Collaboration, Awareness, and Communication in Real-Life Escape Rooms

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ABSTRACT
Real-life escape rooms involve players being locked in a room where they have to solve puzzles in order to escape. We conducted an observational and interview study with 38 escape room players to understand how groups of people collaborate in escape rooms, what opportunities escape rooms present as learning environments for improving collaboration, and how the design of escape rooms affects collaboration. Our results show that escape rooms provide people with opportunities to practice a range of collaboration skills, yet not all generalize to real world collaborative situations outside of the escape room. Thus, people may have an opportunity to practice communicating and maintaining an awareness of others, but the design of the room restricts such behaviors. These findings raise design opportunities for future escape rooms related to team dynamics and roles, the acquisition of situational and workspace awareness, and the teaching of conflict resolution techniques.

Author Keywords
Escape rooms; collocated collaboration; communication; team building; relationship building

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

INTRODUCTION
In real-life escape rooms, players are locked in a room or series of rooms and tasked with solving puzzles in order to escape under time constraint. Escape rooms emerged in Japan in 2007 and, by 2012, began to proliferate in numbers and migrate across Asia, into Europe, and eventually North America and Australia [32]. Since then, escape rooms have increased in styles and numbers around the world with influences from live-action role playing games, treasure hunts, as well as a similar video game genre where players help an avatar escape from an on-screen room [32]. The clues and hints to escape room puzzles are often hidden in boxes with some form of combination or key lock that need to be unlocked in a predetermined order. Once players solve the puzzles in the room, they learn how to unlock the final door of the escape room. Rooms are decorated with objects and décor to match a theme and narrative where the objects themselves are typically used to help solve the puzzles. For example, the position of darts on a dartboard may give hints to a combination lock’s code. Basic levels of technology are a part of many real-life escape rooms. This includes the use of sensors, lights, displays, etc. that are programmatically controlled or incorporated into puzzles. As escape rooms evolve, it is likely that they will include an increasing amount of technology. For example, this may contain the use of increased context sensing and tangible computational puzzles (e.g., the use of objects with sensors/actuators in them as part of puzzles). Escape rooms may even become distributed where players connect over distance from different rooms and help each other over video or audio communication systems.

Escape rooms are interesting in that they have the potential to offer researchers and designers with a means to explore a range of social and technical research questions. This is similar to how alternate reality games (ARGs) have been used over the past decade. For example, ARGs have allowed HCI researchers to explore social issues such as trust in strangers [7], new forms of education [9,10], and the limitations of connectivity [6]. Escape rooms could be valuable for studying topics such as the use of networked devices (e.g., as part of the ‘Internet of Things’) and context-aware computing, since escape rooms are now starting to include computationally-enabled objects. Escape rooms also naturally lend themselves to exploring research questions around communication and collaboration skills since players are often corporate groups or teams of family/friends [32] and many escape rooms are marketed for team morale events, birthday parties, and get-togethers. One could imagine the potential for escape rooms to be designed as a form of educational environment to teach work teams a particular workplace skill, or to teach school children a lesson in math or problem solving. Escape rooms could be designed for families as a means to foster intergenerational collaboration and communication between parents and children, or grandparents and grandchildren.
Despite the potential, designing escape rooms for the aforementioned situations can be difficult as it is not clear what design factors are important to think about and address as a part of escape room design or study and how technology could and should be used within escape rooms. The challenge is that, beyond anecdotal evidence, we do not have a strong sense of what happens in escape rooms in terms of how play and collaboration manifest themselves. This is because escape rooms offer a different context than situations involving more typical acts of collocated collaboration in society (e.g., meeting room activities, collocated board game playing, collocated console gaming). Escape room players are subject to various design constraints, including time pressures, a small spatial area, a narrative theme, and environmental effects to create a desired type of atmosphere. Understanding how these design attributes affect play amongst players is important if escape rooms are to be designed as learning tools, research instruments, or training programs for specific demographics in the future. Thus, our research goal was to understand how groups of people play and collaborate in escape rooms, what opportunities escape rooms present as learning environments, and how the design of the room affects play and collaboration. This knowledge could then be used by designers, researchers, or educators who want to create escape rooms or leverage ideas from them to teach particular skills, simulate certain types of experiences, or evaluate particular group behaviors.

The contribution of our research is twofold. First, we present what we believe is the first observational study of play within escape rooms. Here we describe how collaboration and play occurred in the escape rooms we studied. Second, we use this knowledge to describe the opportunities that escape rooms present more broadly as learning environments that are enhanced with technology. Our results show that escape rooms could be used to test and explore social and technical questions around leadership, group hierarchy, proxemics, and distributed cognition where technology in the form of networked devices and as part of context-aware environments could be used to teach or study behaviors on these topics. Compared to ARGs, escape rooms provide a different type of learning and testing environment. Escape rooms are closed-ended, require less orchestration during play, and have a different type of immersion than ARGs. In comparison to lab studies, escape rooms provide a fun environment with potentially more realism. This presents a valuable alternative design space for exploring some situations. Based on these findings, we sensitize the reader to a series of design challenges that should be thought about as a part of escape room design, particularly in the case where escape rooms might be used to target specific types of collaborative activities or groups (e.g., training programs, education). These lessons focus around team member roles, awareness, and social conflict where technology can enhance the experience.

