Escaping Together: The Design and Evaluation of a Distributed Real-Life Escape Room

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ABSTRACT
In real-life escape rooms, players try to escape a locked room by solving a series of puzzles. Currently, escape rooms involve collocated collaboration; however, there is potential for them to be distributed. We explored the design of a distributed escape room that connected two distance-separated rooms through audio/video links and shared artifacts. We evaluated it with pairs of participants to explore the design factors that affected player experiences. Results show that an audio connection created feelings of social presence. Video links augmented this connection to help players share knowledge and artifacts, however, showing less over the video feed created curiosity. Players expected a parallel setup between artifacts and puzzles in the rooms, despite the rooms being designed to vary in similarity and how closely players needed to collaborate. These results suggest directions for the design of audio connections to represent remote players, video feeds for sharing artifacts and promoting curiosity, and the use of both similar and dissimilar artifacts as a part of puzzles.

Author Keywords
Escape rooms; distributed collaboration; awareness.

ACM Classification Keywords
H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – CSCW.

INTRODUCTION
Real-life escape rooms are a new genre of game based on live-action role-playing games, treasure hunts, and online escape rooms [47,52]. Players are locked in a series of rooms and must solve puzzles in order to escape. Some include technology in the form of programmatically controlled doors or lights, computers, or sensors [47,52]. Escape rooms have been found to be a potential avenue for co-workers or friends to explore and enhance their collaboration skills, socialize with others, and build team morale [47,52]. Thus, they could be used by researchers or designers to explore a range of social and technical questions, depending on how they are constructed [52]. This is akin to the way alternate reality games (ARGs) have been used to explore social questions around trust, learning, and relationship building [1,6,9,10] and technical questions around connectivity and device usage [2,5]. For example, escape rooms could be used to study or improve relationship dynamics such as between co-workers, family or friends [52]. They could also augment educational programs for teaching workplace skills [52]. However, given their relative infancy, we know little in terms of how to effectively design escape rooms.

Real-life escape rooms typically involve collocated play where groups of players must be in the same physical location together in order to participate [52]. Yet, in reality, co-workers may be distributed around the world. This distance-separation means that they do not have many opportunities to practice their collaboration skills or participate in team building activities with remote colleagues, though it could be highly valuable [50]. Similarly, many family members or friends live apart and do not have opportunities to perform shared activities together over distance [46]. Distributed escape rooms offer one potential solution to these problems. By distributed escape room, we are referring to an escape room that connects two or more rooms over distance where players participate as a team, despite being in different locations.

The challenge, however, is that it is not clear how to best design distributed escape rooms to produce an enjoyable experience. We do not know: 1) what kinds of video and audio connectivity should be used to join the rooms; 2) how artifacts should be connected across the rooms; and, 3) if and how puzzles should be designed to support independent and joint work. To explore these points, we iteratively designed a distributed escape room called *Escaping Together* that connects two distance-separated rooms. We specifically explored three ways of connecting the rooms: video/audio connections, shared artifacts, and puzzle design. Next we conducted an exploratory study of Escaping Together with pairs who played in the distributed escape room—one partner in each of the rooms. Our goal was to understand if and why participants felt a sense of social presence with their partners; how play manifested in the rooms; how partners worked together or apart from each other; and, to what extent the design of the rooms affected these behaviors. By social presence, we refer to the feeling that one's partner is present and with you in the room [7].

Our results show that participants strongly valued the audio link to connect with their partner, while stationary and mobile video links periodically augmented this connection.

CHI PLAY '17, October 15-18, 2017, Amsterdam, Netherlands

ACM ISBN 978-1-4503-4898-0/17/10…$15.00
https://doi.org/10.1145/3116595.3116601

In contrast to prior research on workplace collaboration (e.g., [22,32]), seeing only part of the remote room over video was valuable as it created curiosity in players who wondered what the remote room was like. Players' expectations of collaboration affected their approaches to puzzles. Participants imagined the escape room environment (e.g., puzzles, artifacts) to offer a parallel setup between rooms; in contrast, the escape room did not always require joint work and artifacts were sometimes different. These results suggest that distributed escape rooms require ways of providing social presence through audio that is decoupled from video; video feeds for sharing artifacts where it can be valuable to not show all aspects of the remote rooms in order to increase curiosity; and, a mixture of puzzles and artifacts where some are similar and others are not. Similar artifacts and shared puzzles will help create feelings of social presence, while dissimilar ones will help create feelings of intrigue and curiosity.

RELATED WORK

Escape Rooms

Real life escape rooms are a new genre of game that have evolved from live-action role playing games, treasure hunts, and online escape rooms where players try to free an avatar by solving puzzles [47,52]. Many different types of escape rooms exist in various facilities around the world where themes vary [47]. Depending on the escape room, players solve logic puzzles, spatial or mechanical puzzles, and word or math puzzles [47]. A survey of proprietors of 175 escape room facilities around the world found that 13% have an open model where players solve puzzles in no particular order, 37% have a sequential model where puzzles are designed in a linear sequence, and 45% have a path-based model where there are multiple sequential paths of puzzles [47]. Escape rooms are played by corporate groups, adult friends or family, and young adult friends [47]. A study of collocated players in an escape room showed that escape rooms provide players with opportunities to practice collaboration skills such as communication, situation awareness, and conflict resolution; however, the design of escape rooms can restrict such behaviors [52]. We build on this work to explore the design of escape rooms that are distributed across locations.

