Avatar: Enabling Immersive Collaboration via Live Mobile Video

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ABSTRACT

Live mobile video streaming is gaining popularity around the world, thanks in part to increasingly pervasive smartphone ownership and cellular broadband coverage. We see an opportunity for mobile video streaming to enable new task-oriented experiences such as remote shopping, virtual interactive tourism, auditing and verification, mobile crowdsourcing, and remote physical-world games. We posit that such applications may eventually lead to new employment opportunities for remote agents in developing countries.

In this paper we report our experiences conducting a technology probe for one such use case: an 'escape-the-room' physical puzzle game where some of the team members remotely interacted with a video stream that was produced by other team members who were physically present in the escape room. We designed and built a mobile streaming system called *Avatar* which we deployed in our study with 26 participants. We report findings from our study, including observations about appropriate communication modalities for remote collaborative game playing, as well as unexpected interactions and points of friction between participants.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**; *Computer supported cooperative work*;

KEYWORDS

Remote collaboration; Mobile video streaming; Games

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1 INTRODUCTION

Live video streaming platforms such as Periscope, Facebook Live & Youtube Live have gained popularity in the last few years, with particularly high numbers of new users in developing countries [11]. This popularity is enabled by decreasing costs and widespread availability of smartphones and cellular bandwidth. Content creators on live video streaming platforms have found engaged audiences for game playing, remote viewing of events (e.g., music concerts), disaster response coordination, and *collective witnessing* of injustice or corruption [17]. As mobile video streams, low cost 360 degree cameras, and augmented reality video streams become mainstream, we expect that the scope of use-cases for live video streaming will continue expanding.

We see an opportunity for mobile video streaming to enable a new class of experiences: task-oriented cooperative work and play. We envision use cases such as remote shopping [16], where parents of young children or persons with disabilities who need to stay at home can interactively shop for items that require browsing (e.g., clothing) by interactively instructing a worker with a mobile phone to browse on their behalf; or spot checking and auditing, where donors and funders who are far away from a site (e.g., a construction area or NGO's premises) employ locals to visit and verify through a live video stream that work is completed as expected.

These use cases have three distinguishing traits in common:

(1) Participants of the stream (both creators and viewers) are collaborating in real-time towards a goal and may communicate in both directions to achieve that goal.
(2) Participants on either side of the stream may not know each other.
(3) Depending on the nature of the interaction, there may be an asymmetric power relationship between the creator and viewer of the video stream, e.g., when the viewer of the stream is paying the creator to complete a task.

These unique characteristics present opportunities as well as challenges. For example, there is a need to ensure ethical behavior on the platform, and provide an environment where all participants are comfortable and engaged with the experience.

In this paper, we explore one example of a task-oriented experience: enriched collaborative mobile video streaming in a physical-world 'escape-the-room' puzzle game. *Escape rooms* involve collaborative puzzle solving where collocated team members try to escape from a series of locked rooms within a defined time frame. We tweak this setup to include remote team members who need to coordinate with other team members who are physically present in the escape room in order to solve puzzles that have been designed to require remote collaboration. We chose this particular technology probe as an exercise in understanding the types of interactions that will take place between participants, the most appropriate UX features for smooth game-play experience, and how games such as escape-the-room can be redesigned to enable technology-mediated puzzles. Similar alternate reality games (ARGs) have been studied in previous literature to explore research questions around *trust*, *privacy* and *ability to collaborate efficiently* [13, 14].

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We conducted our technology probe with 26 study participants. We report findings from our study, including observations about appropriate communication modalities for remote collaborative game playing, as well as unexpected interactions and points of friction between participants. We also describe the iterative design of the mobile video streaming system, which we call *Avatar*, that we built and deployed in our study. We experiment with various UX elements as part of Avatar, such as text messaging versus voice messaging, and control modalities such as a virtual joystick. Our results leave us optimistic that Avatar and other systems like it can enable new and exciting experiences.

