we simulated the audience in respect to modification activations, which participants also knew about. This was

[10] https://en.wikipedia.org/wiki/Slender:_The_Eight_Pages, last accessed: 2022-07-19

[11] https://www.overwolf.com, last accessed: 2022-07-19

[12] We did not explicitly check which of the streamers actually uploaded the video, but we know that at least one participant did so.

Name (ID): Description
Environment Projection & Lighting (M1): When active, a projector projects a picture of a dark forest and light strips emit ambient lighting (see Figure 1, left). When deactivated, the light is turned off and a pure black color shown. It combines several of the positively rated room modifications.
Swap Mouse Clicks (M2): When active, the mouse buttons (left: collecting pages, right: toggling flashlights) are switched.
Swap Key Bindings (M3): When active, the left and right movement bindings are switched.
Play Ambient Sounds (M4): When active, a sound file with sounds indicating Slenderman is approaching is played.
Play Background Music (M5): When active, the theme song from the Halloween movie by John Carpenter is played.
Display Effects (M6): When active, the screen goes black, down from the top and back up again (in 200ms in total).
Vibration Feedback (M7): When active, a repeating vibration (8 sec. pause, 2 sec. vibration) is emitted from a smartwatch.
Eye Tracking Heat Map (M8): When active, an eye-tracking heat map (using a Tobii eye tracker) showing the points the streamer looked at is shown on the second screen, to keep the game playable.
Analyze Emotions (M9): When active, the emotion of the streamer is derived by the Affectiva Emotion SDK through a webcam and displayed as an emoticon directly on the primary screen in the upper right corner.
Measure Heart Rate (M10), Stress Level (M11) or Skin Temperature (M12): To measure the individual biometric values, an Empatica E4 wristband must be worn by the streamers during the experiment. When active, a chart is displayed in the lower left corner of the game screen, in which the corresponding real-time data is shown (see Figure 1, right).

Table 8. The modifications used in the study.

done so as not to introduce an uncontrollable bias through a different streamer community, random viewers joining on a live-streaming platform or trolling tendencies in a real community. In addition, we also judged it as problematic to recruit people to simulate viewers across all trials.

We provided a typical streaming setup (i.e., gaming PC, dual-screen setup, keyboard, mouse, microphone, over-ear headset, webcam). The dual-screen setup was chosen to allow participants to play the game on the primary screen and use the second screen to show the streaming software. As it offers a live preview, participants would see exactly what they recorded. In addition, the second screen shows how the heat map of eye-tracking data (M8) looks like for viewers. Every participant was informed about the study's purpose in full and we assessed their previous experiences with "Slender: The Eight Pages" and in producing "Let's Plays" through a questionnaire. To introduce the game, the controls and the game mechanics a video was shown. After this, participants were to play for three minutes to get familiar with it. To prevent frustration (which might impact the modification perception as well), we provided a printout of the forest map, with the points of interest marked, and a printout of the game controls, the modification names, and their icons.

Participants were equipped with the hardware, the room was prepared (e.g., turned off the room lights) and another video explained our modification approach together with the information that, in a real setting, the audience would active them. Then the game started and every two minutes a modification was activated (randomized order, each modification only shown once) for one minute, followed by one minute without a modification being active. After all modifications were

presented, we ended the game and provided sheets with four questions per modification in the same sequence as they experienced them in the game (i.e., twelve times): *How much did you enjoy the modification?* (abbreviated with Enjoyment in Table 9; 6-point scale from "very little" to "very much"); *I can imagine that this modification might appeal to viewers in general* (Viewer General); *My viewers might like this modifier* (Viewer Own); *I can imagine offering this modification to my viewers in live-streams* (Using Own) (all 6-point scales from strongly disagree to strongly agree). To help them remember the modification, a 20-second video showed a game situation with the modification. Then a closing questionnaire to assess the general perception was provided, followed by a semi-structured interview (with the audio being recorded and later transcribed through a thematic-based content analysis [10]) to assess the pros and cons that they saw. The study duration was 60–75 minutes per participant. The study was approved by the Ethical Review Board of the Faculty of Mathematics and Computer Science at Saarland University (No. 18-8-4).

