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Co-located many-player gaming on large high-resolution displays

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***Abstract*—Two primary types of multiplayer gaming have emerged over the years. The first type involves co-located players on a shared display, and typically caps at four players. The second type of gaming provides a single display for each player. This type scales well beyond four players, but places no requirement on co-location. This paper will attempt to combine the best of both worlds via co-located many-player gaming on large high-resolution displays.**

Results show that with more people, a greater amount of the time during a game was filled with vocal interactions between players. There were also more physical movements in the larger games. Over the course of this study, we learned that good high-resolution games will: provide a singular gameplay area, take advantage of the physical space in front of the display, provide feedback that is localized to each player, and use input devices appropriately.

Keywords- high-resolution, multiplayer, co-located, gaming, large tiled display, collaborative

I. INTRODUCTION

Multiplayer gaming has evolved considerably over the years. However, two primary types of multiplayer gaming have emerged. The first type involves co-located players and a single, shared display. This type of gaming has historically had a cap of four players due to space constraints. The second type of gaming provides a single machine for each player and provides multiplayer over a network. This type of gaming scales well beyond four players, but places no requirement on co-location. This paper discusses work that attempts to combine the best of both worlds, in the process creating many-player gaming. A many-player game is one in which more than four co-located players share a single display.

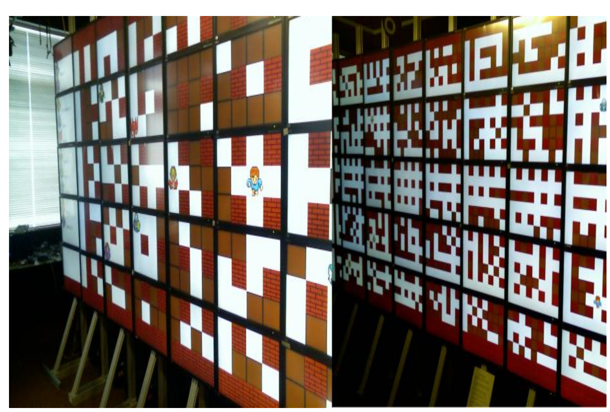
The catalyst enabling this new type of gaming is the rise of large, high-resolution displays. While still far from mainstream, the use of multiple high-resolution displays is becoming much more affordable. The reason why older co-located games have stuck to four players is one of space. A television provides only so much screen space to work with—if more than four players were to play together, the amount of space available to each player (physical and virtual) would become too small. Large, high-resolution displays address this issue both in terms of resolution and in the large physical dimensions of the display itself.

Because of the high resolution, a much greater volume of information can be displayed at any one time. This information capacity can be put to use to increase both the number and detail of game objects.

There are two useful qualities to the physical dimensions of a large, high-resolution display. The first of these is the large size of the screen itself, both in physical space and in pixel density. The second quality is the large open space that is typically present in front of such a large display, allowing players to move to a larger extent than in other situations. This open space creates numerous possibilities for both game design and for the interaction amongst players in a game. They are now able to move around both in the game sense as well as in a physical one. The players' physical presence can become an aspect of the game, either as an active part of playing the game or inadvertently as players move about the space in response to the game.

This space also opens the door to incorporating physical actions into the game itself, similar to the trend that has begun with the Nintendo Wii. The physical actions would be a distinct part of the game.

FIGURE 1: PYBOMBER RUNNING IN FOUR- AND TWELVE-PLAYER MODES



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Another motivation behind this paper is to study what sorts of group dynamics evolve when such a large number of players are playing together on a large display. When scaling beyond the typical four-player co-located games, larger groups may have different interactions and dynamics than smaller groups. These differences may be all the more pronounced due to the shared nature of the display. This paper hopes to find some evidence one way or the other.

Overall, this paper is an exploratory study for a new area of research. It attempts to answer some of the fundamental questions about games on large, high-resolution displays with many players. These questions involve both the design of such games as well as player response to them. The research questions are as follows:

- What kinds of social interactions occur among so many players? Are they any different from those that take place with four players?
- Does team-based gameplay have an effect?
- How do players move and physically interact in the physical space in front of the display? How do they react to other players getting in their way?
- Are there any special design principles for high-resolution games?