In the long run we ultimately aim to demonstrate that real-time mobile video streaming can enable new and sustainable employment opportunities, especially for people in emerging regions like India & Brazil. Several important research questions on the path towards this goal remain unanswered, but we view this study as an important first step.

2 RELATED WORK

There is extensive literature from the HCI community on remote collaboration experiences. These include one-to-one video streams for immersive telepresence [3, 6], interactions with multiple video streams [5], attempts to guide viewer attention, asynchronous video collaborations [1, 4, 8] and sharing media during a video call. Among these studies, some focus specifically on games, social play and distributed collaboration between people.

At a high level, our study is unique in that we focus on collaborative, task-oriented experiences, where the participants may be anonymous and there may be asymmetric relationships between the participants. While others have studied use cases that have one of these characteristics (e.g., anonymity), the conjunction of these characteristics bring about unique opportunities and challenges.

2.1 Live Streaming

The last few years have seen an extensive number of live streaming applications like Meerkat, Periscope,[1] Twitch[2] and Youtube Live.[3] Initial studies by Juhlin et al. showcased how streamers faced technical issues involving camera management [9]. Over the last few years, the increasing pervasiveness of smartphones with decent cameras have resulted in an explosion in video streaming. It has become common to publicly broadcast user-generated streams of political events, protests, concerts and debates.

Hunter et al. showed that customization of video environments results in more social engagement for families while interacting over live video [7]. This study was primarily focused on children and their interactions with family members. Additional work by Tang et al, shows the usage of pre-recorded video reactions as a means to enable interactive meetings with remote participants [15].

2.2 Escape Room Experiences

Escape room experiences involve players being locked in a room or a series of room with puzzles that need to be solved in order to escape. The first observational study on collocated play in escape rooms was performed by Pan et al. [13] to identify collaboration styles, communication methods and identified conflicts during game play among peers. This was followed by a study on distributed video based experiences for escape room performed by Shakeri et al [14] which involved two geographically distributed teams playing similarly designed escape room and tried to identify the extent of collaboration and effects on team building.

2.3 Participatory Live Modalities

As live video streams have evolved, a number of projects have explored interaction and communication modalities for live stream experiences. Several papers found that providing contextual information during the video stream results in better engagement and more active participation from the users who are watching the live stream [5, 12]. Yonezawa et al. designed a system that enabled remote viewers to control the light and camera angle of the broadcast which resulted in more engagement from the viewers [18].

Hamilton et. al performed a study with remote watchers from Amazon Mechnical Turk watching a live streamed jazz event to identify the role of multiple communication modalities like the usage of hearts, event wide text chats and push to talk audio to identify which of the features enable engagement from viewers [5]. The study pointed out that the usage of hearts in multi-stream experiences are noisy and participants preferred to use the push to talk to interact with the streamers of the video. The study asked crowd workers to watch and interact with the streamers and tried to identify how they could influence the video stream where the watchers felt like they were in control.

Among closely related work, a study by Shakeri et al. uses video links to create an escape room setting where multiple groups are playing in different physical locations within rooms that are similar [14]. The study, which aimed at finding how closely players could collaborate, showcased that video links augment connections to help players share knowledge.

The unique contribution of our study compared to the work done by Shakeri et al. is the creation of a similar engaging experiences with remote viewers engaging with a group of streamers who are in the escape room. We also introduce gaming specific artifacts to the remote viewers to use during the video streams as a means of interaction with the streamers.

3 AVATAR PROTOTYPE

Our Avatar system contains two different user facing components. The first component is a live streaming Android application which is used by the streamers (hereby referred to as *avatars*) to stream live video and audio content. The second component is a web-based viewer interface for the remote viewers (hereby referred to as *controllers*). All the communication is enabled and tracked by a server running the real time live streaming infrastructure. Building all these components from scratch enabled us to collect necessary telemetry. Telemetry refers to the collection of usage metrics by the application. The metrics we track include the messages sent between the avatars and the controllers, the number of application crashes, quality of audio & video being obtained in addition to other engineering telemetry to identify the health of the application.

