BragFish: Exploring Physical and Social Interaction in Co-located Handheld Augmented Reality Games

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ABSTRACT
In this paper, we present our research on social interaction in co-located handheld augmented reality (AR) games. These games are characterized by shared physical spaces that promote physical awareness among players, and individual gaming devices that support both public and private information. One result of our exploration of the design and evaluation of such games is a prototype called BragFish. Through BragFish, we aim to investigate the connections between the observed game experience (focusing on social and physical interaction) and the designed affordances of our AR handheld game. Our evaluation of BragFish shows that most of our participants form strategies for social play by leveraging visual, aural and physical cues from the shared space. Moreover, we use this as an example to motivate discussions on how to improve social play experiences for co-located handheld games by designing for shared spaces.

Categories and Subject Descriptors
H.5.1 Multimedia Information Systems

General Terms
Design, Experimentation, Human Factors.

Keywords
Augmented Reality, Co-located Handheld games, Social Play.

1. INTRODUCTION
In recent years, novel interaction technologies have become an inspiration for new classes of digital games. Platforms such as the Nintendo® Wii™ [5] and DS™ [4], and controllers like the Sony Eyetoy® [2] have introduced new interaction styles and attracted a broader range of players. Augmented Reality (AR) technology––where computer generated graphics are rendered on top of real world objects—has recently become available in consumer products, such as the PS3 game "Eye of Judgment"™ [1]. This trend toward leveraging more physical and natural interfaces in the game industry raises deeper questions about the relatively unexamined connection between interactive technologies, game design, and new types of play experiences.

We are particularly interested in exploring these connections in the context of co-located handheld augmented reality (AR) games. Due to the wide availability of handheld gaming devices, ad-hoc wireless networks, devices with built-in cameras, and 3D graphics acceleration, it is finally possible to deploy multiplayer AR games and run them smoothly on mobile platforms. Many prior research examples use games as a vehicle to test AR technology, usually by making AR versions of existing games. However, some of these examples downplay the inherent interdependence between the affordances of an AR interface and the possibilities for game play. Rather than uncritically adopting the stance that "new technology automatically leads to better game play", we believe that more fundamental questions must be answered by game designers and researchers alike: What are the key affordances of AR and what are the compelling interactive techniques they enable? How can designers creatively leverage the advantages of AR technology via appropriate game design? And what kind of new play experiences can be facilitated?

Currently, in multi-user handheld AR practice, predefined patterns of markers are used for tracking. They serve as a shared physical space overlaid with a virtual environment through private devices that have their own displays and sound. The fact that each player has his or her own device, which serves as a window to the shared space, means that (unlike multiplayer tabletop or console games) each person perceives both shared and private information. This gives game designers much more control over what information is available to each player, allowing them to create situations that require players to pay attention to each other and not just the computer screen. We are particularly interested in learning how this experience is different from other multiplayer handheld gaming experiences, in which players tend to sit together, yet focus on their own devices, according to previous research [32].

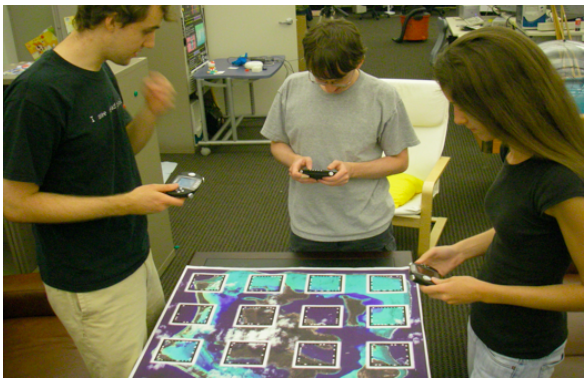


Figure 1. Three players playing BragFish

In this paper, we present our work designing, implementing and evaluating a multiplayer handheld AR game prototype, BragFish (see Figure 2). This experience leverages hybrid features from both handheld video games and board games, and aims to foster social play among friends and families (see Figure 1). In addition to trying to create a fun game, we use BragFish as a research tool to explore the relationship between the distinctive characteristics of handheld AR technology, specific aspects of the game's design, and the resulting social play. We are particularly interested in identifying what factors affect the emergent social interaction triggered by handheld AR interfaces.