Pervasive Games and Social Play

Escape rooms are similar to pervasive games—games that move beyond computers to take place on mobile or other ubiquitous devices. Alternate reality games (ARGs) are a type of pervasive game that blends game play with real life [3,4,17,36,41], often as a form of transmedia storytelling [8,9,10]. Escape rooms are similar in that they include a theme that bridges real life and an alternate reality, though the level of orchestration in them and attempts to blur real life and the game is arguably less than ARGs.

Distributed collaboration has been studied in several ARGs and pervasive games with a focus on exploring trust in strangers [1,6], creating and utilizing a sense of community [43,44,49], and privacy in public spaces [56]. Studies of these games and others have shown that distributed collaboration can help players to learn [9], create shared understanding [55], increase player motivation [43,44,48], and cause reflections on society and technology [1,4,5,6]. Collaboration can be aided through the development of leadership and roles [54,65] and digital tools that connect people across space and time [44,45,54,65]. In particular, this may involve online forums if play is asynchronous [54,65]. When play is synchronous, audio links have been found to make partners feel especially close to one another while video is difficult to use to support fine-grained collaborative tasks over distance [56]. Our study builds on this work to explore how distributed escape rooms should be connected and how collaboration should be supported.

Researchers have also studied social presence and emotions during game play more generally. Studies have found that social presence (sometimes called spatial presence) is higher when people play against other humans as compared to strangers or computer opponents [23,58]. Feelings of strong social presence have been linked to player enjoyment of games [58] and higher arousal levels have been linked to playing with a friend [38]. Higher levels of social presence can be achieved between distributed players when they are working towards collaborative goals [16,62]. We measure social presence in our escape room and explore puzzles that support joint work and independent work to understand their tradeoffs in distributed escape rooms.

Distributed Collaboration

Researchers have extensively explored the topic of distributed collaboration as it relates to teamwork amongst small groups in a work setting. This is similar to what occurs in escape rooms, with the addition of a work environment and focus. Situation awareness includes information about what is happening around oneself and how that information can be used now and in the future [18,29]. It helps collaborators establish joint goals [18,29]. When people collaborate, they maintain a sense of workspace awareness: knowledge of the actions of others in a shared workspace [25,26]. This awareness allows collaborators to coordinate their actions and move into and out of closely-knit groupwork [25,26,63,64]. Tightly coupled work is when partners need to frequently wait or interact with others, or loosely coupled work when partners work independently for long periods of time [60].

Team cognition refers to the execution of coordinated behaviors amongst team members where team members are aided by awareness, communication [11,21,30], and common ground [11], including ongoing knowledge of what team members are doing [11,18]. Group communication and team dynamics are important factors for determining how well teams perform at a given task [15,31]. Collaborators also typically develop a shared mental model—a shared mental representation of their situation, which includes knowledge of the tools available

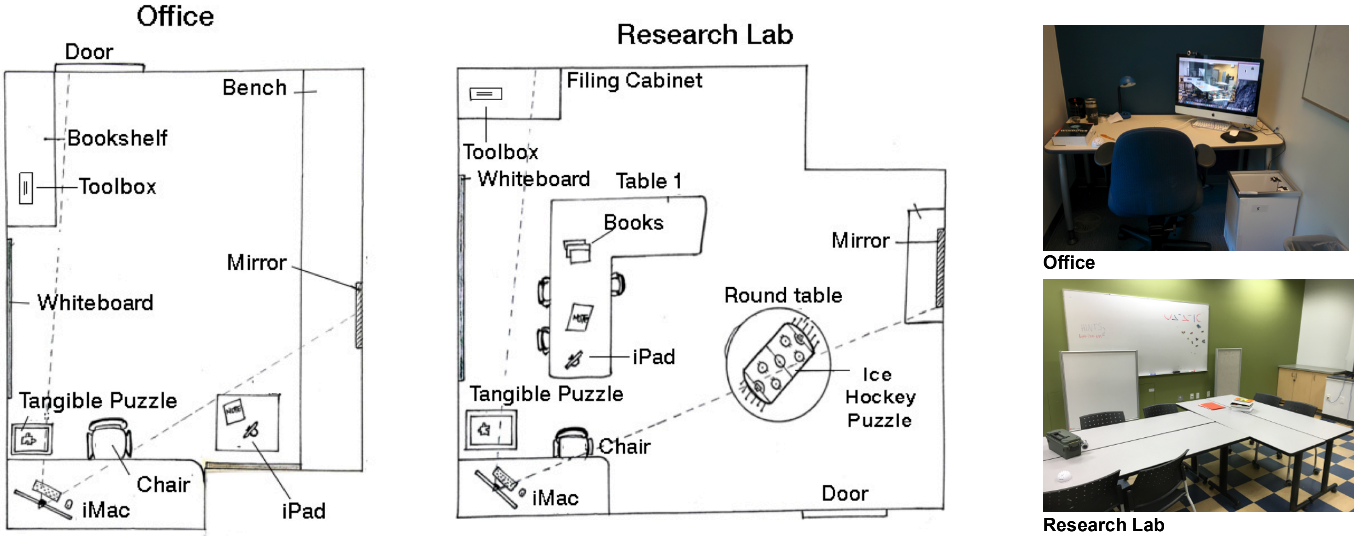

Figure 1. The distributed escape room: an office connected to a research lab.

to them, the goal of their task, and what other team members know [13,28,39,40]. Shared mental models are valuable in situations where team members all work in similar roles [11]. We explore these ideas as part of teamwork in distributed escape rooms, noting when and how players maintain awareness and shared mental models.

Distributed Collaboration Puzzles and Tasks

Studies of workplace collaboration over distance have often included elements similar to what one would see in a distributed escape room. For example, partners typically work in two different locations and share a visual workspace of some form [51]. Video or audio systems aid communication and collaboration. Within the space, partners solve a puzzle or perform a task as a pair or group, where many studies have followed a helper/worker situation (e.g., [24,34,35]). In these studies, the worker completes the task with knowledge shared by the helper.