[1] https://www.pscp.tv/
[2] https://www.twitch.tv/
[3] https://gaming.youtube.com/

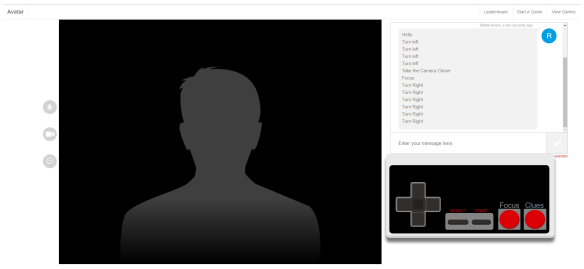

Figure 1: Web viewer client for the controller consisting of various interaction modes like push to talk audio, text based chat and a virtual joystick

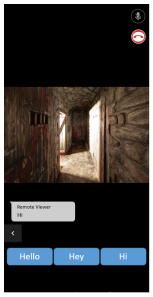

Figure 2: A view from the mobile application of Avatar showing a sample video scene and a message from the controller

3.1 Viewer Web Application Client

As shown in Figure 1 we provided the controllers with a web application to view a live stream and interact with the avatar. This enabled remote participants to easily access the video stream using their computers. The controller watching the live stream could interact with the avatar using any of the following available communication modes detailed in section 3.3.1, 3.3.2, 3.3.3 and 3.3.4.

3.2 Streaming Client Mobile Application:

As shown in Figure 2, we provided the streamers (avatars) with a mobile application capable of initiating a stream and sharing it with the controllers, as well as sending messages or speaking back to the controllers. The camera of the mobile application was restricted to the back-facing camera to provide the controllers a first person view of the game and to help protect the privacy of the avatar. We did this partly to experiment with providing the controller with a view of the avatar where the controller can help provide suggestions and instructions to the avatar. The video was streamed to a web service hosted on the cloud and a live video session was initiated over WebRTC [2]. During the study, the video from these mobile devices were streamed using 4G cellular connections.

3.3 Communication Modalities

We integrated novel communication modalities in the video streams like the use of a virtual joystick to immerse the remote viewer and provide a sense of control. Similarly we added additional modalities like *audio streams*, *text messaging* and *quick replies* to the mobile application.

3.3.1 ***Using a virtual joystick:*** As a novel interaction technique to play the escape room in a remote collaborative setting, we provided the controllers watching the stream with a virtual joystick that they could interact with using the standard arrow keys on the keyboard, the *W-A-S-D* keys generally used by gamers on a QWERTY keyboard as directional input and clicking the directional arrow buttons using the mouse. Each click on the interface sends a text chat message to the avatar who is paired to the controller based on the chosen direction, e.g., *turn left*, *move forward* etc.,

We also tried simulating a game controller with a virtual joystick containing a directional pad with 2 buttons. These buttons were used to quickly send fixed messages *Focus* and *Show Clues* to inform the avatar to sharpen the focus on the object in the stream and to show the visual clues that were collected so far within the escape room. These buttons and directional *quick messages* can be sent rapidly and as frequently as the controller would like it. For example, triggering the Up arrow results in a message *move ahead/take the camera closer* while the left arrow results in a message *turn left*.

3.3.2 ***Toggle Audio Streams:*** The Push-To-Talk (PTT) audio streams were used in multi-stream scenarios during the Rivulet study [5] to explore how remote participants engage in such experiences. Unlike in the Rivulet study we do not restrict the participants' usage of the PTT feature by time and hence design it as a toggle switch to enable or disable audio streams. In our prototype we implement the toggle-able audio stream feature to determine how and when controllers use this interaction mode with the avatars.

We expected these toggle-able audio streams to be easier for interactions between the controller and the avatar when the avatar performs an additional task related to the escape room in addition to the live stream.

3.3.3 ***Text Messaging:*** We implemented a text messaging system within the application similar to popular applications like Twitch, Periscope and Youtube Live where text chat is a prominent feature. We hypothesized, for the streamers, the text messaging mode would be used to convey important information regarding the escape room game during the session. Similarly, we hypothesized, for the controllers, the text messaging mode would be used to convey small instructions to the streamers in the escape room. We see later in the results that this hypothesis is in fact partially true but comes with its own set of challenges.