BACKGROUND

Real-Life Escape Rooms

There is very little empirical research on real-life escape rooms. The only documented study that we know of is Nicholson’s [32] white paper that reports on a survey completed by proprietors of 175 escape room facilities around the world. The survey documents the different styles of escape rooms and shows that they contain a range of puzzle types including logic, spatial and mechanical (e.g., moving an object a certain way), and word or math puzzles [32]. Puzzles are presented in an open (13%), sequential (37%) or path-based model (45%) [32]. Open models allow players to solve a number of puzzles all at once where they provide clues to a final puzzle. Sequential models have a linear sequence of puzzles. Path-based models have multiple sequential paths where solutions from each path allow players to solve a final puzzle. Player groups consist of groups of adults over 21 years (37%), corporate groups (19%), groups of young adults (19%), intergenerational groups (parents and children) (14%), and date night couples (11%). Nicholson suggests that escape rooms be designed for varying player experiences (e.g., hardcore vs. casual players), replayability (so players can play multiple times with different puzzles), and cultural diversity (designing to match the local culture where the game is being played).

While valuable as a means to understand who plays in escape rooms and how the rooms are generally structured, the existing research does not explore what happens within escape rooms in terms of play and collaboration. This makes it unclear as to what types of group behaviors escape rooms support and what design factors affect them.

Pervasive and Alternate Reality Games

Similar to escape rooms are Alternate Reality Games (ARGs)—a type of pervasive game that takes place in the real world and includes an overarching narrative that seeks to blend together the game and real life [7,15,26,29]. ARGs are seen as a form of transmedia storytelling as narratives are presented across a series of mediums [8,9,10]. This can make it difficult to design replayable ARGs so researchers have suggested designing ARGs with multiple story paths and a narrative that is not time dependent [21]. While escape rooms contain themes, narrative, storytelling, and sometimes actors [32], their level of orchestration is much less when compared to ARGs. ARGs have been found to be open-ended where they provide players with flexibility in terms of how they understand the ARG, as well as closed-ended where play is carefully planned and orchestrated with a definitive end game for players [8]. Escape rooms are only closed-ended, given the single overarching goal of escaping the room. They also do not tend to blur together real life and the game environment in the same way that ARGs do [7]. To complete an ARG, players move along trajectories or paths, which intersect at varying points with the canonical path created by the game’s designers [4,5]. As stated, escape rooms can vary in their model of paths through the game.
Collaboration has been studied in several pervasive games and ARGs. For example, studies have explored trust in strangers [7], the limits of connectivity and GPS [6], heightened awareness of one’s environment [2], improved navigation [3], community creation of game content [30,31], and spatial and temporal separation [41]. Collaboration has been shown to occur amongst pervasive game players who know each other either as family, friends, or schoolmates [9,30] and even strangers who have similar shared interests (e.g., game genres) [3,34,41]. Such collaboration benefits player motivation [33], learning [9], and can create a shared sense of history and location [35]. Yet collaboration is not always easy and spatial and temporal separation can deter collaborative efforts [41].

Collaboration can be aided when players develop various levels of leadership in order to coordinate their efforts [34,41]. For example, studies of the ARG I Love Bees showed a military strategy for establishing hierarchy and leadership [34]. The use of digital tools and player-adopted tools are also seen as being valuable to overcome spatial and temporal issues with game locations that are spread across a country [41]. Researchers have suggested supporting collaboration by connecting players together across larger communities and groups, e.g., connecting novices with experienced players [21]. One way this can be done is through asynchronous groupware that allows players to help each other through simple acts of recordkeeping [30,31]. In escape rooms, collaboration likely occurs amongst players to solve the puzzles and escape the room, yet we do not know how the concepts from the related literature may or may not apply to escape rooms, given their specific context and environment. Escape rooms constrain players in terms of time and space; in contrast, the pervasive games found in the literature typically span much larger environments and timeframes.

### Awareness and Coupling

There is a body of research that explores how small groups of co-workers collaborate together in shared physical spaces such as meeting rooms. Given that 19% of escape room players are co-workers [32], we detail such processes. Situation awareness is defined as “being aware of what is happening around you and understanding what that information means to you now and in the future” [16]. It helps people decide what information is important in order to accomplish a particular goal [16,23]. Even when seeing the same information, people’s awareness can be different [36]. When groups collaborate, they naturally maintain workspace awareness: knowledge of each other’s interactions and activities in the workspace [19,20]. Workspace awareness allows people to coordinate actions with collaborators, anticipate the actions of others, discuss tasks, find opportunities to help one another, and move into and out of closely-knit groupwork [19,20,23]. This latter aspect is known as coupling and focuses on the degree to which collaborators are working together [39,40]. When partners need to wait for others fairly frequently for them to finish their own work it is tightly coupled [37]. If partners can go for long time periods on their own without interactions with group members, it is loosely coupled [37].

Collaborators are often mobile in common spaces when working together (e.g., around a shared table) [40]. Sometimes they use divide-and-conquer strategies to complete tasks, sometimes they will perform parallel work, and other times they will be performing closely coupled work [40]. Social protocols are often used to negotiate and move into and out of different coupling styles [40] and this behavior is fluid and frequent [39]. Workspace awareness comes from people explicitly talking about what they are doing, overhearing the conversations of others, listening to people’s verbalizations that go along with their actions, and paying attention to body language and the use of artifacts [20]. As group members work in different areas in a collocated setting, they also tend to partition spaces as theirs or the groups to exhibit aspects of territoriality [38]. They even maintain a certain social distance to give each other appropriate space to work [23]. In our study, we show how and why escape room players move between coupling styles and how the use of space/territoriality, workspace awareness, and situation awareness is different in an escape room than typical meeting settings.