5.3 Participants

Six German streamers (gender 2x female, 4x male; all aged between 25 and 30) took part with three reporting to stream multiple times a week, the other three multiple times a month (with one streamer reporting that he had stopped streaming recently, but had streamed frequently before). The streaming experience ranged from multiple months up to two years and three also stated that they had created "Let's Plays" for even longer. The streamers reported that they had around 3–14 viewers (M=9.5, SD=3.6, Mdn=10) on average, and thus need to be seen as "smaller" in the ecosystem of Twitch.tv, fitting with the long tail distribution there, where most streamers have only small viewer numbers [11]. Although the inclusion of more popular streamers would have been worthwhile, we deemed this to be acceptable for a first exploration of this topic with streamers, especially in light of the lab study setting. All participants reported to consume live-streams/"Let's Plays" on their own and two stated that they had already played the game in the past.

5.4 Results

We describe how the used modifications were perceived, which further ideas arose and participants' general perception.

5.4.1 Modification Perception. Table 9 shows that streamers had a different impression of the enjoyment value of the individual modifications: While all but M12 had a clear, positive tendency to be perceived as enjoyable, it seems that M2–M5 and M10+M11 are considered particularly enjoyable. These modifications also received high values for Viewer General and Viewer Own. It is interesting to note that M2 and M3 were modifications that received lower ratings from the viewers in the online study (here it was: M2: M=3.5, M3: M=3.6). Considering the modification categories of the first study, we see that *I/O* (M2, M3, M4), *Streamer* (M10, M11; at least from a sensor perspective) and *Room* (M4, M5) are covered, indicating that **every category offers appealing instances from a streamer's perspective**.

Explanations for the lower scores were derived from the interviews: M6, was seen as annoying for viewers, depending on the game situation (e.g., if something needs to be read in the game) (Participant 2, P2), again hinting a context dependency. M7 was characterized as too weak to even impact mouse movements (which that participant would assess as interesting) (P1), too loud (might interfere with the recording) or requiring something to be worn[13] (P2); P4 found it funny, but also boring, and thought it could become more interesting, if it mimicked the in-game steps. M8 was stated to be problematic because it might overlay information, even on a second screen (P4). Overall, these criticism highlight that **unobtrusive modifications** that do not interfere with

[13]Together with the Empatica E4, this was too much for this participant.

Modification	Enjoyment			Viewer General			Viewer Own			Using Own		
	M	SD	Mdn	M	SD	Mdn	M	SD	Mdn	M	SD	Mdn
Play Background Music (M5)	5.7	.5	6	5.8	.4	6	6	0	6	6	0	6
Measure Heart Rate (M10)	5.5	.5	5.5	5.7	0.5	6	6	0	6	5.8	.4	6
Swap Mouse Clicks (M2)	5.7	.5	6	5.8	.4	6	5.8	.4	6	5.7	.7	6
Play Ambient Sounds (M4)	5	1.5	6	5.5	0.5	5.5	5.7	.7	6	5.7	.7	6
Swap Key Bindings (M3)	5	1.2	5.5	5.7	.5	6	6	0	6	5.3	1.1	6
Measure Stress Level (M11)	5.3	.8	5.5	5.3	.7	5.5	5.2	1.1	5.5	5.2	1.5	6
Display Effects (M6)	3.8	1.7	4	3.7	1.7	4	3.5	1.6	4	3.5	2.2	3.5
Vibration Feedback (M7)	3.8	1.6	4	3.7	1.2	4	3.7	1.7	4	3.5	1.8	2.5
Analyze Emotions (M9)	4.2	1.6	4	4.2	1.5	5	3.7	1.6	3.5	3.3	1.6	3.5
Measure Skin Temperature (M12)	3.2	1.6	3	3.8	1.6	3	3.3	1.7	3	3.3	2	2.5
Eye Tracking Heat Map (M8)	4.2	1.3	4.5	4.2	.9	4.5	3.2	1.6	3	3.2	.7	3
Environment Projection (M1)	3.7	1.8	4	2.8	2	2	2.5	1.3	2.5	2.7	1.8	2

Table 9. The perception (on a 6-point scale) per presented modification, for the four questions asked (see Method section).

the stream's quality (i.e., the loudness/the readability) or did not put a burden on streamers (i.e., wearing gadgets) **should be focused on**. M9 was mentioned as providing no benefit for viewers who can already see the streamer (P5) and P6 was not sure whether it worked properly. M12 was assessed as "useless", because it would be uninteresting for viewers (P3), unnecessary (P4) or less relevant for viewers (P5). Finally, regarding M1, complaints included that it created a contrast issue with the projector, making the usually dark streamer room too bright (P1), that it was not that convincing in the lab-room setting (P2), that one would need a projection space (P4) and that the light was not visible to potential viewers (P6). These aspects highlight that it is important that **modifications offer enough appeal and non-redundant information, and always need to provide something interesting for viewers as well.**