We know that sketching interfaces [35], a view of unmediated hand gestures [34], and immediate visual feedback of collaborators' actions [24] are valuable and aid situation and workspace awareness in shared digital workspaces containing video and audio connections. Collaborators value a stationary overview camera [22,32] along with mobile cameras [57]. Stationary cameras are sometimes even preferred over head-mounted cameras [22], though head-mounted cameras can provide collaborators with proactive assistance [32]. We build on these explorations to explore video and audio communication within a distributed escape room to understand when and how video and audio connections are used between partners. Here the difference is that people are participating in a game under time constraints with specific design elements that may be different than workplace and study settings. Players are also working to solve complex puzzles that are more varied and challenging than one would find in typical controlled experiments of distributed collaboration. This makes it unclear if and how findings from distributed collaboration in the aforementioned studies apply to distributed escape room play and design where there is a larger focus on enjoyment rather than getting 'work' done.

DISTRIBUTED ESCAPE ROOM DESIGN

We designed a distributed real-life escape room called Escaping Together to let partners play in interconnected escape rooms over distance. The goal was to allow players to share the experience together, feel social presence over distance, collaborate to mutually exit their locked rooms, and have an enjoyable experience. Escaping Together contained two rooms, one for each partner. Naturally, there are many ways to design a distributed escape room, e.g., multiple rooms, multiple players in each room, etc. We chose what we felt was a base case for exploring distributed escape rooms. Future work could expand on our model.

We designed our distributed escape room to fit an academic espionage theme where one room was a professor's office and the second room was the research lab of the professor (Figure 1). As part of the theme, players were told that one of them had failed a class and so they were trying to break into the professor's office and research lab in order to try and figure out how to change the grade. Grading sheets were somewhere in one of the two rooms. Players could talk to each other and see what was occurring in the other room through an audio and video connection (e.g., Google Hangouts) running on both a tablet and a computer in the room. Players were told that as soon as they entered the rooms, the doors would be auto-locked because there was unauthorized access detected. They were given 45 minutes to escape their respective rooms before an alarm would sound. They could ask for three hints as a team during their play by 'phoning a friend' (the researchers).

We focused on exploring three ways of providing connectedness to the players—different aspects of the rooms that were used to try and create feelings of social

Table 1. Puzzle descriptions and goals.

Puzzle	Description	Goal	Type of Artifacts	Answer
1: Mirror	Each room had its own spatial puzzle where partners had to figure out a lock code using a mirror and whiteboard (Figure 2).	Have players start by exploring their own room and seeing what objects were in it.	**Similar** – both rooms had a mirror and whiteboard but they contained different numbers on the whiteboard.	**Different –** each room had a unique answer.
2: Grade Sheet	An Ottendorf cipher using a student grade sheet and books.	Have players work more closely together to achieve the same answer, while still giving them the chance to work independently.	**Similar** – both rooms had a grade sheet and books, but the contents were different.	**Same –** solving the cipher in both rooms produced the same numeric code.
3: Hockey Table	'Worker plus helper' puzzle where one partner uses an information sheet to tell the other where to position players on a table hockey game (Figure 3).	Force players into tightly-coupled work.	**Different –** one room had a table hockey game, one room had an information sheet.	**Same –** solving the puzzle produces a single numeric code used in both rooms.
4: Table Puzzle	A tangible computing jigsaw puzzle [53]. Players placed physical puzzle pieces on a digital table and moved them around. Pieces from both tables were shown on a computer screen in each room (Figure 4).	Have participants jointly come up with the final solution to their rooms to escape together.	**Similar** – each partner had different pieces of the same puzzle.	**Same –** each partner produced two numbers that, when joined, were the final numeric code to the rooms' locks.

presence and a shared experience between players across the rooms. The three elements we explored were: 1) ***Audio and Video Links:*** an audio connection and mobile and stationary video feeds; 2) ***Artifacts:*** a mixture of shared and non-shared artifacts across the rooms, including both computational and non-computationally enhanced objects; and, 3) ***Puzzles:*** a mixture of puzzles where some required tightly coupled collaboration and some could be solved independently.

1. Audio and Video Links

We included two types of video feeds between the rooms as a means to help players feel connected over distance and share their experiences (e.g., helping each other on puzzles or sharing their enjoyment of the room) along with an audio link associated with one of the video links. The first video feed was a mobile (tablet-to-tablet) connection, and the second video feed was a stationary (computer-to-computer) connection. Looking at one room's tablet showed the view from the other room's tablet. Similarly, looking at one room's computer showed the view from the other room's computer. We felt this mapping would make the video connections easily understandable.

We included the tablet as we anticipated that people would want a video feed that they could move around to show different parts of the escape room and engage in camera work as part of the experience; this builds on prior work on distributed collaboration [20,22,32,33]. Each tablet was on a stand so it could be easily positioned and set down, as opposed to having to hold it continuously. We included the computer as we anticipated that players would value seeing a static view of the entire workspace, akin to the benefits found for stationary displays in remote collaboration tasks [22,32]. Dashed lines in Figure 1 show the captured area of the stationary cameras.

We pilot-tested different video and audio configurations where we changed the starting location of the tablets and the locations of the computers to see their effects. We found that it was better to have the mobile and stationary cameras in different locations so that players would use them at different points in time. Having them in the same location meant the mobile camera rarely moved. We brainstormed the use of a head-mounted camera, but decided against it as we felt that, similar to other research, it would be less valuable for fine-grained tasks like puzzle solving and large amounts of camera movement could be awkward [33,56].