3.3.4 ***Quick Replies:*** Studies in the past [5, 12] have not experimented with two-way text messaging integration during video streams. A reason for this could be that streamers need to focus on a variety of things to provide a good quality streaming experience to their viewers and react to the messages being sent to them rather than actually type out the replies from their mobile devices. We hypothesize that in a real world collaborative game scenario, two way chat messaging systems would play a crucial role and there is a need to provide the streamer accurate and relevant *smart replies* [10] to increase their engagement with the viewers.

4 PRELIMINARY USER STUDY

For our preliminary exploratory study we recruited 26 participants (21 Male & 5 Female), with ages between 18-25 years, from within

Microsoft Bangalore. The study was approved by our IRB. We organized and grouped the participants into four different teams, and attempted to place people who did not know each other beforehand onto the same teams. We recruited participants through through word of mouth and email advertisements.

Two teams played as a group of 7 members and the others played with 6 members each. The goal of the study was for the teams to collectively find and piece the clues together and escape from the room. The total time for each team to escape from the same room was recorded by the game keepers. The team to complete the activity in the fastest time was termed as the winner and was presented with an opportunity to design their own escape room experience and challenge the other teams to completing it within a specific time limit.

4.1 Design of the Escape Room Experience

For the study, we partnered with an existing escape room company, Riddle Room[4] and re-designed one of their popular game experiences to enable remote collaborations. The escape room experience consisted of 3 physical interconnected rooms filled with clues that the players need to solve within 100 minutes. Solving the clues in the first room opens up the door to the second and subsequently to the third door.

Game Narrative. The game involves the avatars who are locked inside the series of rooms to play the role of thieves performing a heist with the help of the controllers playing the role of hackers who are assisting them remotely. The thieves streamed from the room in which they were locked to the hackers using the Avatar application described in section 3.2. The hackers viewed these streams on the web client described in section 3.1. As a part of the game narrative, the thieves need to perform a heist in a secure warehouse and steal a valuable golden statue. The hackers aiding them have gathered intelligence that could help the thieves successfully steal the statue. The thieves need to effectively collaborate with the remote hackers and put together the clues to solve the series of puzzles and help their teams escape. The hackers had a first person view of what the thief was seeing and needed to guide the group of thieves to successfully solve the puzzles and retrieve the golden statue.

4.2 Methodology

The teams played the escape room experience one at a time. The role of hackers was randomly allocated to members in each group using a random number generator. Each member in the group picked a number between 1-7 or 1-6 depending on the number of players within the group, This was followed by a computerized process where a program picked two random numbers given a range. The players who had previously picked these numbers played the role of hackers, behaving as controllers in our study while the others played the role of thieves, behaving as the avatars. The players were then briefed about the game and the narrative of the game along with a short verbal instruction about the parts of the room settings that are not a part of the game, e.g., power sockets on the walls, flooring etc.,

While the avatars entered the locked rooms to begin their game, the controllers were made to sit in another room in the same building away from the avatars to simulate a long-distance remote collaboration experience over video. We informed each player of the group about the intent of the research study, and gave them a consent form to sign before participating. After the session, we provided the participants with questionnaires (some of the questions are listed in Appendix A.1) probing them about their experience, their willingness to try something similar again. We also conducted semi-structured group interviews on the topic of what they felt could have been changed for a better experience.

During the study, one of the researchers took an observation role and observed the actions of the avatars and controllers while taking notes about the behavior and the reasons behind the usage of different communication modes provided to the participants. We compensated each of the participants 1000 INR (15 USD).

4.3 Data Collection & Analysis

Our data consisted of observational and interview notes taken using paper and pencil, as well as the results from the questionnaire which we collected digitally using a web form. We recorded the first person view from the streamer along with the audio stream from both the avatar and the controller. We iteratively read through the data, and listened and watched the recording to identify various interaction behaviors. In addition to the information collected in this manner, the data regarding the number of messages sent, the number of clicks made on different available communication modalities along with other telemetry was recorded on an analytics service.[5] After the study terminated we deleted all data.