Changes were suggested: P5 would change the vibration to the whole chair, not just the arm; P6 would show the passive modifications (i.e., the sensors) all the time, not just for a set time frame, and would change the eye blinking effect to representing his eyes blinking for the viewers, instead of a random blink. New feature suggestions included controlling the light in a room (e.g., leading to flickering lights) or controlling other smart home devices (without clarifying which exactly) (P2); using an apparatus that is able to spray water into the streamer's face, executing random key clicks, changing the contrast of the game screen or giving small electric shocks (that would not affect health negatively) (P4); reducing the brightness of the screen for the streamer only, or directly impacting the game (e.g., disabling the flashlight) (P5). Electric shocks were also mentioned by P6. Regarding changes and new features, privacy/security concerns were verbalized twice, and it was mentioned that modifications that would impact health in any respect should be prohibited.

5.4.2 General Perception. The idea is perceived to increase the fun viewers experience with the stream (M=6, SD=0, Mdn=6) and every participant would offer this in their own stream (M=6, SD=0, Mdn=6). This view was also expressed by five streamers during the interview[14]: *Super. I thought it was great.* (P2); *I enjoyed it a lot, definitely. Very good. Especially the fact that you as a*

[14]Translated from German

spectator have the possibility to interact is awesome. (P4) and *Personally I thought it was really cool. It was really a bit different from what is there already* (P5). Four streamers saw the approach as annoying for streamers in a positive way, as they thought this was something that viewers would like to do (e.g., *Everyone wants to annoy streamers* (P1)). Three streamers highlighted that viewers would be more active in a stream (e.g., *[It] would continue to motivate the viewers to take part and not only be lurking in the stream or be 'away from keyboard'.* (P3)). Additional aspects mentioned were *[it] would [complement] the streams very very [sic] positively (P2), it would extend the gaming experience* (P4) and *it has a huge potential, because it increases the entertainment value for people many times* (P6). Overall, **streamer's see audience influence beyond the game as a positive approach**. Participants think that the game was a good fit (M=5.7, SD=.5, Mdn=6) and that they liked to play it modified (M=5.8, SD=.4, Mdn=6). It was underlined, similar to the first study, that a horror game is a good fit for the modifications by five streamers (e.g., *Especially with this game and these modifications, I think this was really great.* (P2)).

There were different opinions which viewers should be able to interact with the modifications. Four streamers think those who support the streamer more should have more impact (e.g., *I think I would sort that by loyalty or something ... how often do they watch? How often are they present [in the stream]? How active are they really?* (P2)). What "support" means in this sense was not specifically the same across the participants, as it sometimes meant being a regular, a subscriber or a donator. Some streamers would empower subgroups alone, e.g., channel subscribers should be the only ones to use the modifications (mentioned 3x, e.g. *the subs should have benefits compared to lurkers*[15] (P1)); another idea (3x) was that viewers who donate something can activate a modification. Some participants also explicitly stated that "lurkers" should not be able to use the modifications (3x, by P1–P3). Another aspect was that in low-viewer streams (although it was unclear what is low), every viewer should be able to take part (3x, by P1, P3, P6). Two streamers (P4, P5) also explicitly stated that they would not exclude anyone from taking part. Mixed views also appeared for whether one viewer should have full control over the modifications in a turn-taking fashion (2x) or whether a voting system should be used (3x). Overall, this view shows that streamers have different opinions in respect to who should be able to participate and thus, **a realized tool needs to be customizable to allow for these viewpoints.**

The context dependency identified in the previous study was found again. All participants clarified that interactivity beyond the game is dependent on the stream type: For skill-based streams (e.g., playing ranked games) they would either turn it off (e.g., *If I play for fun I don't care, but when I play in the League ... the tool would be disabled completely.* (P1)), or would only use passive modifications (2x; i.e., sensors from the *Streamer* category). Also, a **situational dependency** was mentioned (3x): Some active modifications would be better or worse depending on the game situation (e.g., *... if the moment is not suitable, then [the modifications] do not have any use. Then, you think ... that they don't matter. But if the moment is right, they are perfect.* (P3)). Finally, the game/game genre was also mentioned to have an impact (3x, e.g. *... it is quite dependent on the game genre, when to allow activating which modification* (P2)). And two other participants thought that there are games that would never be suitable for offering any kind of modification, while in contrast, one participant thought that every game would be a fit for the set of modifications used in the study. This strong context dependency might have led to three participants explicitly expressing the need for having customization options to enable or disable modifications beforehand and in relation to the expected course of the stream.