### Team Cognition and Shared Mental Models

Team cognition is “the seamless execution of coordinated behaviors” amongst team members [18,24] while distributed cognition refers to cognitive processes distributed across members of a social group [24]. Team cognition and coordination is aided by awareness, communication [1,11,18], and common ground [11] and is created by pre-existing knowledge of team members and conditions and ongoing interactions between team members [1,11,12,22]. Team cognition will more easily develop if team members know each other and train together [17,22]. Team members who are familiar with one another have been found to perform better at tasks initially in a group setting; yet, over time, such differences fade as team members get used to one another [22]. Group communication and team dynamics are critical and affect how well a team does at a task [14,25].

Teamwork can also depend on the ability for a team to develop a shared mental model of their situation [13,28]. This is particularly the case when team members take on similar roles such that shared knowledge amongst them is important [11]. A mental model is an understanding of how something works that lets people understand and interact with their environment [13,16,27]. A team or shared mental model is a mental representation shared by team members [13,22,27,28]. Team mental models consist of knowledge of equipment and tools, goals of the team, awareness of what teams members know, and knowledge of effective team processes [13]. Teams with a shared mental model are likely to work better together because they will be in
synchronization more [27]. In our study, we show how mental models are shared between players in escape rooms and how player relationships affect teamwork.

**STUDY METHODOLOGY**

The goal of our exploratory study was to understand how groups of people play and collaborate in escape rooms, what opportunities escape rooms present as learning environments for improving collaboration and team dynamics, and how the design of escape rooms affects collaboration. As part of these goals, we wanted to understand what works well in the design of escape room and what challenges exist. These challenges might suggest missed opportunities for supporting collaboration, which future designs and technology may be able to address. Our study was approved by our research ethics board.

**Participants**

We recruited teams of players through word of mouth, email advertisements to our university department, and social media posts. Thirteen groups of players, including a total of 38 people (19 female), agreed to participate. Groups ranged in size from two to five players and were self-selected, typically representing co-workers, friends, couples, or family, though four teams had people who were strangers with at least one person on the team (recruited by a mutual friend). Most players were in their early to mid twenties with the exception of four players who were in their 50s. 15 of 38 participants had played in at least one escape room prior to the study, 17 participants had never participated in an escape room, and 6 participants had done more than five. A large amount of participants were undergraduate or graduate students, though many held jobs outside of school. Occupations varied, e.g., programmers, administrative assistants, health care providers, analysts.

**Location and Themes**

We partnered with Time Escape, an escape room facility located in Greater Vancouver, Canada. We also played in six different escape room facilities in order to gain a firsthand understanding of how teams participate in an escape room and how rooms and puzzles might vary across facilities. We found a large consistency across facilities in our region in terms of the general style of puzzles and escape room themes yet they varied in quality. Naturally, escape rooms vary more broadly across the globe in terms of style, theme, and content [32].

Participants could choose to participate in one of four different rooms at Time Escape where all had a science fiction or mystery theme. This is because it is the most common type (and nearly only type) of escape room in our region. Themes included spaceships and aliens, a historical castle, a haunted cabin, and time travel. All rooms had a 45 to 50-minute time limit and teams were allowed two hints. Rooms varied in size but all were under 150 square feet; thus, they were relatively small rooms and spatially could only reasonably accommodate six people at a maximum. This was the limit imposed by the escape room facility. Three of the escape rooms contained a series of 2-4 interconnecting rooms with a locked door between each. All rooms had a sequential structure of puzzles such that they needed to be completed in a preset order; however, one could find clues for future puzzles ahead of time.

**Method**

Players first selected which type of themed room they wanted to participate in from the set of four. Then, during each game session, one researcher accompanied the team into the escape room to observe game play and collect handwritten notes. This was guided by a semi-structured observational checklist that included concepts and questions based on the related work, e.g., coupling styles, situation awareness, workspace awareness, communication styles, player interactions, spatial orientation, player positioning, puzzle-solving strategies. The observer took notes on these concepts in addition to other behaviors that he saw. The observer did not assist the players in any way. Two different researchers took on the observation role (one observed ten teams, one observed three teams); this allowed them to discuss what they saw with different teams as part of our analysis. Only two teams escaped their room and the remaining eleven teams did not—this reflects the escape room’s reported acceptance rate of less than 20%.

After the session, participants completed a paper-based questionnaire that asked them questions about their past experiences in escape rooms, their motivations for playing escape rooms, what they felt was easiest/hardest about the room, their strategies for solving the puzzles and working as a team or individually, and how the escape room affected their relationship with their teammates. We used our knowledge of the related literature on collaboration to guide our questions. Most questions were open-ended in order to be exploratory and understand a range of player experiences in detail. After completing the questionnaire, participants were interviewed as a group about their experiences with questions that were similar in nature to the questionnaire. For example, we asked, “How did you let others know what you were doing?”, “How did you know what your teammates were doing?”, “What would you change about your strategy for next time, if anything?”, “What would you change about the escape room, if anything?” This lasted 15 to 40 minutes depending on the team. Teams of participants were compensated with a $40 payment and a 10% discount on their admission price of ~$20 per person.