2. Artifacts

The rooms contained various artifacts that were needed to solve the escape room puzzles. We selected objects for each room that we felt fit the theme, style of the rooms, and the puzzles. For example, objects included puzzle pieces with motion tracking, books, a small travel bag, etc. Thus, objects were a mixture of computational and non-computational. We chose three types of artifacts:

a) ***Duplicate artifacts*** - the same artifact was found in both rooms (e.g., the exact same book was in each room). We included them to see how connected participants would feel when given the opportunity to work on their own (using their own object) or help out their partner (since the needed object was the same).

b) ***Similar artifacts*** - the same type of object was in both rooms but with different content or information (e.g., a different book in each room). We included them, again, to see how connected participants would feel, this time with similar but slightly different objects. This could allow them to work on their own or help their partner in a loosely coupled fashion by talking about their objects.

c) ***Different artifacts*** - completely different objects in each room (e.g., a toolbox in one room, a bag in the other room). Our goal was to create intrigue by having completely different objects be a part of the puzzle. Participants could not always assume that they needed to use the same object at the same time and they would likely want to converse about the different objects in each room.

Across all three object types, our goal was to learn how the objects would be used, shared, or referred to over the video and audio links. We placed some objects out of camera view in the rooms so that players would need to utilize the mobile camera to share them. While some objects were not computationally-enhanced, we used them to further understand how computational objects that had similar properties might be designed. Table 1 describes the puzzle-specific artifacts as part of our puzzle descriptions.

3. Puzzles

We designed a series of four puzzles for each room that players needed to solve in a *sequential order*; thus, while clues may be visible puzzles at any point in time, the puzzles had to be solved in a linear fashion in order to escape. We felt that a sequential path would be most straightforward for players to understand as a first time experience in distributed rooms. This also reflects the style of play found in escape rooms within our region of North America, though we recognize that escape rooms around the world vary and sometimes include multiple paths [47].

Figure 2. Puzzle 1 with a mirror and whiteboard.

Figure 3. Hockey table in the 'research lab' room.

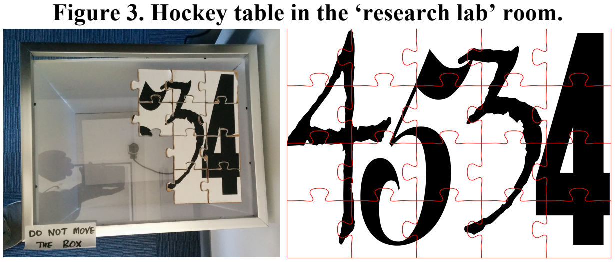

Figure 4. Puzzle 4 containing interconnected playing boxes (left) and an on-screen visual (right).

Table 1 shows details for our puzzles. We included puzzles where the goal was to enable loosely coupled collaboration or individual work (Puzzles 1 & 2), as well as puzzles that required close coordination and consultation between partners, in an effort to force collaboration to be tightly coupled (Puzzles 3 & 4). While past research has shown that collaborative work increases feelings of social presence [16,62], we wanted to understand how differences in collaborative work would affect player experience and enjoyment in the escape room. We conducted pilot tests with three pairs to assess the difficulty of our puzzles. Our goal was to make the escape room somewhat easier to complete than typical commercial escape rooms (10-20% success rate) so that, when conducting a study, nearly all the players would experience each of the puzzles and be able to compare their thoughts on each. We reduced the difficulty of our puzzles as a result of pilot testing.

EXPLORATORY STUDY

We conducted an exploratory study of Escaping Together to understand if and why participants felt a sense of social presence with their partners; how play manifested in the rooms; how partners worked together or apart from each other; and, to what extent the design of the rooms—the audio/video links, artifacts, and puzzles—affected these behaviors.

Participants

We recruited seventeen groups of players, including a total of 34 people (21 female). All teams included two people who were self-selected as partners, representing co-workers, friends, or family members. Of these participants, 27 were aged 19-25, three were 26-30, one was 31-35, and one was 41-50. 20 of 34 participants had played at least one escape room prior to the study. Most of the participants were undergraduate or graduate students.

Method

First, players individually completed a questionnaire that asked for demographic information and their experience with escape rooms. Second, we explained the rules of the escape room, which included telling players that they could use anything that was present in the rooms to solve the puzzles, including computers, but could not open any additional applications beyond what was already running. This included the video connection and software running our tangible puzzle. Next, we described the storyline to the players and then brought each player to his or her own room. Players were randomly assigned to one of the rooms. Players did not see the other person's room in-person.

Once players entered the room, they had 45 minutes to escape. After playing, participants individually completed a post-study questionnaire that had them rate the difficulty of each puzzle, the strength of their team work and individual work for each puzzle, their enjoyment while completing each puzzle, and their sense of social presence with their partner. We defined social presence for them as "the feeling that your partner was present and with you in the room" [7]. Next, we jointly interviewed participants to understand their experience. Interviews lasted 20 to 40 minutes. We asked them questions about what they enjoyed the most, what they enjoyed the least, how they used the video and audio communication system, what was valuable or challenging with it, and how and when they collaborated.

Audio Communication

We varied the audio link that was available to connect the two rooms during the study because it was unclear what the effects would be of having the microphone/speakers on a mobile vs. stationary device. We enabled the microphone/ speakers on the tablet for half of the participants, and enabled them on the computer for the other half.