In this paper, we describe a study which examined the social interactions and physical movements of players in a high-resolution game with a varying number of players and two types of gameplay. We demonstrated that the social dynamics and typical movements change as the number of players increases.

We also share some of the lessons that were learned with respect to the design of high-resolution games. These lessons take the form of a series of characteristics that a good high-resolution game should possess.

II. Related Work

. The indication from previous studies is that users will prefer to move around the display to gain better insight into a particular location [1, 2]. Due to the nature of the shared display and game area, virtual navigation is not present. However, when run at full resolution physical navigation will be important in attempting to see the entire display at full detail. It has been shown in previous studies that when forced to navigate, 100% of users preferred physical navigation to virtual for several general types of tasks [3].

The most closely related study on high-resolution gaming was conducted at Virginia Tech [4]. This study involved high-resolution gaming compared to normal desktop computers. Matches were conducted between normal computers running a strategy game and the same game played across a high-resolution display. The findings were that players on the high-resolution display performed significantly better than those on the normal desktop computer.

III. The Game

Since there are no preexisting many-player games on high-resolution displays, a custom game was created to be used in studies. This game is known as PyBomber. The basic game mechanics of PyBomber were inspired by the classic game called Bomberman.

The goal of PyBomber is for a player to blow up as many other players as possible, while minimizing the number of times he or she is blown up. Players score one point each time that they kill another player. Players lose a single point every time they kill themselves.

At the start of the game, a significant portion of the gameplay area is filled with brown blocks. These blocks serve two purposes. The first purpose is to create an unpredictable gameplay area. The second purpose of the blocks is to provide powerups. When hit by an explosion, a block is destroyed, stops the explosion, and sometimes provides a powerup to the player.

PyBomber can be played in two different configurations: team and free-for-all. The free-for-all variant of the game pits every player against every other player. In the team variant of PyBomber, the players are split up into two equally-sized teams: blue and green. In this mode, killing a teammate is grounds for a single point to be deducted from that player's score. All of the players on a given team have their player image tinted to reflect their team color.

The resolution of PyBomber in four-player mode is 4000x1500. When there are twelve players, the resolution is increased to 8000x3000.

IV. Experiment

Since high-resolution, many-player gaming is a new field, this study is exploratory in nature. The independent variables in this study are the number of players and the type of gameplay. The study includes both four- and twelve-player variants of PyBomber. The two types of gameplay are team and free-for-all.

A. *Hardware Used*

All trials were run on the GigaPixel display. The GigaPixel display is a large tiled display that is composed of fifty monitors powered by a cluster of twenty-five computers. Each monitor has a resolution of 1600x1200. The total resolution of the display is 16000x6000, or 96 megapixels.

Players interact with the game using a Nintendo Wiimote. Each player is provided with his or her own Wiimote to use. An ordinary laptop computer with Bluetooth was used forward input from the Wiimotes over the network to the computer running the game. Video footage of the user trials was recorded digitally from cameras mounted on the roof of the lab space.

The space in front of the GigaPixel display is approximately 18ft wide and 9ft deep. This space is completely open for movement by players, with no chairs or other obstacles.

B. *Experimental Design*

Both of the independent variables, the number of players (4 or 12) and the gameplay type (free-for-all or teams), were run within-subjects. The conditions were applied to groups of four, rather than the specific participants within said group. To balance these conditions, the ordering varied amongst them. The number of players could either be four and then twelve, or twelve and then four. The gameplay could either be free-for-all then team, or team then free-for-all. Every fourth group of participants would be exposed to a particular ordering.

A full trial involved two groups of four participants. The first group of four would arrive and play the four-player variant of PyBomber. Within the four-player variant, they would have three rounds of the first gameplay condition. They would then play three rounds of the other gameplay variant.