**Data Collection and Analysis**

Data was in the form of observational notes, handwritten questionnaire responses, and interview notes. The escape room company did not permit us to collect any photo or video data from the observations because of privacy concerns; they did not want to risk any visual clues or secrets of the rooms becoming public.

We explored the various data using thematic analysis and affinity diagramming. We iteratively read through our data and noted various interaction and collaboration behaviors.
Two researchers then categorized responses from participants and our observations into groups with similar meaning and ideas. We reviewed these concepts and discussed differences in opinions, which led to the refinements of some categories. We found large clusters of data around concepts of awareness, communication modes, and group dynamics. Within these clusters, we found subcategories including leadership, verbal communication, non-verbal communication, awareness through verbal exchanges, awareness through peripheral viewing, the constraints of physical artifacts on collaboration, loose and tight coupling for puzzle solving, and social conflicts. We further discussed these categories to decide which collaborative behaviors we felt were most critical to the players’ experience. We selected these categories as the focal areas for our results sections.

Anonymous quotes from participant interviews and questionnaires are shown in our results along with vignettes of player activities from our observations. Vignettes are based on our observations while participants’ thoughts and feelings articulated in them come from our questionnaire and interview data. To preserve the confidentiality of the escape room’s puzzles, we have changed the types of objects described in the vignettes to similar yet different objects, e.g., a photograph might be changed to a book cover. This does not affect the behaviors we describe.

**LEADERSHIP ROLES AND EXPERTISE AT PUZZLES**

Leadership roles sometimes arise in collaborative activities as a means to help guide the activities of others [34,41]. We observed that when teams first entered the escape room, one or more players in the team took on a leadership role within the group. Players did not explicitly call them the ‘leader’ but implicitly they acted in this capacity. We observed men take on this role in 7 of 13 teams, while in the remaining teams a woman took on a leadership role initially. Consider Team 1 as they first entered the room:

*Team 1 consisted of five players who were all friends—one woman and four men. When they first entered the room, there was little discussion of strategy or what to do. Instead, P3 (male) started directing players to perform certain actions. He told P2 to start looking for clues and P4 to point her flashlight at the wall. P4 found a card on the back of the door that she thought was the first puzzle to work on. P3 noticed P4’s finding and started describing how he would solve the puzzle to his teammates.*

P3’s leadership role reflected his past experience of competing in several escape rooms. He knew what types of items to look for and had strategies in mind for solving puzzles. Thus, he had a clear mental model of what needed to be done. He was quick to tell his teammates this and share his experience. In this way, he began to create a shared mental model amongst himself and his teammates.

Other teams followed a similar process to Team 1. Unlike teamwork that may occur outside of an escape room where leadership selection and the assignment of tasks may involve some time and discussion, leadership roles coalesced very quickly amongst the teams we observed and without any discussion. This is likely because of the time pressures of the room. There was a general understanding amongst players as to who had the most experience with escape rooms and puzzles, since many of them had talked about it before their participation, and players were quick to accept and trust this expertise. Players with the most experience in escape rooms nearly always took on a leadership role. If there were several experienced players in the group, they would share the leadership role and guide those who were less experienced than them. When all team members were inexperienced at escape rooms, social roles and personalities outside of the escape room played a role in determining a leader. For example, in Team 7, all three participants were first time players but one of them was more vocal in the group. The participants were from the same church group and P21 was one of the public speakers for the youth service. P21 assumed a leadership role in the group by suggesting what other players should do.

We observed that teams that were made up of just couples (Teams 11-13) saw fluctuation in terms of leadership where leadership roles changed frequently. However, when teams had three or more players, leadership roles tended to persist throughout the duration of the team’s escape room time. The exception was when certain players built up experience and credibility through their play activities. This sometimes caused dynamics to change. For example, if a particular player solved a puzzle, she was likely to have more influence with her team members on subsequent puzzles.

*P31 acted as a leader of Team 10 early on in their session when he discovered a series of hidden symbols on portraits hanging on the escape room’s wall. He told his teammates about them and suggested how they should use them. As team members tried to solve the puzzle using P31’s suggestions it became apparent that P32 had her own ideas about how to solve the puzzle. She figured out the meaning behind the portraits and then solved the puzzle. When the team found the next puzzle to solve, P32 led the team by making suggestions of what to try.*

**COLLABORATIVE COUPLING STYLES**

While one might expect that the linear nature of the escape rooms we studied would require collaboration that was always tightly-coupled—team members working together and requiring each other—collaboration instead moved fluidly between loosely and tightly coupled teamwork.

**Transitions between Coupling Styles**

Team members often began by working in parallel to figure out what they first needed to do in the room. This collaboration was loosely coupled and represented a divide-and-conquer strategy. For example, when teams first entered the escape room, they often spent the first couple of minutes searching around the room for combination locks that they would need to open as well as any artifacts that
they might be able to use to solve puzzles. This included, for example, pictures hanging on the wall and toys or other props. Once one or more team members realized what needed to be done, they would converge and naturally transition to a more tightly coupled style of collaboration where they would discuss what to do and sometimes work in small groups on specific tasks. Such tasks often relied on the work of others. Consider Team 12:

Team 12 entered the escape room and the players began searching independently for objects that they could use. P36 (female) found a UV flashlight and started to shine it around the room. P35 noticed P36 shining the flashlight and went over to help her. Together they started to use the flashlight to look around the room and what they could use to unlock the first lock. P36 handed the UV light to P35 so she could enter numbers into a combination lock. As she did this, P35 started telling her possible numbers to try. P35 waited for P36 to test out each number that he told her.