Data Collection and Analysis

We observed all sessions from a remote video feed in a separate room and kept notes about participant behaviors. We recorded the interviews and fully transcribed all audio. We recorded videos of all the study sessions and reviewed them to compare participant activities to their responses in the interview questions. We coded video transcripts of the study sessions noting distinct behaviors. We used inferential and descriptive statistics to compare the responses on the post-study questionnaire. We performed open and axial coding on the transcribed interviews and our observational notes to draw out categories of results. We conducted a selective coding process where we discussed and explored our coding categories as a team of three researchers to converge on what we felt were the design aspects of the distributed escape room that were most critical to the way in which players behaved and collaborated. These emerged as situational awareness through audio and video, sharing artifacts, expectations around collaboration, and puzzle structures.

Next we present our results where we first present players' general reactions to the escape room along with a quantitative analysis of their experience. Following this, we explore the qualitative themes uncovered in our analysis. We caution that our study entailed a largely exploratory approach where we iteratively prototyped a distributed escape room with purposeful and thoughtful elements and tried it out with participants. Thus, our study was not a carefully controlled laboratory study with varying conditions that might allow us to draw out clear cause and effect relationships while reducing confounds such as learning effects. Instead, through observations, interviews, and questionnaire responses, we thematically draw out what we feel really matters when it comes to the design of distributed escape rooms based on the observed and reported actions and feelings of participants.

Table 2. Median/range ratings for each puzzle.

Puzzle	Team	Individual	Partner	Difficulty	Enjoyment
1 Mirror	4 (1 to 5)	3 (1 to 5)	4 (2 to 5)	3 (1 to 5)	4 (2 to 5)
2 Book	4 (2 to 5)	3 (1 to 5)	4 (2 to 5)	3 (1 to 5)	5 (2 to 5)
3 Hockey	5 (3 to 5)	4 (1 to 5)	4 (1 to 5)	3 (1 to 5)	5 (2 to 5)
4 Jigsaw	4 (1 to 5)	3 (1 to 5)	4 (1 to 5)	4 (1 to 5)	4 (2 to 5)

GENERAL REACTIONS AND EXPERIENCES

Seven teams were able to escape and the mean time for completion was 34±7 minutes (range 23 to 42 min) out of a total possible 45 min. This represents a 41% completion rate. Five teams ran out of time on the final puzzle, four ran out of time on the 3rd puzzle, and one team did not make it past the 2nd puzzle. Thus, 12 of 17 teams worked on all four puzzles to varying extents. Median times (and ranges) spent on puzzles for teams that completed them were (in seconds): Puzzle 1, 600s (220-1448s); Puzzle 2, 575s (180-1740s); Puzzle 3, 750s (240-1560s); and, Puzzle 4, 330s (210-580s). Thus, Puzzle 3 typically took the longest.

Based on the post-study questionnaires, Escaping Together was enjoyable for players and created a sense of social presence. The median rating of enjoyment by players individually (1-Not at all enjoyable to 5-Very enjoyable) was 5 with a range from 3 to 5. The median rating for having feelings of social presence with one's partner (1-Low to 5-High) was 4 with a range of 2 to 5.

Table 2 shows the median ratings and ranges for a series of questions about each puzzle where we have only included data for the 12 teams (n=24 participants) that attempted all puzzles. Column 2 shows scores for how well the participant felt they worked as a ***team*** on the puzzle; Column 3 shows how well the participant thought s/he worked on the puzzle as an ***individual***; Column 4 shows how well the participant thought his/her ***partner*** worked on the puzzle; Column 5 shows the perceived ***difficulty*** of the puzzle; and, Column 6 shows how much the participant ***enjoyed*** the puzzle. All were rated from 1-Low to 5-High.

We found a statistically significant difference in scores for how well they worked as a ***team*** across all four puzzles based on Friedman's test, $\chi2(2)=17.79$, $p=0.0005$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.0125$. Significant differences were found between Puzzles 1 and 3, and Puzzles 3 and 4; *thus, players felt they worked best as a team for Puzzle 3, compared to Puzzles 1 and 4.* This likely reflects the strong need for tightly coupled work in Puzzle 3. We did not find any statistically significant differences in ratings of their individual work across all four puzzles (based on Friedman's test, $\chi2(2)=0.8$, $p=0.849$) or their partner's individual work (based on Friedman's test, $\chi2(2)=1.37$, $p=0.711$). Thus, *participants generally felt that their individual performance, as well as their partner's did not vary across puzzles.*

We found statistically significant differences in scores for the difficulty of puzzles based on Friedman's test, $\chi2(2)=9.63$, $p=0.022$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.0125$. Significant differences were found between Puzzle 1 and Puzzle 2 only. We did not find significant differences for enjoyment of the puzzles (based on a Friedman's test, $\chi2(2)=6.46$, $p=0.0913$).

Next we describe a series of themes that emerged in our qualitative analysis as critical design factors for distributed escape rooms. These themes provide elaboration on when, why, and how participants felt they worked well or did not work well with their partner, and how the various ways we designed the rooms appear to have affected play.

CONTINUOUS AWARENESS THROUGH AUDIO

First, participants told us that the audio link played a pivotal role in creating a sense of presence with one's partner and maintaining situation and workspace awareness of what was happening in each room. This was a result of its location and ubiquity throughout most of the room (e.g., sound could be detected and heard from nearly anywhere). Our observations showed that audio was used far more consistently throughout all of the teams' sessions than the video link. The audio link allowed players to stay in contact with each other while moving around and working freely. They would verbally describe what they were trying, make comments about things they noticed in the room, and answer questions from their partner—most often while they were *not* looking at the video feeds. In this way, the audio link provided situation awareness of what each person was doing, but only if they chose to verbally describe it. Some teams held a conversation nearly continuously throughout their entire session. As Team 3 described, this constant communication created a strong sense of presence.