From the questionnaire responses obtained from the avatars, we found that 7/18 of them have previously started video streams on other platforms like Facebook Live, Youtube Live while 10 of them had never done anything of this type and 1 did not wish to disclose their experience with live streams.

Two out of the four teams managed to successfully solve the puzzles and escape within the allowed time duration. The two teams together had 6 out of the 7 experienced video streamers and therefore were able to use video streaming more effectively than the other teams.

5 RESULTS & DISCUSSION

5.1 Effectiveness of Collaboration Modalities

Some of the collaboration modalities that we introduced in the application like the virtual joystick and the toggle based audio seem to have played a significant role in establishing efficient communication between the participants. Audio however seems to be the most effective and the preferred mode of communication between the participants. That said, in our observation we did notice that the other modes of communication available were used for specific purposes, as we illustrate below.

Usage of Virtual Joystick: Game based modalities like the usage of virtual joystick seemed to be a very effective means of remote collaboration for real time remote collaborative games.

[4] http://riddleroom.in/

[5] https://azure.microsoft.com/en-in/services/application-insights/

A total of 217 chat messages were sent during the 4 game sessions with an average game play time of 1 hour 34 minutes. More than 50% (29/55) of the messages sent by the first group were sent using the virtual joysticks' quick action messages. Approximately 40% (21/47) of the messages sent by the second group were sent using the virtual joystick. More than 60% (48/77) of the messages sent by the third group were sent using the virtual joystick and roughly the same percentage of messages were sent by the fourth group with the help of the virtual joystick.

The most used quick action message by the controller to the avatar was the virtual joystick *"Focus"* button. This is because the camera takes a little amount of time to focus on the image and send a clear image during the video stream. The quick movements made by the avatar momentarily blur out the video stream to the controller.

1/8 of the controllers felt that they were in control of the actions made by the avatar while the others felt that they were mostly collaborating and not in control of the avatar. However approximately 20% of the avatars reported a lack of control over their actions during the video stream.

Usage of Text based messaging & Quick Responses: All the other messages sent during the game sessions in each of the group were mostly text description and answers to the clues. For example, the controllers messaged the exact sequence of the letters to be arranged on the cryptex by the avatars to reach the box with a key hidden inside it. However, there was one message among the 217 messages where the controller cursed the avatar.

The role of text messages in remote collaborative games is to reinforce the final message that is meant to be communicated. Critical messages and complex clues were primarily shared via text messages. Since the text messages sent were very specific to the context of the game, our 'quick reply' suggestions did not make sense to the avatars and hence were barely used during the entire study.

Usage of Toggle-able Audio Streams: The most effective and widely used feature were the audio streams. Audio streams were very helpful to convey complex instructions which were too long to type by the controllers and also to convey content in other languages (Hindi and Kannada mixed with English). There were multiple instances during the study where the avatars and the controllers changed the language they used to communicate. While all the games started with the participants speaking in English, it didn't take very long to code-switch their communication.

It was quite common for the avatars to get distracted while solving the puzzles and miss some of the messages which slowly fade out from the phone interface showing the stream. Audio served as the means to regain the attention of the avatar and repeat a message sent by the controllers.

While two groups used the audio by toggling on and off when needed, the others left the audio stream switched on after toggling it from the default *off* position and left it that way throughout the game session. Surprisingly, this action did not seem to distract the avatars and in fact resulted in more streamlined voice based discussions.

5.2 Showcasing Leadership & Trust

The authors observed that the game started with the avatars and controllers not trusting each other and shared information regarding their surroundings and the clues very selectively. The slow reaction of the avatar to the messages and instructions sent by the controller further affected the trust relationship between the participants and resulted in all the groups spending maximum amount of time solving the first puzzle.