As can be seen, P35 and P36 started out in a form of loosely coupled collaboration and this transitioned into tightly coupled work where each relied on the other person. When teams worked closely together, it was evident from their activities and discussion that they shared a similar idea or mental model of what needed to be done to complete the puzzle. Yet if they became stuck or unsure of what to do next, they typically would transition back to a loosely coupled style of collaboration to pursue their own ideas.

“People tend to work together when they both understand the puzzle. Otherwise if someone doesn’t understand a puzzle they will either step back or try to work on something else.” – P19, Male, Interview

Teams also commonly converged together when they became stuck over a period of minutes and were unable to progress. In these cases, none of the members of the team had the correct mental model needed to solve the puzzle. At this point, team members discussed if they should ask employees for a hint. Taking a hint was considered to be a major decision since they were a limited resource. As such, teams most often came together and tried to reach a consensus. For example, Team 10 sat down on the floor together for more than ten minutes when they became stuck on a puzzle. They exchanged thoughts about potential strategies and talked through the need to get a hint.

Sometimes puzzles contained elements that required players to work together by performing synchronous actions. The need to collaborate in these situations was not always obvious to players at first, but, once they recognized it, players typically converged quickly to work together.

Members of Team 13 encountered a puzzle that required them to compare two thermometers that were on different walls of the room. It was not possible to see both thermometers at the same time given the distance between them. P37 started by walking back and forth between the two thermometers. It appeared difficult for P37 to remember the numbers on each thermometer when arriving at the next one. P38 recognized this and started telling P37 what number was on the thermometers closest to her. P37 stopped walking between the thermometers.

Physical and Spatial Constraints
The physical constraints of the rooms themselves affected players’ collaboration and where people positioned themselves or moved. As mentioned, the escape rooms that we had in the study were relatively small (~150 square feet or less). This meant that there was not a lot of room for team members to work in. Team members moved throughout this space readily and we did not notice any sense of territoriality. That is, team members did not avoid areas in particular because they thought their team member was working in it despite sometimes being relatively close to one another. When team members were working closely together on a puzzle, they would situate themselves in the same area and stand or sit right next to each other. Often this was very close—sometimes touching shoulders or bumping arms—because of a lack of space.

P1 was staring at a series of light up buttons on the wall trying to figure out how they worked. He was stuck for several minutes so he yelled out to others for help. P3 came over quickly and moved very close to P1’s position in front of the lights. They were almost touching. P1 and P3 stared at the wall for a moment together and then P1 started to move away from P3. There were no verbal exchanges and P3 then took over the space previously occupied by P1 to get a better view. P1 wandered to a different part of the room in an attempt to search for more clues and assist P2.

As can be seen, movement sometimes did not involve verbal exchanges. In other instances, team members would ask others to move so they could get better access to an area. These requests were sometimes abrupt likely because of the time pressures brought on by the escape room.

As players unlocked doors and moved between rooms in a multi-room escape room, they would sometimes be working in separate rooms. This made it harder to collaborate because players could not see each other or their actions.

Players in Team 3 were standing around a dimly lit lamp wondering what it could be used for. P9 noticed that there was a power cable running from the lamp to the other side of the wall in a separate room that they previously unlocked. P10 went into the other room to look around to see where the power cable went. After some searching, he found that it went to a hand crank. He started cranking it not knowing what effect it might have. This started to generate enough power to increase the brightness of the lamp in the first room but P10 couldn’t see it happening. P9 started yelling to P10 in the other room to keep cranking.

While the challenge with multiple rooms is somewhat obvious, puzzles could easily, and inadvertently, force such collaborations to occur. Yet the tradeoff is that having
multiple locked rooms and moving between them was exciting for players as it suggested progression in the game.

Artifact Constraints
The escape rooms that we studied were all relatively dark given their mysterious themes. To assist players, staff provided teams with a limited number of flashlights, dependent on the number of players in a session. For our study sessions, it was between two to three flashlights per team. In addition, rooms contained a number of physical artifacts that were needed to solve the puzzles. These items, again, affected how players worked together or did not.

P33 found a UV flashlight in the room and starting panning it around the wall to see if it would illuminate any hidden text. P34 suggested shining it on a particular area and P33 did so—they both looked around the room together. Eventually, P34 asked to use the flashlight and P33 gave it to her. P33 started moving around the room to look for other useful items. P33 found a rope and started to toss it towards a box a few feet away. P34 continued to look for hidden text with the flashlight. P33 managed to retrieve the box using the rope and P33 and P34 then came together and took turns trying different passwords for the box’s lock.

As can be seen, items were scarce. This meant team members had to share them. This sometimes necessitated players to work in a tightly coupled way. We also observed that the person who found the item would most often maintain a sense of ownership over it, at least initially. Thus, they would use it on their own, or follow the directions of others for how they should use it. For example, P33 took P34’s suggestion on where to shine the flashlight rather than initially giving it to her. When items were exchanged between players, it often implicitly suggested a responsibility to take over the task of directly using the object. For example, in the above vignette, the handing over of the UV flashlight saw P34 take over the searching task and P33 move on to another task. There was no verbal acknowledgment. Instead, P34 understood her new task and took it on.