At this point, the second set of four participants would arrive. Also, a group of four "filler" players would arrive. The filler players' purpose was to pad out the game to the full twelve players without requiring twelve actual participants. The primary difference between filler players and participants was that the fillers were not being studied. Since they were not being studied, they were able to play in multiple sessions. This reduced the number of participants needed for the full set of user trials by a third. It is important to note that the important factor is having twelve players involved in the game, not that all twelve players are experiencing PyBomber for the first time.

The twelve-player trial would then commence, following the same team/free-for-all ordering as the four-player trial that just concluded. Three rounds of each condition would still be played. After finishing all six rounds of PyBomber, the first group of four participants and the four filler players would depart.

At this point in time the second group of four participants would stay around and play the four-player variant of the game. Again, the ordering for team/free-for-all would remain the same. It would also involve three rounds of each condition. After the six rounds were concluded, the four participants would depart.

This layout of user trials provides an equal number of participants experiencing four- and twelve-player games first. However, every one of these participants would have experienced the same gameplay type first. In order to balance this out, the next trial would have everyone experience the other gameplay variant first. Together, this experimental design balances both of the independent variables' ordering effects.

C. *Demographic Information*

A total of thirty-two participants participated in user trials for PyBomber. Twenty-eight of the participants were male, while the remaining four were female. The average age was twenty-four years old, with a minimum of nineteen and a maximum of thirty-three. A majority of participants were students, nine undergrads and thirteen graduate students. When asked to rate their skill with video games, twenty-six of the participants rated themselves as intermediate or advanced.

The four-person groups of participants were recruited as a whole. This was an attempt to maximize the players' familiarity with each other. It was hoped that the players knowing each other prior to playing the game would increase the potential for social interaction.

D. *Data Collection*

Every trial of the game was recorded both on video and in the game itself, as a replay. The replay enables researchers to re-watch any individual round in its entirety. It is also possible to go back and as a batch re-run all of the trials to gather specific information. The specific information that was harvested from the replays was the number of kills, deaths, suicides, and team-kills for each and every participant in each and every round.

The video was processed similarly to the game recordings. Every trial was run through VCode [5], a video tagging program, with the purpose of tagging specific actions within the video. The tagged actions are: utterances, conversations, trash talk, physical reactions, movements, and view adjustments. Duration was also captured for: conversations, trash talk, and movement. Everything else was simply a point in time.

Utterances: any vocalization by a participant. A single utterance could be as simple as saying "yes" or as complex as a sentence. During a conversation, each new response was counted as an utterance.

Conversations: any dialog between two or more participants. A single person speaking does not count as one. The beginning of a conversation was tagged when the first person begins speaking, and ends when the last response finishes being spoken.

Trash talk: any speech by a player that was interpreted as a taunt by the analyst. This metric was tagged in a similar fashion to conversations.

Physical reactions: when a player reacts to the game in a very obvious way. An example of such a reaction would be a participant throwing their hands up in the air after dying in the game.

Movements: whenever a participant was changing location by more than two feet. Any small motion, such as shifting weight around or taking a single step, was not counted as movement. Movement tags remained active as long as one or more participant was in motion. The movement tag was begun when a participant started moving, and ended when the last participant stopped moving.

View adjustment: whenever a player made some sort of visible motion, involving more than just their head, to get a better view of the game. Simply looking around did not count. A common example of view adjustment was a person craning their neck to see around someone standing in front of them.

E. *Video Analysis*

No significant differences were ever found between team and free-for-all gameplay. Therefore, all of the following analysis will disregard team or free-for-all as a variable, since it made no statistical difference in any of the results.

Before analysis, all of the data was normalized by the number of players in the game. This normalization allows a comparison of how many times the average player would perform each of the measured actions. These results can be seen in Table I.

Every one of these results was statistically significant ($p < 0.05$) save one: the number of utterances per person. The number of physical reactions, conversations, and trash talks per person all declined when moving from the four-person variant to the twelve-person version. However, the number of movements and view adjustments increased significantly.