[15] Those who are just watching the stream without engaging with the chat or the streamer.

5.5 General Takeaways and Limitations

From the results we derive the following takeaways for this study: [information in brackets denotes on what bases we derived them]

- **Game-independent viewer integration is perceived positively**: Streamers uniformly saw the appeal of such viewer integration, although not every modification was perceived as highly useful in its current state. There are two interpretations: First, streamers, in general, see more appeal in this kind of viewer integration than viewers. Two modifications were rated much better and the interview themes showed that streamers think that viewers could become more active in the stream. It needs to be kept in mind that in the previous study several modifications received particularly bad ratings (while here we used a "best case" setting) and thus, viewers' views might have been primed negatively for the overall approach. Nonetheless, from both study results, it is apparent that modification instances of all three categories are perceived positively. [Above 3 scores in Table 9; Section 5.4.1; Section 5.4.2 in respect to the general perception; takeaways from the first study]
- **Context matters**: Also from the streamers' perspective, the context matters: The game, the game situation, the genre and the type of stream are all aspects that would at least lead to a different selection of available modifications, or in some cases even to a disabling of all modifications. [Results in respect to the context dependency in Section 5.4.2]
- **Customization options**: Non-uniform participant views were present in the first study and are also visible in this study with streamers. This underlines the need for customization options: On the one hand, the modifications offered to viewers need to be adjustable by the streamer beforehand, so that they can set their stream plans in relation to the modifications they will allow. On the other hand, who of the viewers should be able to impact the modification activation should also be configurable for the streamers, as here, several options are possible, and it apparently depends on the streamers and their community whether all viewers should have the same impact or whether subgroups should be empowered, even to the point that they alone can decide. [Results in respect to customization in Section 5.4.2]

This study had limitations. First, the sample was small (and only consisted of German content creators), which was a result of the lab study situation in an area which did not have many major game live-streamers. Second, the streamers were told what the study was about beforehand. If they had been completely against such an approach, there would have been a chance that they would not take part, which could have led to a selection bias. Third, the "best case" setting was realized with only one horror game. Maybe other horror games would lead to different results. Also, different genres and stream types should be examined. Fourth, we had no audience, i.e., streamers knew that no one (but us) was watching them. Although we tried to mitigate this with the video recording (that they could take with them), it was not a real situation, and thus, that could have affected the results. As stated, this was done to increase the validity and ensure comparability among the streamers. Fifth, the streamers, given their average viewer counts, are part of only one cluster found in [4]. Certainly, this is a weakness of this second study, especially as interactions might change (for both viewers and streamers) depending on the number of viewers in a stream (see also [32]). Thus, the results might only be applicable for this first cluster (covering streamers with lower viewer numbers) and for those streamers who do primarily entertainment instead of competitive streams [32]. A follow-up study should also focus on more popular streamers. Nonetheless, for this limitation, it needs to be kept in mind that Twitch has a long-tail distribution in viewer counts, i.e., only a few channels have many viewers, and most channels have only a few viewers (e.g., [11]). Thus, by considering streamers with smaller viewer numbers, we contributed results that are still applicable for a large portion of channels on Twitch today.

6 DISCUSSION

We had three research questions (RQs 1–3, see Introduction) that were targeted in the two studies: we learned that, in general, the idea of extending the audience influence space is a valuable research direction that is perceived positively by streamers (RQ 2) and to a certain extent by viewers as well (RQ 1). Game live-streaming allows players to transform their private play into public entertainment and in doing that, often, they share not only how they play, but also other aspects of their life with their community [32]. As viewer interaction is important for live-streaming (as highlighted in the related work section), the idea of allowing viewers to also impact something in the streamer's environment seemed not to be far-fetched and was confirmed in our study. Ideas discussed in the studies add another layer of interactive options: viewers could not only communicate with the streamer and influence the options offered by the game or the platform itself, but could also interact with objects around the streamer. Considering "*broadcasters continue to innovate in ways far beyond simply piping out gameplay.*" ([32], p.58), this might open up new opportunities for them.