SITUATION AND WORKSPACE AWARENESS
Situation and workspace awareness are critical for establishing smooth collaborative work and come from knowledge of what others are doing in the same environment [16,23]. In many work settings, this awareness is gathered through a combination of verbal and non-verbal communication, and the peripheral viewing of activities [16,19,20,23]. Yet, in escape rooms, we found that verbal communication dominated awareness gathering.

Verbal Communication
The most common way that team members stayed aware of what others were doing was through verbal communication. Players would often shout across the room to get a response from a team member or to form an agreement to ask for a hint. For example, if one player found a clue or a solution that would benefit the team, s/he would verbally announce it to the team. If a team member needed assistance from another team member, s/he would yell across the room. Rather than a more typical calm conversational tone, verbal communication was often louder, more direct and sometimes reflected little patience with others. Verbal exchanges were found throughout several of the previously presented vignettes. In addition, consider Team 4:

Team 4 consisted of a very experienced escape room player and two first time players. When the experienced player, P13, came to the realization that the puzzle he was working on was very similar to a puzzle he had done before in another escape room, he became noticeably excited and called loudly to P14 and P15 to come over. P13 told them what he knew what to do to solve the puzzle and described the steps for it—the conversation was short and to the point. Next, P13 started moving back and forth between two pieces of paper that were attached to the wall at different locations. He told P14 and P15 to match the lines drawn on the paper together and that they should form four digits; this would likely be the combination to the lock.

While searching for clues, some players would often ‘think aloud’ as they worked. Here they verbalized what they saw and what they were trying to do to solve the puzzle. The hope was that others would hear what they were doing and try something similar. Consider Team 11:

P33 and P34 were trying to figure out what the numbers on two different wall maps meant. P33 was standing near one map while P34 stood near the other. As they thought through the puzzle, P34 kept saying her map’s numbers out loud over and over. P33 heard this and would occasionally glance between P34 and the map closest to him.

Similar to the above situation, we noticed other teams and players counting items out loud and reading words out loud that they found on walls or objects. Our interviews showed that other players noticed this behavior and found it helpful to gain a sense of what others were doing.

Non-Verbal Communication and Peripheral Viewing
The use of non-verbal communication tended to be more rare than verbal communication when it came to maintaining situation and workspace awareness of what others were doing. Team members were often more focused on their own efforts as compared to that of their teammates and they did not often look around to see what other people were doing. Instead, players quickly tried to work on their own tasks. This is likely because of the time pressure imposed by the escape rooms. Body language was also not seen to be very useful for communicating steps to complex logic puzzles. Unless the room supplied team members with some form of writing board, they could not write down notes or answers which others could see and understand. Thus, information about how a team member was solving a puzzle was often ‘in their head’ and not somewhere visible for teammates to see. Sometimes team members even preferred to not write things down because they felt it was
faster. Consider Team 2 where P7 preferred to memorize answers to a puzzle rather than write them down:

*Team 2 consisted of two women and one man. P7 was trying to memorize a sequence of symbols to enter into a combination lock. P8 stood next to her with a writing board and marker but did not write anything down. Instead, P7 tried to only use her memory. P6 and P8 watched but did not know why P7 was trying the numbers that she was.*

In our interview, we learned that this was frustrating to both P6 and P8, but they felt they needed to trust P7’s memory and judgment so that they did not get into a fight with her.

At times the dim lighting in the rooms (in order to create mystery and match the themes) made it difficult for players to see what others were doing, what artifacts they were using, and what body language or gestures were being conveyed. Teams had only a limited number of flashlights or objects with light to help them see.

In the rare cases when people did look or glance around to see what was going on around them, they would notice where people were generally positioned and if they were using any artifacts in the room. As illustrated in previous vignettes, the peripheral awareness of the actions of others was sometimes used to change one’s own course of action.

**SOCIAL CONFLICT**

Our participants saw social conflict as somewhat inevitable given the time pressures placed on them. When teams progressed smoothly through the game session, we found it unlikely that conflicts occurred. As one might expect, it was only when a team began to struggle or was not satisfied with their progress that conflicts arose. Most often team members recognized that they should set aside any differences in opinion in favor of focusing on solving the puzzles. That is, the conflicting parties understood the pressing need to escape the room and were willing to put their emotions aside for the time being. The conflict, however, sometimes resumed post-game when team members would chat about their experience.

Social conflicts that were minor in nature occurred when team members disagreed about puzzle-solving strategies or were ignored in the decision making process of taking a hint. In these cases, we observed noticeable annoyance on the faces of the affected players or a change in their behavior over the course of seconds to minutes.

*Team 12 started in the escape room with P36 telling P35 what he should look for and try to find. The two searched for several minutes and then P35 appeared frustrated. He said aloud that he wanted to receive a hint. Rather than talk with P36 first, P35 walked directly to the button to call for the hint and pushed it. After receiving the hint from staff, P35 began telling P36 not to waste time looking around the room aimlessly anymore and that she should be more focused on the clue. He began walking between two pictures on the walls to double check what numbers P36 had read off of them to ensure she was correct. P36 stopped working and watched P35.*

As can be seen, discontent emerges between P35 and P36 in this situation and it led P35 to be more ‘bossy’ with P36. This frustration led him to ignore her in the decision to take a hint. Sometimes other teams saw people being ignored during hint decisions as well. Team members were either preoccupied with their own individual work and did not notice a team deciding on a hint or team members felt a player’s input was less relevant because of puzzle inexperience. For example, Team 6 voted to see if they should receive their first hint. In this case, every team member was given the chance to voice an opinion. But as time passed, the more active team members forgot P21 during the voting for the second hint. The team did not realize their mistake and apologized to P21 after the study. P21 was frustrated but able to forgive his teammates.