"There wasn't really a lot of moments of silence. Even when we were like doing different tasks, we kept the conversation up, so I felt like she was actually there instead of only talking to each other when we were doing. Like when we were trying to solve something, in the process we were still communicating constantly and therefore it feels like you're right there." - P6

We observed that some participants stopped talking with each other because they were trying to focus on their own tasks. Participants told us that, in these situations, they did not know what their partner was working on and many assumed it was a continuation of what they had last heard, even if this was not accurate. Only when something important arose, such as one partner figuring out how to solve part of a puzzle, did participants start to talk again.

In some cases, descriptions of one's activity over the audio link raised confusion and did not suffice since players were not always looking at a video feed to see what was being referred to. The video display was not always close by them, but audio could be captured and heard anywhere.

In cases where audio was present on the computer, we observed that players gravitated towards the desk area with the computer, and made use of the stationary camera more than the portable one. When audio was present on the tablet, players in the office would often work near the table that the tablet was placed on. In some cases, they even sat on the floor next to it. Consider Team 1:

P1 and P2 collected the artifacts in the rooms and carried them so they were all next to the desk with the stationary camera and audio source. P2 even carried the hockey table over to the desk—he had to lift it at an awkward angle and you could see the strain in his face. After moving the objects, P1 and P2 remained seated at the desks nearly their entire time in the room.

As can be seen, the audio source was a magnet for players' location in the rooms. What was most surprising about this behavior was that the audio connection picked up audio anywhere in the room, and the speakers were loud enough that it could similarly be heard from anywhere. Thus, the desire to be 'next to' the audio source was very strong despite its accessibility throughout the room. In fact, nearly all participants said that the audio made them feel like their partner was 'right there'; thus, it was the strongest representation of the remote person. For example, P20 said he felt a lack of togetherness with his partner whenever he had to move away from the stationary audio source.

SHARING OBJECTS AND CREATING INTRIGUE

Participants described the role of the video as being secondary in nature where it augmented the audio link, though this did not diminish its importance. Video was selectively used in order to communicate information that was visually shareable. This is similar to studies of workplace collaborations [22,24]. For example, we observed that teams would use one or both of the video links to show objects in the room that they thought were important (e.g., books, the hockey table, the digital puzzle pieces). This allowed them to know how similar the two rooms were and if the same artifacts were present.

"For the book one, we can show each other which book. We would be like, oh we only have one in common!" –P3

Participants told us that this process usually worked for sharing basic information, such as what objects looked like, but it was somewhat inefficient or unworkable for complex information associated with the puzzles (e.g., numbers on pages, detailed writing). In these cases, the audio link had to be used to describe the object or how to use it.

When puzzles involved loosely coupled or individual work, we found that participants most often ignored the video feeds and went for long periods of time (e.g., in the order of minutes) not looking at them. Thus, unlike studies of workplace collaboration [24], immediate visual feedback of a collaborator's activities was not as important for completing the task since participants sometimes wanted to explore their own ideas for solving a puzzle and cared less about seeing their partner's approach. The time pressures of the room meant that they could not linger and watch their partner. Like studies of workplace collaboration [22,32], the stationary camera helped give team members an overview of what was in each room, though it was difficult in practice to see the entire room given camera angles and the shape and size of the rooms. This meant that what was on or off-camera mattered. Consider Team 1:

Upon completion of Puzzle 2, P1 found the lock on a bag in her room and applied the combination in order to open it.

P2 figured the lock he was looking for was likely similar to P1's so he started looking around his room for it. P2 told P1 that he was still looking for his lock but having problems finding it. The camera was positioned in such a way that the lock was not visible, so P1 could not help in locating the lock despite trying to look at the video feed.

Conventional wisdom based on the related work would suggest that seeing an entire room as part of an overview would be extremely valuable [22,32]. However, in contrast, a constrained view of the remote room helped create curiosity. We observed this as all groups engaged in conversations at varying points in time where they asked questions about what was in both rooms. They wondered how the two rooms might be similar or different and what artifacts were in the remote room. They also spent large amounts of time sharing the view of objects over the mobile video link. For example, Puzzle 3 required the use of a toy hockey rink in the research lab and a list of player positions in the office. Because the objects were so different, many participants said they felt additional curiosity and excitement as they wanted to know details about the object in the other room. Consider Team 15:

P30 was very interested in seeing the hockey table and repeatedly asked P29 to show her different views of it with the mobile video camera. They were trying to solve Puzzle 3 by moving players into different positions. After each set of movements was complete, P30 asked P29 to see the result in spite of P29's verbal descriptions.

Some participants told us that they liked that not everything could be seen in both rooms. The placement of artifacts outside of the camera view meant the room was more mysterious. In this way, the low-fidelity video view (a small portal on a screen) of the remote location forced participants to imagine what the room looked like in detail.

"I think not being able to see each other's full room actually made the experience better." – P8

Despite the intrigue that came with different objects in each room, players said that they enjoyed the escape room more when they were able to use the same types of items together at the same time; they felt it increased feelings of playing *with* their partner. For example, this included the digital puzzle pieces for Puzzle 4 that were progressively revealed as each puzzle was solved—creating sporadic feelings of connectedness each time a new piece was found—and the book in Puzzle 2 that was the same in each room and used for the Ottendorf cipher. For example, P3 said that having the book in common made her feel less alone. This was also the case with the mirrors in Puzzle 1.