Figure 2. BragFish: Interface and handheld gaming device

Lessons from Eye of Judgment

To help us raise research questions and refine methods for later user studies for BragFish, we performed an informal evaluation of the then-new PS3 game *Eye of Judgment* (EoJ) by observing several rounds of play with different players and asking them for feedback. Just as with BragFish, in EoJ AR technology appears to be one of the major inspirations for the game design, attempting to leverage the affordances of this interaction paradigm. The goal of our evaluation was to identify both the effective and ineffective game mechanisms in this first commercial AR game.

In EoJ, the use of the camera to view the cards enables the seamless and automatic score keeping and rule enforcement that often motivates computer implementations of card games (e.g., there are many computer programs to automate rules and combat in role playing and tabletop real-time simulation games). However, one big issue with this game is that the graphics and "AR" added little to the game beyond pleasing "eye candy;" the game could be played as a card game without the PS3 and/or without AR. In the game, the AR technology functions as an enticement and reward for players using the system, rather than as an integral part of the game. In our view, it is unlikely that once the novelty wears off, this added value will entice players to continue playing what amounts to a fairly basic card game under a camera, in front of a TV. In contrast, our design of BragFish takes advantage of AR technology by exploiting the shared physical space, and embedding it into the design of game mechanism.

2. RELATED WORK

To understand how mobile games can be used to enhance the social interaction, we need to first understand how current games, including both video and non-video games, can support or fail to support social interactions. In the pre-computer age, games were valued as social experience. However, in the last few decades, the emphasis on single-player computer and video games change how games are designed and played. Even in massively multiplayer online games (MMOG), where players control their avatars to interact with other player's avatar, the prevalence and extent of social activities are found to be over-estimated. Players are more likely to be playing "alone together", and they tend to have more "spectator experience" rather than direct interaction [15]. This lack of social interaction in multiplayer online games points us back to more traditional games, such as board games and sports, in which more face-to-face social interactions are involved. One of the most important elements of these game experiences is the shared physical space where people can express themselves using the full range of human social and physical abilities. We choose to use shared game spaces as a basis for the design of our games, and augment the real world space with a parallel virtual space accessed by the handheld device. However, a shared space does not simply mean players sit close to each other. As found by Szentgyorgyi et al., social interactions between players with the Nintendo DS are actually less than traditional console gaming due to the lack of a shared display, the reduced potential for spectators, and the closed nature of game play experience [32]. Their research showed that there is much room to improve for the social play of current multi-player handheld games, providing a niche for AR handheld games to fill.

Prior to our work, a number of game systems and research work strive towards social interaction in hybrid board/video games, including, "False Prophets", a tabletop display game system with a custom sensor interface [23]; "Wizard's Apprentice", a computer-based augmented board game [27], and "TViews", a digital tabletop role-playing game [24]. These gaming systems are also inspired by leveraging the advantages of both digital and physical media to promote social play. By user study, we aim to deepen the understanding of the occurrences of social play and emergent behavior when framed by a publicly shared space and private devices.

Recently, pervasive and alternate reality games are emerging as an active research topic in HCI and computational entertainment [9, 12, 17]. These studies have investigated how players construct social context, how players generate their own tactics and strategies from multiple trials, how "seamful design" is used, and how social dynamics (collaboration and competition) emerge [9]. We ground our game design in this work by recognizing the importance of identifying and carefully considering the visible seams of technology (such as tracking speed, and networking bandwidth) in game design, and also integrating the physical and social environment into the game play.

While Eye of Judgment is the first commercially available augmented reality game, there have been a number of research projects devoted to handheld AR games, such as MonkeyBridge [8], AR Soccer [25], and Laser Cannon [16]. AR Tennis [20] and SymBall [19] both bring the game of Table Tennis to a mobile platform. The former is particularly related to our work because it takes advantage of the physical space and shows the user a live-video view of the game space. Our work also relates to (and can learn from) a number of research games developed on interactive Tabletops. These projects have investigated the hybrid digital/physical space [23], social interactions over a shared board [22], and social skills development [28]. In our game, we also

facilitate interaction around a shared board for the purpose of studying social play amount participants.