*“Feel a bit bad forgetting to ask my friend if he wanted to ask the second hint.” – P20, Female, Questionnaire*

We only saw major conflicts occur amongst two teams. By major, we refer to conflicts that had a noticeable effect on the team throughout the remainder of play, e.g., a player stops participating or there is a verbal argument. In each of these cases, the teams included at least one stranger to a team member (as opposed to teams where all players knew each other). Players said they had a harder time communicating with those people they did not know. Sometimes they held back on things they wanted to say. Other times, players did not listen as closely to those they did not know well, and there was a lack of trust. For example, a major conflict arose with Team 5 where two participants (P16 and P17) refused to talk with each other after the game. Prior to the study, P16 and P17 did not know each other and had been recruited by a mutual friend to participate. During the course of the escape room, they recognized that they had different play styles and personalities. The team had been unable to escape their room and felt this was a result of a logic puzzle that the team spent more than ten minutes on. While the team tried to complete it, P16 became impatient and offered to take over the puzzle. P17 was primarily working on the puzzle and refused to let P16 help and, instead, she continued to solve the puzzle at her own pace. The puzzle was eventually solved, but participants became wary of each other’s suggestions. After the study, P16 and P17 said:

*I found it is hard to prove something is wrong to people you just met. If you try you could possibly offend someone. If you don’t, you won’t make progress! It is a tradeoff.* – P16, Male, Questionnaire

*“If the people you don’t know and they play well, may be made friends. If the people you don’t know, and not good at team work or no contribution, definitely would not want to be friends and never play again.” – P17, Female, Questionnaire*
DISCUSSION
We now discuss our results and their implications for design. Our goal is to sensitize readers, including designers, researchers, and educators who might use escape rooms to study particular research questions, commercial escape room designers who create escape rooms for the public, as well players of escape rooms (including companies that might use them for team building events) to the potential benefits of escape rooms as well as the ways that escape room designs may affect participation in them. We feel this is especially important if escape rooms are designed to specifically teach certain skills, such as strategies for effective collaboration and communication practices, specific workplace training, or as tools to build relationships, such as between family members (e.g., parents/children, grandparents/children). What may seem like simple design decisions can easily turn out to not be the case (e.g., puzzle structure, number of rooms, lighting). For this reason, we explore how the design breakdowns that we observed suggest opportunities for technology interventions as a part of escape room design.

Collaboration and Awareness
First, we found that escape rooms provide people with opportunities to practice their collaboration skills where they are able to perform various nuanced collaborative acts. Team members move between loosely and tightly coupled group work and can practice methods to smoothly do so; they can practice gathering situational and workspace awareness; they can practice their communication skills; and, they can practice the development of a shared mental model. The time pressure of the room tends to cause people to ‘not hold back’; thus, it brings out somewhat of a more ‘authentic’ form of a person in a short manner of time. That is, one can see how another reacts and collaborates when under time pressure and a potentially increased amount of stress as a result. This could certainly be advantageous as a means to learn about others and develop team skills in a short amount of time. This is promising because we know that many people participate in escape rooms for such reasons [32]. It also suggests that escape rooms may be valuable environments for teaching more specific types of workplace or school training that involve collaboration.

Yet escape room designs can easily make it so the collaboration and communication skills being taught and practiced are not entirely like situations outside of the escape room. This raises questions about their generalizability. Research shows that in collocated settings it is important for team members to gain situational awareness of what is happening [16,23] and workspace awareness of collaborators’ activities [19,20,23] where this comes from hearing others, and seeing artifacts and actions [16,19,20,23]. However, escape rooms may have different attributes than common work or educational locations in order to match a theme and narrative, and create a sense of panic (e.g., time pressure, multiple rooms). This may cause people to overly rely on verbal communication and raises questions around how escape rooms might be designed to encourage non-verbal communication and situational awareness through peripheral viewing, while still maintaining a sense of allure brought by the escape room’s theme and narrative.

Critical points in time when team members in our study needed to gain situational awareness, but perhaps did not, involved the changing use of artifacts (which were often scarce) as well as the movement of a person through the room, which could suggest a changing strategy or the finding of artifacts that might be of value. Given that a key problem was people overly focusing on their own work at the expense of knowing what others were doing, one could imagine the design of technology that attempts to make the work and actions of others more salient in an escape room. For example, one could imagine a reactive escape room environment where objects provide audio or visual feedback when picked up or put down, so that players may be more likely to glance at the direction of the feedback and gain a greater sense of situational awareness—one of the challenges we observed in our study. Similarly, one might imagine feedback of player movement throughout the room with areas of the room briefly lighting up when players enter or leave them, as an example. Ideas such as this may allow players in escape rooms to gather a greater sense of situational awareness even within themes that are dark and mysterious. It may also help to train people to know that such knowledge is valuable and can aid collaboration. Of course, one would not want such feedback to be overly dramatic or overt. Thus, technology designs would need to offer a careful balance.