A different way of looking at these results would be to see how the social interactions fill the time that is available. In order to help find this out, all of the metrics recorded during a round were divided by the duration of that particular round (in seconds). This provides an idea of how many instances of each metric could be expected per second. These results were then inverted, to provide the average number of seconds that could be expected to pass between occurrences of that metric. All of the values, as well as their significance, can be seen in Table II. A graph of them can be seen in Figure 2.

Across all of the metrics, the amount of time between occurrences was significantly lower in the twelve-player variant of the game. This is most pronounced in movements and view adjustments.

TABLE I: THE VIDEO ANALYSIS METRICS, NORMALIZED BY PLAYER COUNT

Metric	4 player average	12 player average	p-value
Utterances/person	13.20	11.99	0.18
Conversations/person	0.66	0.37	0.0024
Trash talks/person	0.23	0.15	0.032
Physical reactions/person	2.47	2.03	0.043
Movements/person	0.063	0.35	<0.0001
View adjustments/person	0.016	1.74	<0.0001

TABLE II: THE VIDEO ANALYSIS METRICS, NORMALIZED BY TIME

Metric	4 player average	12 player average	p-value
Seconds between utterances	4.62	1.56	<0.0001
Seconds between conversations	69.98	55.07	0.03
Seconds between trash talks	135.43	106.00	0.02
Seconds between physical reactions	18.87	10.08	<0.0001
Seconds between movements	129.76	55.16	<0.0001
Seconds between view adjustments	192.664	12.08	<0.0001

Another interesting analysis to perform is to look at the percentage of a given round that is filled by these metrics. For example, it can be seen in Figure 3 that in the four-player variant of the game, almost no time is spent moving. However, in the twelve-player version of the game, about 9% of any given round was spent with one or more players physically moving around the play area. Every single one of these metrics proved to be statistically significant.

In order to gain further insight into how a round is comprised, the utterances that make up a round were mapped to a timeline. These timelines can be seen as Figure 4 and Figure 5. All of these timelines involve the same people. The four-person group in the first set of timelines was a part of the twelve-person group that is shown in the other set.

An interesting result that can be gleaned from these timelines is that the utterances are bursty in nature. This is especially obvious in the four-player version of the game. In the twelve-player version, many of the bursts of utterances overlap, leading to a consistently high level of speech.

It can be seen from these timelines that the four-player rounds were fairly sparse in terms of communication. Large gaps in speech were commonplace. The twelve-player variant differs from this in that a sizeable portion of any given round is filled with utterances.

The time between rounds of the game typically involved the players gathering and talking amongst themselves. This sort of social interaction is to be expected with such a large group of people. Nonetheless, the co-location of the players is critical to their continued interaction.