Social play has been seen as an important component of the game experience in the community of game research. Salen and Zimmerman [30] identify two kinds of social play: one occurs "inside" the game and emerges through the specific game mechanisms; the other happens "outside" the game and relates to the players pre-established social roles. We are interested in both of them. Social presence is another useful lens for studying social effects with a new medium, and often refers to a communicator's sense of awareness of an interaction partner [31]. In the context of virtual reality, Palmer defines social presence as "effectively negotiate a relationship through an interdependent, multichannel exchange of behaviors" [26]. In handheld AR games, we are particularly interested in how specific game mechanisms and the shared (physical and virtual) space effects social presence between players, and consequently, how the difference of social presence influences the social play experience.

3. DESIGN OF BRAGFISH

For the past two years our research team has been exploring the design and implementation process for a new class of handheld AR games. Our goal has been to create AR games that utilize a shared physical space coupled with personal devices that provide both public and private views of virtual game objects. Our belief has been that such games provide a social user experience that leverages the desirable features of both traditional game forms such as board games and that of modern video games.

3.1 Design Process

Our exploration of this new gaming space has followed the iterative prototyping and evaluation process commonly used in game design [18]. We currently have several handheld AR games in the design pipeline, but BragFish in particular has been in development since the beginning of our research project. BragFish is a multiplayer AR game where the goal is to catch fish. The design of BragFish was initiated by our empirical and intuitional understanding of handheld AR technology. The major goal of the design is to explore the hybrid physical-virtual space that is enabled by the AR technology.

We have created and play-tested both simple paper prototypes as well as several technology prototypes of our BragFish designs. The creation of BragFish has been challenging as we have focused on developing an understanding of handheld AR games in general, while simultaneously tackling the technological and implementation hurdles that are intrinsic to any new medium. Before we conducted the formal evaluation reported here, we demoed intermediate systems to dozens of visitors to our labs, and used their feedback to refine the game. The design process of BragFish, although focused on a specific game, has taught us a great deal about what game mechanics and user interfaces are appropriate for this class of social AR games.

The initial BragFish prototypes were informed heavily by traditional board games and aimed to provide a similar social experience that defines many traditional games, specifically the discontinuous interaction and changing levels of focus on the game created by turn-based play (i.e. social play where players may want to engage actively with the game for several minutes at a time, or they may wish to put their devices down and have a conversation). However, evaluating the social dynamics in such an uncommon style of computer game would not provide insights that could be reliably compared to most existing mobile games, where the player tends to be focused on the game continually. Therefore, to support the evaluation we created another version of BragFish that supported continuous play (similar to current mobile games) and the participants in the evaluation were encouraged to engage in the game for the entire play period.

3.2 Game Play

BragFish is played on a physical game board with Gizmondos, which are handheld game devices with a camera mounted on the back. The board is covered with a regular grid of fiducials. The core game mechanic involves the players navigating their boats around a lake, casting their lines, reeling them back in, dumping fish onto the dock and ramming other players' boats to steal their fish. The players look at the game board through the device screen and control their boats using the device's buttons. Casting of the hook and lure (referred to from here on simply as "the bobber") is controlled by pointing the crosshair that is fixed in the center of the screen at the target location on the map. The virtual boats and fish, water and effects are rendered on top of live video streaming in through each player's camera. There is a radius around the boat where the player can see fish. A boat has three kinds of skills: ramming, defending and fishing. All of the skills increase when corresponding action is performed, and decay at a fixed rate. Ramming skill decides the probability of stealing a fish from the rammed boat. When the ramming skill goes up to a certain level, the player will become a pirate, with an icon shown on top of the boat. When fishing skill goes up, the range of fish that can be seen from a boat is increased, and a fisherman icon is rendered on the boat after fishing skill reaches a threshold value (see Fig. 3. left).

Figure 3. (left). The icons are rendered on top of the boat to show the role of the player; (right). The red vertical bars indicate that tracking is not currently working.

3.3 Design Goals

3.3.1 Encouraging Social Interaction

Having networked devices and co-located players does not guarantee that social interaction is increased, which has been found by Szentgyorgyi et al. [32]. Although our current device, the Gizmondo, shares similar form factors with the Nintendo DS, the use of AR to overlay the game space on a physical game board introduces a shared space among players. All players are aware that they share a one-to-one mapping between the physical space and the digital game space, which builds a common ground for social interaction that guarantees common interpretation of the physical actions of players in the game space (i.e., supports inter-referential awareness [14]).