Social Dynamics
Second, we learned that escape rooms provide people with opportunities to practice leadership skills and varied social dynamics, where this may not always map to social hierarchies and roles outside of the escape room. Leadership was often based on puzzle solving experience, yet similar to studies of ARGs [34], this was also an emergent behavior based on the completion of game tasks. Like other teamwork situations [13,22,27,28], leaders worked to share their mental model of the situation—in this case, how the escape room puzzles might be structured. Based on our post-game discussions with teams, we recognized that players and groups come into the escape room with an existing set of social roles and structure. For example, some people were used to being social leaders in a group because of workplace or family dynamics and hierarchy (e.g., a manager of a workgroup, a parent of a family). These dynamics sometimes dissolved in the escape room and new ones emerged based around one’s experience with puzzle solving tasks. If players are not expecting a shift in social status and it occurs, social conflicts may arise. On the other hand, some players may have a positive experience if they are interested in or okay with experiencing a new role within the group.
This raises design questions around if and how escape rooms should be designed to preserve existing team dynamics and roles. For example, should escape rooms be specifically designed for workgroups where elements of the escape room ensure that a team manager remains as a leader? This could be done, for example, by giving certain instructions or clues to just the manager. A similar approach might be used to strengthen existing notions of family hierarchy. If technological artifacts were placed in the room, they may, for instance, react differently to different people depending on their social role. For example, an object may reveal more information when held by a parent than her child. This reflects the varying degrees of understanding that we saw players have when looking at and thinking about objects in the room. On the other hand, there might be ways to consider the design of escape room puzzles and activities that purposely work to disrupt the normal social order of groups so that people learn new skills and, perhaps, gain a greater sense of appreciation for the skills that others bring to the table. Again, technological artifacts may be programmed to respond differently to different people and this might purposely change over time to encourage them to explore new roles and interaction styles.

**Social Conflicts**

Third, escape rooms provide people with opportunities to face and deal with conflicts where they might learn important conflict resolution skills. Our results showed that conversations in escape rooms can become domineering in nature, people may lack patience with others, people may infringe on typical expectations of territoriality and personal space [38], they may work in much closer proximity to each other than they are typically used to [23], and they may be forced to use shared artifacts even if they do not want to. These all have the potential to lead to social conflict. However, this brings with it the opportunity for people to understand and learn from what may make them feel uncomfortable, and, if conflicts arise, seek ways to resolve them in a positive manner.

This suggests that escape rooms could be designed to teach common conflict resolution skills, such as the sharing of ideas or listening to teammates’ views. For example, digital puzzles might require the inputting of ideas from multiple different teammates before a successful answer is accepted. Resources and puzzle artifacts may be imagined as varying in numbers depending on sensed dynamics in the room. For example, if tensions become high like we sometimes observed (e.g., loud voices are sensed), digital objects may be replicated so that people can be encouraged to work on their own for a bit to step away from a situation. This could work with items digitally projected on a wall or physical objects that can be ‘turned on’ or ‘off’ programmatically. Changing interactive visuals in the room (e.g., lights turning on in certain areas) may also encourage people to move to different areas depending on social dynamics. In this way, play could be migrated between tightly coupled and loosely coupled work, as needed, to encourage good collaboration skills and conflict resolution techniques. Puzzle paths could even be adjusted on the fly to move between sequential and parallel paths. Sequential paths may be beneficial for teams that are working well together, as we saw for many teams, while parallel paths may work better for team members that are experiencing problems, such as those who do not know each other well and value more independent play like was the case for several teams in our study. While automatically sensing social dynamics and reacting to them may be difficult, escape room staff could monitor behaviors and adjust the contents of an escape room and its appearance from a control room, if the escape room had a greater degree of technology embedded in it. Thus, a greater degree of room orchestration by escape room operators—more similar to that seen in ARGs (e.g., [7])—and the ability to do so, may be beneficial.

**Limitations**

While valuable, our study is limited in that our players were mostly of a younger demographic (early adulthood) with a cultural background specific to the area of North America that we studied. Thus, our findings could be culturally specific to this age group and cultural background. Further studies should explore how players of both an older and younger demographic (e.g., children) play together. Studies of escape rooms in countries with likely different cultural backgrounds (e.g., Asia) would offer compelling cross-cultural comparisons to our results. We also suggest future work that explores different types of escape rooms beyond the science fiction/mystery ones that we studied. We also note that the average number of players in our study groups (~3) is less than the average size of groups reported in Nicholson’s survey of escape rooms [32]; as such, real world situations may see slightly different group dynamics.

**CONCLUSION**

Our paper described an exploratory study of players’ collaboration in escape rooms through observations, post-play questionnaires, and interviews. Our results describe the ways in which play manifested itself in escape rooms and how the design of the room affected teams’ experiences and activities. We found that escape rooms can provide learning environments for exploring social questions around leadership, group hierarchy, conflict, proxemics, and distributed cognition. We also found opportunities for furthering the use of technology in escape rooms where designs could be used to enhance collaboration, awareness, and communication. This presents opportunities for researchers to explore the design of reactive, computational environments where one could research social and technical questions around the use of networked devices/objects, context-aware computing, etc. We offered several design ideas as starting points for exploring these avenues.

**ACKNOWLEDGMENTS**

We thank the Natural Sciences and Engineering Research Council (NSERC) of Canada for funding.
REFERENCES