In respect to RQ3, it should be considered that the streamer study was a "best case" setting, while the viewer study was situated in a broader context in which many audience influence options also received non-positive ratings; this could have an influence on perceptions. In the viewer study, we clustered the influence options into three categories, and saw viewers' perceptual differences among them: Actuators that affect the streamer directly, and modifications that alter the streamer's hardware, received the worst ratings from viewers, potentially, because the viewers in our survey feared that it would interfere with the stream experience too much. Regarding the discussions around viewer motivations and viewer types (e.g. [1, 13, 25, 32]), those who watch primarily because they want to learn how to play the game better would potentially not get much enjoyment out of activating such modifications and might be annoyed if others activated them. In contrast, those viewers who are more interested in the streamer's personality would potentially enjoy the modifications more, to see how they would react to such elements. This study did not consider such individual differences in viewers, but this would be a reasonable next step, for example by using the proposed viewer type questionnaire [25]. Considering that the streamer perceptions of features differed compared to viewer perceptions to a certain extent (for example, the selected *I/O* modifications received notably higher streamer ratings compared to viewer ratings), this underlines the value of such studies, as the results can be used to guide streamers on which options they might want to offer. Besides the different study settings, the differences might have arisen because the streamers focused more on the potential entertainment value that it could provide for viewers in general. Nonetheless, through both studies, congruent perceptions for modifications were also found, i.e., there were modifications that were rated positively by viewers, and that streamers would also enjoy and use in their streams (e.g., having an impact on sound/music, showing heart rate/stress level). Also, some other aspects that were rated as interesting by viewers (e.g., impacting picture projection on the walls) received lower ratings from streamers mainly because of specific circumstances (e.g., how they were used in the lab study or the question of how our participants would realize them at home) and not because of general reservations (as, for example, the mentioned feature would need a projector and potentially other camera setups to be of use for viewers). In general, the congruently rated influence options should be focused on first in follow-up studies to further investigate audience influence beyond the game in "in the wild" studies.

It also needs to be noted that the live-streaming context is diverse [32]: not only do viewer motivations differ [25], but also streamers have different personalities and motivations for why they stream (e.g., just for fun, or because it is their profession), and behave differently in respect to the amount of viewers they have. But also on the level of what is broadcast, variety is seen (e.g., from gaming to social eating to art streams), and purposes also very (e.g., live-streams of

competitive games in eSports contexts, vs. entertainment-only gaming). One aspect that became obvious through our studies is that there is no game independent audience influence beyond the technical viewpoint, potentially because of diversity: Viewers and streamers judge the modifications in respect to the actual content of the stream. For this, it is not just the game and its genre (and the in-game situation) that matters, but also the reason why streamers play/present it, and their goals (e.g., showing skills or playing just for fun). The context influences which modifications should be available for viewers to activate, up to the point that in some cases, no modifications at all should be available. It needs to be kept in mind that participants of the first study had to take a general viewpoint while participants of the second study saw the modifications instantiated in a horror game. Given the results in respect to context factors, we assume that some of the modifications that receive low viewer ratings will be more appealing in certain contexts: If a streamer plays a game "just for fun" and aims at a high entertainment value for the audience (and also clearly communicates this to the viewers, to manage expectations), potentially such a context might boost the perception of *I/O* or *Streamer* actuator modifications, while these are problematic in competitive online play. In contrast, there, using solely the *Streamer* sensor modifications, such as measuring the pulse, might be especially relevant, as it does not interfere with the streamer's skill shown in the stream, but can add value for the viewers. The same might be true for those modifications that could support game immersion (e.g., certain *Room* and *Streamer* modifications), if highly immerse games (e.g., horror games) are played.

To this end, the conducted studies need to be seen as a starting point, as we revealed these context factors, but can only make educated guesses on which modifications are suitable for certain contexts, given the approach we followed. Follow-up work is needed to generate guidelines. As we already started to integrate factors such as whether a game is played in single- or multiplayer mode, the stream's purpose also needs to be considered. A game that is played to beat a speedrun record might fall in the category of "competitive" play, thus restricting the modification options to non-interfering ones, although the game genre itself might suggest that other modifications work as well.