We also designed the game mechanics to encourage social interaction, including mechanisms to intensify the conflict between multiple players and introduce social roles. Beyond simply competing for a limited fish supply, the boats have the

ability to ram into each other, and steal fish from each other. When successful, the rammer's ramming skill will increase, which means that she has a better chance of stealing the fish from others in the future; at the same time, the ram-ee's defending skill is increased, making it is less likely that they will lose a fish next time they are rammed. By balancing the game in this way, we are enabling players to adopt different roles according to their personality and the strategy that they prefer: more aggressive play will lead to the role of a pirate, while players who are more interested in fishing will become a fisherman.

3.3.2 Leveraging Players' Physical Movements

The interface for BragFish is designed to provide transparency of player actions to opponents via physical movements in order to encourage players to interact and observe each other and not just the virtual space. Keypad buttons control boat movements. Players cast by centering their camera (indicated by a crosshair in a translucent circle in the middle of the screen) on the desired location in the lake and pressing a button. After the cast, the bobber will be positioned at that location in the lake. The player can then reel the line back in by holding down a button on the keypad. If a fish "nibbles" the line the device vibrates and the player must hit a button immediately to reel it in.

Each of these player actions is discernible at many levels. If a player is pointing the device at the game board and looking at the screen it is likely that she is actively seeking fish while a player that is simply holding the device in her hand (and perhaps glancing at it) is not as actively engaged in the game; she may be waiting for a fish to strike or taking a break from playing. If a player is actively participating, even casual observation reveals what action she is taking (as the movements for navigating the boat, casting, and reeling in a fish are quite different) and the position and orientation of her device indicates where the actions are taking place.

Just as with actual fishing it is very obvious when an opponent hooks and catches a fish. When a fish "nibbles" an opponent's line the player will observe (via sound and visuals) the opponent's device vibrating followed by the opponent locating the appropriate button and pressing it to catch the fish. These sudden rapid movements by a player are an indication that she is finding success in the game.

3.3.3 Maintaining Awareness of Game State

BragFish uses visual and aural feedback, along with haptic feedback (i.e. the device vibration) to convey game state to the players. The goal is to take advantage of the affordances of AR while supporting casual, unfocused play. Information that is only of interest to an active player is registered with the virtual scene (e.g. boat and fish locations). Information that would be used by a player to maintain awareness of state (e.g. whether a fish is on the line, or how many fish you have caught) is presented either as haptic or audio feedback, allowing a casual player to continue social interaction while still participating.

The most important feedback to the player is the status of her line. This information is conveyed haptically so that a player can monitor her line without having to look at the device and without having to actively engage in the AR component of the game. If a fish "nibbles" the hook there is an initial short vibration to indicate to the player that there is an opportunity to catch a fish. The player must then immediately push a button to actually catch the fish.

The auditory and haptic feedback received by a player is discernable by other players if they are paying attention. This serves to increase the tension in the game, as the relative success of the players is made clear to the other players. The players are also able to check on the number, size, and type of fish the she has caught by hovering the crosshair over the dock and other boats. This information is viewed as a standard 2D display on the device.

Another important aspect of game state is to indicate and recover from the technology breaks, in particular losing AR tracking of the game board during the game play. When the tracking is not working, two red bars are shown on the sides of the screen, and the crosshair will spin (see Figure 3, right). Users can adjust their movements or positions after seeing these signs.

4. IMPLEMENTATION

BragFish was developed for the Gizmondo handheld gaming device. The Gizmondo has a 2.8-inch LCD screen with a 320 by 240 resolution and a rear-facing camera. The device runs Windows CE, and the application was written in C++. BragFish uses the Studierstube Tracker (StbTracker), which is a computer vision library for detection and pose estimation of 2D fiducial markers [7]. It also uses Mobex3D [3], a 3d graphics game engine designed for handhelds.

BragFish supports up to three players, with networked play carried out wirelessly over Bluetooth. One device is used as the game host and acts as both server and client, while the other devices ask to join this hosted game. The server broadcasts messages to the client devices while the clients communicate directly with the server. The messages passed between server and clients include fish catching requests and acknowledgments, position updates, and collision notifications.