EXPECTATIONS OF COLLABORATION

One of the most engaging aspects of the room's design was the extent of participants' knowledge of how much or how little collaboration was needed to solve the puzzles and how much they needed to work together. From a theoretical perspective, they were grappling with knowing how much of a shared mental model they needed to have. Each puzzle had varying degrees of collaboration, but participants were not aware of that ahead of time. As a result, participants said that the lack of knowledge created curiosity and sometimes tension. From our observations, we saw that participants tended to assume that the rooms were providing a "parallel" setup. Then, as they worked, participants adapted their attempts to solve the puzzles by shifting between ideas relying on a shared mental model of the situation to those involving individual mental models. For example, we observed that they would start out by talking with their partner to come to an agreement on how to solve a puzzle, and, then when realizing this may not be the correct way to solve it, they would begin working on their own. By observing partners' conversations, we saw that participants began to realize the rooms were related but not necessarily parallel.

"The whole collaborative part was really interesting. It's just that I found that I thought it would be a lot more collaboration involved because first two [puzzles] was mostly just individual." – P20

This challenge came out most strongly for the first two puzzles since they were designed to support individual or loosely coupled work. In the first puzzle many teams initially thought that each mirror would hold the code for the lock in the *other* room rather than their own. Thus, they assumed they needed to use the video feed to solve the puzzle. Teams tried to solve the puzzle in this way using the tablet's camera to share the whiteboard writing. This was often a long process that did not yield the correct puzzle solution. Similarly in the second puzzle, participants expected the puzzle to require a large amount of verbal exchanges. The most commonly observed idea was that the numbers would have to be combined across rooms in some way and that partners would have to tell the remote person their numbers over the audio link. Consider Team 11:

For Puzzle 1, P21 and P22 attempted to show each other their whiteboard markings over the mobile video link. P22 copied the numbers from the video link on to his whiteboard in order to come up with the solution. This did not work, however, since the markings and solutions were meant to be separate for each room. For Puzzle 2, P21 and P22 talked over the audio link to share their cipher numbers with one another. Here they tried, again, to link the numbers together. This time they were trying to use a series of math operations between the sets of numbers in each room.

The idea that tightly coupled collaboration was always required was so strong that some teams even tried 'extra hard' to work together, even though they did not necessarily have to. For example, in Puzzle 2, some players had a more difficult time finding the book for the Ottendorf cipher so instead of continuing to look for it, they read the numbers from their own puzzle sheet to their partner over the audio link, who would then use *their* copy of the book to figure out the answer to the puzzles in both rooms. This was possible, but not necessary, as the book for the cipher was the same in both rooms.

THE REALITY OF THE PUZZLE STRUCTURES

Once players altered their perception that all puzzles would involve closely knit teamwork, the degree to which the puzzles were *actually* interwoven across the two locations affected play considerably. That is, the reality of collaboration, rather than the perception of it, affected play. Our analysis revealed that the puzzles designed to support loosely coupled work allowed participants to work individually, if they wanted to, and build on their individual confidence and abilities. Yet they could still ask their teammate for help, since the puzzles were similar. The puzzles designed to support tightly coupled work forced the teammates to collaborate closely and feel as though they were really 'in' the escape room with their partner. The mixed level of collaboration across the four puzzles was a factor that many players said increased their enjoyment of the distributed escape room.

"It's kind of a change to both have puzzles that only you can figure out. There's a sense of achievement, personal achievement, in that. Then also to collaborate when you do need help. Kind of like having a hint system but with your team." – P10

The downside of having varying degrees of collaboration meant that players were not always synchronized in terms of which puzzles they were working on. For Puzzle 1, partners for 6 of the 17 teams solved the puzzle at approximately the same time because they worked together. Of the remaining 11 teams, four partners helped and waited for their partner to solve the puzzle before moving ahead, and seven teams either did not help at all, or tried to help while concurrently moving ahead. In Puzzle 2, 7 of 17 teams finished at approximately the same time, and only one teammate waited to help their partner. The time pressure of the rooms caused some of the players to continue on their own. Because the remote partner was relatively small in the video feed and they could easily be off camera, our observations showed it was easy for participants to forget about them at times. The lack of synchronization that resulted became highly problematic and meant that even though one partner could help the other solve his or her puzzle (given the similarity), they did not. The last two puzzles forced tightly coupled collaboration; however, a lack of synchronization on Puzzle 2 sometimes meant that partners had to wait for each other in order to start Puzzle 3. This created confusion if one person tried to start Puzzle 3 on their own.

P33 and P34 progressed independently until P33 reached Puzzle 3 and could not move ahead. At this point, they began to collaborate more as P34 tried to help P33 catch up and move through Puzzles 1 and 2. Both found a bag in their rooms and assumed they should be used in the same way; however, in reality, this was not the case as P34's bag was used later on since she was ahead in the puzzles. P33 and P34 became noticeably frustrated and they could not continue without a hint.

It was evident that partners became confused in terms of situation awareness. They could see what their partner was doing over the video link and hear them, but they did not always understand this information, again, because it lacked detail to see exactly what the person was doing. Participants said that this coupled with trying to understand their own puzzle created feelings of panic and tension. For some players, this created a lack of enjoyment at times. For example, P19 said that he felt nervous when his partner moved ahead, as he did not know what she was doing. While he could see her over the video link, she worked in a very focused manner on her own puzzle and did not explain it to him. On the other hand, participants said they felt less nervous when they could work closely with their partner.

DISCUSSION AND CONCLUSIONS

The goal of our study was to understand what factors are important for the design of distributed real-life escape rooms to create an enjoyable collaborative experience for players where they feel like they are participating in a shared experience with remote partners. We now describe the design factors that we feel are most important where the factors raise important questions for researchers and designers who may create distributed escape rooms or other technology-supported distributed social activities for team building exercises, entertainment, or as research tools to explore social or technical research questions.