Overall, our investigation of audience influence beyond the game adds to the ongoing research of interactivity in live-streaming. While works on audience participation games focus on the underlying game, the investigation of influence options that would work independent of it revealed general context factors that need to be considered. Moreover, the studies also revealed that the amount of influence viewers want to exert, can be seen as limited in many cases. Given the role of the streamer and why people consume streams [13] this is not surprising; i.e., besides those who want to troll in streams, the majority would not wish to impact their streaming experience negatively, by interfering with the streamer too much. It is already known that harassment/toxic behavior is something that can also happen on Twitch [32] and many of the modifications could be seen as further channel for this behavior. The viewer study showed that many participants actually had ideas on how the different modification categories could be instantiated, and only a few suggestions might went into a direction that is ethically questionable. When it comes down to the question of viewer influence, this "dark side" could be a general issue, but only a low number of participants in our sample contributed ideas that could be used for this. While this is nonetheless a potential problem, it also needs to be considered that the streamers are those who would be able to choose which modifications to use "in the wild". As found in the studies, "one-size-fits-all" solutions are problematic and thus offering customization options is important. One option clearly should be that streamers can disable/enable modifications that should be in the pool offered to viewers. Thus, while they might not be able to control the exact activation of a modification, they could disable those modifications that they do not feel are appropriate in general. In respect to the different streamer's preferences and streaming goals, it would also be interesting to learn which

modifications are made available by streamers and whether similar behaviors could be observed as the one mentioned in the related work section, in which donations were coupled with playing horror sounds while playing a horror game to increase the incentive to donate. Besides this, the trolling tendencies for abuse of offered modifications might also be restricted, depending on how modifications can be selected by viewers. Here, we also saw different preferences; if majority decisions are necessary to activate a modification, and given viewers' motivation not to interfere with the streamer, this should also help to minimize problematic influence decisions. However, it also needs to be kept in mind that we did not have a specific question to identify those who stream on their own and have already suffered from toxic behavior in the past during their streams through interactive means. Potentially, a sample consisting mainly of participants who had such experiences, might judge the overall approach (or interactivity as a whole) differently. The derived results need to be seen in respect to this, i.e., while we have carried out these first exploratory studies with samples that are common on the live-streaming platforms, a wider variety of viewers and streamers exist that should be considered in follow-up studies.

7 CONCLUSION

In this paper, we built on the past finding that audience influence is an important appealing factor in the context of live-streaming [8, 31]. While focusing on the context of game live-streams, we were particularly interested in exploring the design space of influence options that work beyond the streamed game. Through options that are available independent of the actual content that is streamed, similar to polling systems already often used today [14], audience influence possibilities could be offered consistently, and not only if a game that allows for this is being streamed.

As a starting point for exploring this design space, we conducted an online study aimed at viewers of game streams to understand what ideas they had and how they would rate various influence options, beyond the game, that we called modifications. We learned that, although the range of modifications can be considered large, the viewer's acceptance depends highly on the type of modification. Although not every option was assessed as appealing, several options received positive ratings. Interestingly, the best-rated options were those that would not interfere with streamers too much. Based on the findings of the first study, a laboratory study with streamers was done to see how they would experience some of the modifications. As the first study was done with viewers who should (only-textually) state what they would like to have as influence option, the second study created a best-case setting and allowed streamers to experience the options directly. They appreciated the options even more, compared to the audience. An important aspect that was found in both studies was that there is a context dependency. Thus, this paper indicates that although the modifications technically work independently of the streamed content, the appeal for both streamers and viewers is still bound to factors, such as the game, the game genre and the type of stream (e.g., "just for fun" or "competitive").

Clearly, this paper is only a first step in the direction of audience influence beyond the streamed content. Based on the study results, several opportunities for future work have arisen: First, investigating the aforementioned context factors is worthwhile and has likely implications for interactivity bound to the game as well. Second, instead of a best-case setting study, an "in the wild" study should be carried out. Based on the realization options discussed in the second study, it could be investigated whether the same ratings would occur from a streamer perspective, if the same game and same modifications are used with a real audience. Similarly, also the audience should be able to rate to get a holistic picture of the setting. Third, based on the former results, other games in the horror genre and even games from other genres should be tested. Fourth, an elicitation study, similar to the first study but solely aiming at streamers could be done, to learn whether their perspective results in different ideas that were not elicited from viewers. Fifth, both studies

should be replicated with other demographics to see what differences arise. Not only might other nationalities be of interest, but also people that are less represented in usual samples (e.g., those who have had prior experiences with trolling/harassment in live-streaming settings) to see how they perceive such viewer influence. In addition, studies with streamers having larger viewer numbers in their streams should be carried out, to see how this impacts perceptions. Sixth, having access to the streamer's environment for influencing purposes could impact the social connection between viewers and streamers further (e.g., leading to a faster transition from "bystander" to "regular" viewer). Such social dynamics were not investigated by our approach, but would also be an interesting to investigate.

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