BragFish is played on top of a custom 31-inch square board with an image of a beach island. Overlaid on this image is a 4x4 grid of StbTracker "frame markers" which the Gizmondo uses for tracking. Images are captured using the built-in camera and passed to StbTracker, which calculates and returns the transformations required for the game engine of Mobex3D to align the virtual world with the real world. The camera images are also copied into texture memory to be rendered along with the virtual world so that real world entities are included in the final image. Altogether, the game gets an average frame rate of 15 frames per second.

5. USER STUDY

The purpose of the user study is to understand how AR technology affects the game experience, especially with the shared physical/virtual space. In this study, we try to answer the research questions posed in the introduction.

5.1 Participants, Setting and Procedure

We recruited 9 groups of participants on campus. Each of the groups had 2 players. 7 of the groups were made of friends, while 2 of the groups were made up of strangers. The average age of the players was 24.5. 5 of the participants were female. 9 participants categorized themselves as "casual" players, 5 as "hard-core" gamers, 4 as "cool player"(according to Electronic Art standard, mentioned in [11]). According to Bartle's research about player roles in multiplayer games [10], 8 participants reported that they are "achievers," 8 are "explorers," 5 are "socialisers," and 3 are "killers."

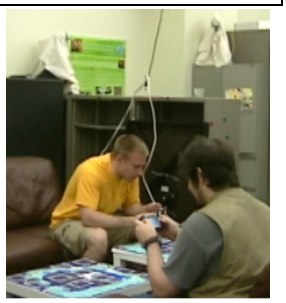
The "game space" for this study was situated in our research lab. The space was configured to provide a comfortable gaming and relaxing environment. Food and drinks were provided to the participants before and after the user study.

We tested 3 configurations of the play space to determine how different communication channels affect the play experience (see Figure 4). The first was the "shared board" (ShB) mode in which two players played with the same marker board; the second was the "separate board" (SepB) mode in which two players each had their own board (they are still able to see and hear each other though); the third mode was "separate space" (SS), which was similar to the second mode except that the two players are separated by a white board between them (and although they could not see each other, they could still hear each other). The communication channels available in each mode are shown in Table 1. The experiment was configured as a within-subjects user study – each of the groups experienced all three modes, and they played three rounds under each mode. To balance the order effect, we changed the play order of different groups according to a 3-by-3 Latin square. During the game, the players were free to sit, stand or move as they pleased. The design of our user study was inspired by Henrysson et al.'s work on evaluating AR Tennis [20] in the sense that we also set up different testing conditions. However, our research method focused more more qualitative data collection and analysis, aiming to answer the research questions of identifying the factors that may make a difference in social play experience of handheld AR games.

Table 1. Three different modes and the communication channels provided by each configuration

ShB: Shared Board	virtual (*inside the game world*), aural, visual and physical cues
SepB: Separate Board	virtual, aural and visual cues
SS: Separate Space	virtual, aural cues

(a)



(b)

(c)

Figure 4. Three settings in the user study: (a). Shared board mode (ShB); (b) Separate board mode (SepB); (c) Separate space mode (SS)

Both qualitative and quantitative data was collected. During the game play, events such as fish catching, ramming and status checking were logged. The game sessions were taped and one researcher took observation notes throughout. At the end of the user study, the players answered a questionnaire to give general ratings for the game design and AR interface, and to compare the social presence (see Table 2) and social play experience. In the end, a semi-structured interview was conducted to understand why certain play behaviors and preferences existed.

Table 2. Major part of the questions for comparing social presence in different modes (questions are selected from previous social presence literature [13])

1	How much social interaction is involved in your game play?
2	How much are you aware of what's going on for the other player(s)?
3	How aware are you that you are being observed by the other players(s) during the play?
4	How much is your play action influenced by the action of the other player(s)? *(note: the actions include: physical movement, dialogs, actions in the game world, etc.)*

We are also aware that the setting of a controlled experiment such as this one cannot reflect how this game would be played under different social contexts, such as at home, in bars or in the lunch room. Therefore, this study cannot fully reveal how the game and resulting social interactions would be affected or appropriated in those environments. These reservations notwithstanding, such studies are useful as they allow us to collect detailed qualitative and quantitative data, which can yield insights not possible through more informal longitudinal studies.