Once the first puzzle was successfully resolved with the help of the controllers, who pieced together the clues from inside the room with what they had, the avatars involuntarily started placing more trust in the controllers and this eventually resulted in the controllers having a leadership role instructing and managing the actions of the avatars.

Leadership roles did not fluctuation much throughout the game since the controllers played a crucial role in solving the puzzles. Our finding that a player who solved a puzzle was more likely to have a higher influence in subsequent puzzles is consistent with the findings by Pan et al. [13] in their research work on collocated escape room games.

5.3 Challenges Around Miscommunication

Due to the time pressure that is constantly top-of-mind in an escape room experience, the avatars primarily adopted audio streams as a means of communication especially in sections of the rooms which had poorer connectivity or when there were message drops during the stream session.

The first group faced a 3 minute window during which there was a 6% video packet loss and 51% audio packet loss. The second group faced a 2 minute window with 90% video packet loss and 0.45% audio packet loss. The third group faced a 2 minute window with 1.5% video packet loss and 23% audio packet loss. The last group faced a one minute window with 0.15% video packet loss and 8% audio packet loss. During these times, the players adopted the usage of audio streams to describe the surroundings and the details of the puzzle without the visual feed.

During the phases of poor connectivity, the controllers and the avatars in the study show higher levels of frustration. This increasing frustration coupled with the time pressure of escape rooms resulted into a louder speech input to the audio streams, change of language used for communication to a local language and in some cases resulted in social conflict.

While technical challenges pose a potential problem for communication, the game sessions exhibited other cases where the teams themselves had verbal communication gaps. We found that several of the teams in fact had a major communication delay, where remote controllers would continue attempting to solve a puzzle after the avatars had already solved it and neglected to inform the controllers that they had done so!

5.4 Understanding Safety & Privacy In Alternate Reality Games

One of our aims with the study was to find out if participants enjoy playing live stream-based alternative reality games. We also asked participants to self-declare if they would be willing to pay for such

an experience and if they're willing to do the same when paired with complete strangers.

12/26 participants in the study mentioned that they would be excited and willing to have a similar experience after being paired to complete strangers. 6 others were unsure and the rest mentioned that they would not be comfortable being paired to strangers.

20/26 participants in the study mentioned that they would be willing to broadcast the stream publicly over popular social media networks to a live audience and interact with such an audience.

Although we did not observe significant issues, sharing live video streams of this kind could bring in significant safety and ethical issues. The viewers of the streams could be disrespectful or coerce the streamer into doing something that the they would not normally do. We asked the participants what they think about silent invisible moderators watching the network and reacting to reports in a real time basis. 19/26 participants mentioned that they are comfortable with moderators in an invisible mode watching and filtering their interactions with the viewers, while 4 of them do not feel comfortable with the idea the rest are undecided.

6 CONCLUSION & FUTURE WORK

In this paper we explored an emerging class of task-oriented real-time video streaming experiences, through our mobile streaming platform which we call Avatar. Our technology probe study of remote physical-world game playing using Avatar gave us insights about appropriate communication modalities, unexpected interactions between participants, and remote game design.

Our ultimate goal is to understand whether live mobile video can enable new earning opportunities, especially in developing countries. Going forward, we hope to expand our study to a wider demographic of participants, explore new usage scenarios and UX elements, and show that ethical challenges can be satisfyingly addressed. We also hope to expand our beyond one-to-one interactions, to include one-to-many or even many-to-many live video streaming experiences.

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A APPENDIX:

A.1 Participant Questionnaire

(1) Have you ever started any live streams on other platforms previously?
(2) Which modes of interactions available did you use?
(3) What kind of help did you request from the controllers/avatars?
(4) Which mode of interaction did you use the most throughout the experience?
(5) Did you feel like you were (in control of the remote streamers/in control of your actions)?
(6) Would you do something like what you did today on your own accord?
(7) Would you feel comfortable with a moderator watching over your video session silently/invisibly to ensure safety?
(8) Would you be willing to do this if the participants are strangers?
(9) Would you do this again if your video streamed was viewed by a large online audience?

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