Audio for Presence and Awareness

First, audio was a very critical component of the distributed escape room. This is how participants 'felt' the embodiment of their remote partner—that person's representation in the remote space—and gathered a large amount of situation awareness; it was not because of the video feed. This is similar to the use of video streaming for distributed location-based games [56], yet unlike a lot of research on video-mediated workspaces (e.g., [22,24,25,35]). The reality is that players in the escape room were so focused on solving puzzles and their own efforts to do so that they did not often look at a video feed as it relates to focusing on the remote partner while performing crucial steps for the puzzles. The video feed was typically only helpful when tightly coupled work was needed, e.g., solving interconnected puzzles or when seeking help, sharing ideas, or sharing objects. Audio was lightweight because it did not involve camera work or staying in a single position, though many people did like to try to stay close to the audio source.

This raises design opportunities for thinking about ways of providing social presence in distributed escape rooms through the use of audio that is decoupled from video. For example, one may consider supporting social presence through various forms of spatialized audio or varying acoustics in order to connect people over distance. Similar approaches have been explored for other contexts (e.g., [42,48]). These findings also mean that if distributed escape rooms are going to be used as part of education or training setups more broadly that participants in them will likely focus heavily on the use of audio at the expense of video. This may or may not be desired, depending on the situation.

Video to Create Curiosity

Second, even though audio was clearly the most important connector between the rooms, video still played an important role. The stationary and mobile video connections were a means for communicating about specific items, especially when there was a low level of similarity between artifacts for a puzzle. The stationary camera also provided an overview of the space, similar to studies of distributed workplace collaboration [22,32]. Yet what was different, given the focus on entertainment in escape rooms, was the value that came from *not* being able to see everything in the remote room over the video links. This helped create curiosity and wonder in terms of what was in the remote room. Our results also suggested little need for additional cameras, such as ones that might provide first person views of the remote location, since players spent little time looking at their video feeds. The only instance where such cameras might be valuable is if puzzles require a large degree of tightly coupled work.

While studies of workplace collaborations suggest camera views that are of a high fidelity and offer both an overview and close-up view [22,32], our results point to different design needs for video feeds in distributed escape rooms. Here we see that a balance is required. On one hand, video links are clearly needed to gather situation awareness and share artifacts. On the other hand, video links that provide limited viewpoints can create curiosity, which is likely valuable in escape rooms as it could lead to excitement and enjoyment for some players who want additional mystery. We suggest distributed escape rooms offer players a mixture of both worlds by providing video feeds, but leaving the display of some information somewhat ambiguous. We achieved this, somewhat unexpectedly, with overviews that did not show the entire room. Other design solutions are certainly possible, such as partially obscuring portions of the video feed, providing low-resolution video, or by progressively revealing video feeds as players progress through the escape room. This area is certainly ripe for further research and design exploration. Designers should also consider that while some players might value the additional mystery and intrigue that comes from ambiguous video views, other players could find them frustrating and this might impede enjoyment.

Expectations and Perceptions

Third, it was very clear that participants' expectations of how much they should collaborate with each other strongly affected play. Thus, the structure of the puzzles and the room's artifacts (both computational and not) played a strong role in the experience. Players came to the escape room imagining a parallel setup where artifacts and puzzles would be the same. Yet, we had designed the escape rooms to vary in this respect and allow players to practice a variety of collaborative skills, including both loosely and tightly coupled work and the gathering of awareness information to aid this understanding and groupwork. This created tensions around synchronization and made it hard to maintain situation and workspace awareness because the actions of others became confusing. Some players liked the intrigue that this experience created, but others preferred the situations where the puzzles were tightly coupled and the artifacts were similar across rooms. Like past research [16,62], participants felt strong feelings of social presence and participants said this came from working on puzzles together and collaborating.

Overall we suggest that distributed escape rooms should focus on puzzles designed for collaborative efforts with a mixture of artifact types. Some artifacts should be designed to be connected and shared across rooms, in order to promote such collaboration. Other artifacts should be dissimilar as a means to create intrigue. With dissimilar artifacts comes a need for technology that can allow players to share details about the objects between rooms. There is also a need for players to understand whether or not the experience across rooms, including the design of puzzles, is parallel or not and if teamwork is needed. Our video tools were somewhat primitive for supporting such sharing and knowledge acquisition. Future technologies might allow the remote user to explore the remote space and objects on his or her own using, for example, multiple cameras, pan and zoom capabilities, etc. One might also imagine more futuristic setups such as the use of mixed reality displays or 360-degree video connections that might allow players to virtually 'visit' the other room and allow them to temporarily see objects for sharing and conversation. There are also likely many other ways of realizing these design goals. The emphasis we make here is on designs that allow exploration while not necessarily requiring the help of the local player since he or she may be working on their own efforts and may not want to engage in camera work that might come with supporting remote viewing setups.

Limitations and Future Work

Our study is limited in that we only explored one type of distributed escape room with only pairs of individuals. We also only tested two types of video feeds. Our escape room was simpler and easier to escape than many commercial escape rooms (given the completion rate). This was appropriate for a study exploring the topic, yet it is not clear if such completion rates would affect player perceptions of enjoyment, difficulty, social presence, and teamwork. Future work should continue explorations of distributed escape rooms with additional numbers of players and rooms, the inclusion of different audio and video setups, and the use of additional interconnected computational artifacts. Our results suggest directions for each of these design investigations.

ACKNOWLEDGMENTS

We thank NSERC for funding this research.

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