5.2 Results and Findings

5.2.1 Overview

The game received positive feedback overall. The following table lists the self-reported results of some dimensions, on a 1 to 7 Likert scale (*higher scores implies more positive experience*).

Table 3. Feedback about the game

	Mean	Std
Enjoyment	5.71/7	1.359
Engagement	5.50/7	0.985
Ease of learning	5.20/7	1.673

Participants showed a common preference of playing with a human opponent rather than a computer-controlled one (mean=2.15/5, *lower scores mean that participants are less likely to prefer to play with a computer*). This result corresponds with Ravaja et al.'s similar findings using Game Boy Advance [29]. Several participants also mentioned in the interview that, they preferred to play this game with friends or family, rather than people they didn't know before.

We observed different game play experiences among the participant groups. Three of the nine groups exhibited a strong social flow between players, which was evidenced by the dramatic emotional cues observed in the players (e.g. gestures, outbursts, excited conversation [21]). Three of the groups showed a medium level of social flow, yet the interaction level inside the game was still high, as evidenced by the amount of ramming and status checking recorded in the log data. Three of the groups showed a low level of social interaction, both inside and outside the game.

So far we cannot tell whether the player experience is related to pre-existing social relationships or gender norms, because the

current data only has two groups of female players, one male-female pair, and only two groups where participants were not friends prior to the experiment. In the future study, it will be interesting to find how the pre-existing relationships and social norms can influence the social play in handheld AR games.

5.2.2 Feedback about the game interface

From players' self-reported rating, we found that they thought that this AR game interface was intuitive to use (avg=3.42/5, std=1.017); and it provided enough feedback during the game play (avg=3.53/5, std=.943).

We identified an ergonomics issue related to the top down view that the game interface requires, in order to provide optimal tracking of the markers on the game board. Using the handheld device was not comfortable for long play sessions, and many players complained that the game required them to "*bend too much*" (P14) and they prefer to "*sit back on the couch*" (P10). Two groups of players alleviated this problem in the SepB mode by tilting their coffee tables to be closer to vertical (see Figure 5).

We originally felt that fishing as an activity lent itself to a handheld AR game implementation due to the fact that, even in real life, this is a slow paced social activity with competitive overtones. However, during the BragFish game play, we observed the game becoming fiercely competitive and attention-demanding under the lab setting. As put by P2, *"(when the tracking is not working) It seemed to get in the way at the worst time. When I see a fish, I get excited and try to position the camera quickly – this caused tracking problem, though."*

Figure 5. Players reconfiguring the game space to get a more comfortable position of play.

5.2.3 Emergent and Embodied Play

Through our observation, interviews and recorded video, we found that players are creatively leveraging the social/physical context and integrating them into their own play approaches, especially under the mode of shared board. The examples are as follows:

- P11 reported how he anticipated the other player's actions in the game by observing his physical movement in ShB mode. In this case, zooming out (pulling the device away from the table) and panning the device meant the other player was preparing to ram or check the other player scores; while zooming in meant he was trying to catch a fish.
- P9 positioned her device on top of P10's device to physically block her view of the screen (see Figure 6, also in ShB mode). This action happened when these two players move close to each other. The separate devices and shared physical space lead to this interesting play behavior.
- P3 reported that his strategy was to intentionally stand in the way of the other player (in ShB mode). He believed that the other player could not get a good position for tracking or zooming in on the board and thus he could not effectively fish.
- P16 turned the game into a fierce action game. He stalked the other's boat, and whenever he heard the fish-catching sound from the opponent's device, he rammed his boat, attempting to steal fish (this happens in both ShB and SepB modes).

The above cases are not an exhaustive list of the creative game strategies employed by the players. The richness of their interactions showed that the players rapidly adapted and immersed themselves in the gaming sphere by receiving and interpreting visual, aural, physical, and virtual cues in their own ways. The potential for such embodied and emergent interaction sets handheld AR gaming experiences apart from many other handheld games, console games and board games. When asked to compare their BragFish play experience with other game experiences, four groups of the players talked about how BragFish is similar to the Nintendo Wii (the game title of SmashBros [6] was mentioned three times), both of which involve more physical and social interaction than traditional games. Interestingly, one of the players described the Eye of Judgment experience as different from BragFish, although both of them are based on AR technology.

Figure 6. A player moving her device on top of her opponents' screen to block her view of the board.

5.2.4 Multi-channel interaction

The purpose of the three modes was to isolate and identify which components of the communication channel matters most. Below are the hypotheses and results:

Hypothesis 1: There is no significant difference between social presence levels in the three modes.

From the study, we found that there is statistically significant difference between all three modes for each of the social presence questions listed in Table 2, except that there is no significant difference between SepB and SS mode for question 2: Awareness of the other player (t-test, t=1.84, p=0.085). The average ratings of the social presence questions (on a 1-7 Likert scale) are listed in Figure 7.

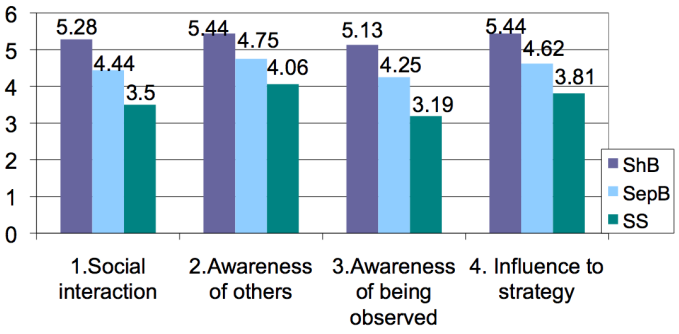


Figure 7. Average ratings for the social presence questions (in a 1-7 Likert scale, 1= least, 7=most)

Hypothesis 2: There is no significant difference between the players' enjoyment of the three modes.

There is no significant difference of enjoyment between the ShB mode and SepB mode (t-test, t=0.76, p=0.45), although a majority of participants (11 people) liked ShB most (6 other players liked SepB most). There is significant difference of enjoyment between the ShB and SS modes (t-test, t=2.78, p=0.015). Moreover, in SS mode, the frequency of verbal communication and self-reported social interaction level is reduced significantly as well (t-test, t=3.50, p=0.003). This result shows that when players cannot see each other, the channel of visual cues is lost and the social interaction diminishes instead of being sustained by an increase in verbal communication.

It is interesting to explore how social presence influences the game experience. One might assume that the higher the social presence is, the more enjoyable the game is. Instead, we found that this is not always true (as shown by the combination of results from hypothesis 1 and 2). An easy conclusion is that visual cues are playing an irreplaceable role in the social play experience, as described by P2, *"out of sight, out of mind"*. But a closer look at the qualitative data reveals instead that each of the three experimental modes has its own affordances that, if designed properly, are appropriate depending on context and player type. The following section discusses the issues inherent to each mode and the resulting design considerations.

- **Space management**

In this context the term "space" means both virtual and real space. In some cases, players reported that with shared board and AR, they can align the real world movements of the other player with the movement in the virtual world more easily and directly (P4, P9 and 10, P11, P16); also, some players reported that they would prefer to stay in their social comfort zone in both virtual and real space (P5, P6, P8). Below is the quote from P5, Group 3 (a group made of two strangers):

"I rammed him once at the beginning, but he did not ram me back, so I stopped…I guess I need to be polite... I just stayed on my side and carried on fishing…"

This is one example of how social norms can override game play strategy. It also reveals that, when designing multiplayer handheld games, social interactions can not be "forced" as players may prefer to remain in the private gaming sphere of their own device.

- **Exposure of technology**

Using the shared board gives players the possibility of interfering with the other's game play by leveraging the technology (and capitalizing on its limitations). Some social groups might deem it inappropriate to impede the other player's game play via physical contact, but it is also easy and fun to manipulate the shared space to the same ends. As mentioned in above section, P10 tried to block P11's view on the screen by putting her Gizmondo on top of the other one, and P3 tried to occupy better physical position for tracking. Both of these examples showed that players are strategically embedding their understanding about how system works into the game play. However, the limits and seams of the technology are equally exposed to both players.

- **Emotional intensity**

Although the proximity between players was approximately constant in each mode, the shared board mode resulted in a stronger self-report of "being together" than the other two modes (ShB vs. SS, t-test, t=3.12, p=.003; ShB vs. SepB, t-test, t=2.57, p=0.012), which was accompanied with the increased numbers of emotional bursts seen in the video. Interestingly, we found two groups (group 2 and 8) in which both players had a stronger sense of "being together" under shared board mode, despite the difference in mode preference: one player prefers shared board (ShB), while the other prefers separate board (SepB). Below is the quote from Group 2.

P3: *"I like the shared board best. I just like it because I know where he is looking… I will assume generally where he is looking, and I am going to bother him along."*

P4: *"I like the separate but close. Everyone has their own (board that they can work on their own). You don't have to worry about bumping elbows with anybody."*

P3: *"I like it though; I can get to your way" (laugh)*

P4: *"(That was a) Distraction~" (both laugh)*

This example shows that a stronger sense of "being together" leads to more intense emotional experiences, which could be more exiting or more frustrating for different players. When designing games with shared physical spaces, we need to take the emotional reinforcement into consideration, so that the negative emotions, such as feeling more vulnerable and losing control, do not overwhelm the players.

6. DISCUSSION

In this research, we focus on handheld AR games that create a shared physical/virtual world situated in the physical space occupied by the players. This style of game is interesting because during game play, the handheld device begins to feel more like a portal into the augmented physical world, rather than the game space itself. This is important because, unlike the studies showing reduced collaboration in multiplayer handheld games (e.g., on the Nintendo DS) in comparison to console games, we have found that multiplayer handheld AR games can foster a strong sense of shared play. We believe that by moving the focus of game play into the real world, this kind of AR game leverages the physical, social and perceptual systems of the players to create a sense of physical and social presence in the game space.

The strong sense of the game being "in" the world opens up new possibilities for play and game design. Consider, for example, that many of our subjects seemed to observe social norms while playing BragFish, much more so than might be expected in competitive computer games (e.g., by respecting each other's physical space). Just as games like Twister play on feelings about personal space, so too may handheld AR games successfully leverage mechanics that require people to occupy each others' space. Similarly, AR games could require players to synchronize their physical movement through space in a much more sophisticated and subtle way than current rhythm games.

One thing we have not explored with the BragFish prototype is the effect of physical interaction with tangible props in the play space. Many AR researchers and designers believe strongly that adding props, such as cards or trackable game pieces, will generate an even stronger sense of the AR environment being tied to the physical space. As with many of these researchers, we have created many small demonstration systems that use multiple fiducial markers to support physical interaction with the AR content. For example, we created a demonstration of an animated virtual dog that walks around a marker board on the table. The player has two cards, one representing a food bowl and one representing a ball. When they are placed in the play space with

the dog, he reacts appropriately, running over and eating the food or playing with the ball. If the card is moved while he is eating or playing, he runs after it. While this interaction is very simple, our anecdotal experience suggests that it is extremely compelling. Both children and adults want to get their picture taken with the dog, play with the cards for longer than we would expect, and try to see what other actions (e.g., petting or poking) the dog might react to. What is interesting is how such simple interactions are so compelling, by simply appearing to be "in" the real world. The question, then, is how would the ability to tangibly interact with the virtual elements in the game like BragFish change the game? We would hope to see more social and physical interaction and an even greater sense of presence and shared play.

7. CONCLUSION AND FUTURE WORK

BragFish was the object of study for our research group as we developed an understanding of how handheld AR technology influences the experience of social play. Over the past two years, the game evolved in parallel to other research efforts, being tested and redesigned continuously. BragFish exemplifies our growing belief in the importance of a shared augmented play space, one that is tightly registered with the physical world so that players can rely on their senses and perceptions of how each other are moving and what those movements mean in the game context.

As we move forward, we are interested in exploring different ways of creating shared augmented spaces beyond using large physical game boards. The rapid pace of technology development will soon make technology such as natural feature tracking possible on mobile devices, allowing us to create games in spaces that are not covered in predefined marker patterns. We are also designing games to make more use of physical props, from game pieces to cards, to explore the impact of such tangible interactions.

In the long run, we hope to continue exploring the potential of AR as a medium for social gaming. Whether through collaborative tabletop games like BragFish, or through wide-scale outdoor games (as technology improves), we believe that immersing players in augmented play spaces, where they have a strong shared sense of social and physical presence, has the potential to revolutionize how people perceive and play games.

8. ACKNOWLEDGMENTS

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