FIGURE 2: THE VIDEO ANALYSIS METRICS AND THE TIME BETWEEN OCCURRENCES

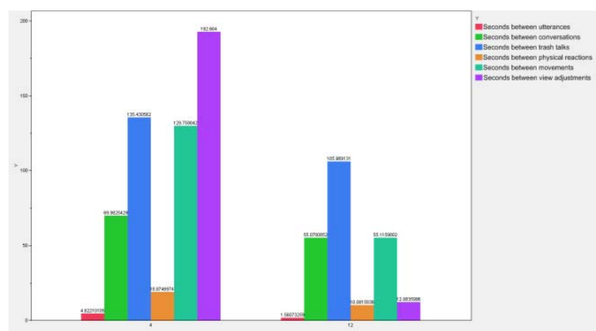


FIGURE 3: THE PERCENTAGE OF A ROUND FILLED BY VARIOUS METRICS

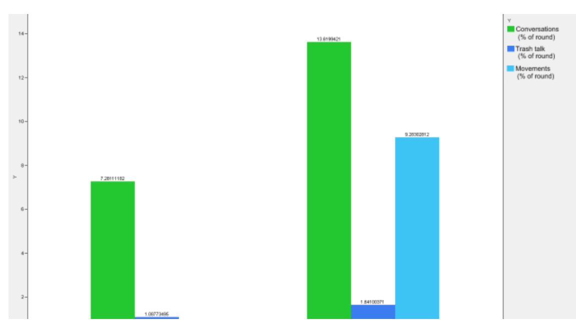


FIGURE 4: TIMELINES OF THE UTTERANCES FOR ALL ROUNDS PLAYED BY A FOUR-PERSON GROUP

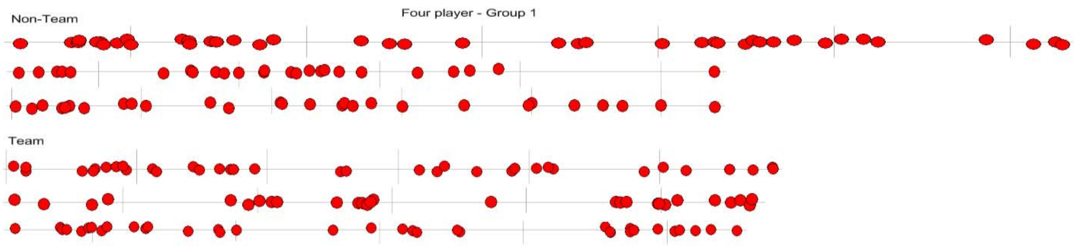
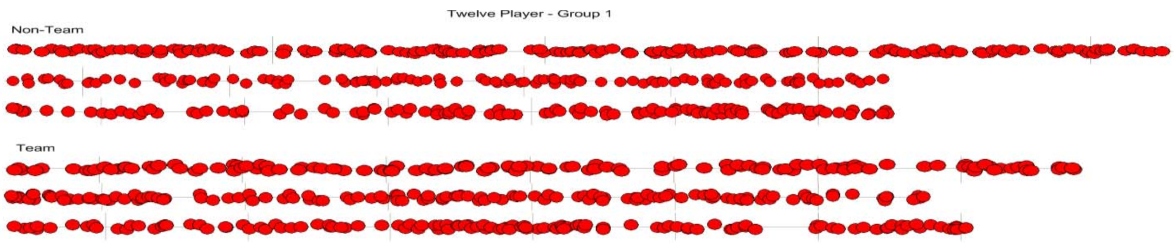


FIGURE 5: TIMELINES OF THE UTTERANCES FOR ALL ROUNDS PLAYED BY A TWELVE-PERSON GROUP



F. Discussion

1) Movement

The amount of movement in the twelve-player condition proved to be much higher than in the four-player condition, even when normalized by the number of participants. A small number of movements can be explained by direct physical interaction between players. For example, after being killed by a teammate one participant moved to the player who had just killed him and shook the other participant to make it clear that he did not enjoy being killed by his own teammate.

Nonetheless, another type of movement happened with some regularity. This type of movement was a participant moving a significant distance in order to improve their view of the game. It almost never happened in the four-player variant of the game, but did occur throughout the twelve-player trials of PyBomber.

This probably happened since the large number of players got in each others' way. They also occurred because objects in the twelve-player version of the game were smaller, requiring players to more closely follow their progress on the display. The combination of these factors led to many interruptions in a player's view of the game.

A common side-effect of this movement would be that another participant's view would be blocked by the movement, causing that person to also move for a better view. This sometimes triggered a chain reaction. In one extreme case a participant moving across the front of the display caused almost every single player to frantically shuffle around to regain a clear view of the screen. This shuffle lasted until the end of that particular round.

For the most part, these view blockages were unintentional. Players did not seem to put any consideration into whether they were blocking someone else's view when they moved. When reacting to a view blockage, a player rarely said anything. The reason for this silence and the non-caring of blocking another player's view is most likely the game itself.

Since everyone was focused on the game, the level of concern they expressed over this normally socially-discouraged action was minimal. Players reacted to a view blockage without much complaint: they just wanted to be able to see again as soon as possible, to prevent themselves from dying in the game.

On rare occasions, the view blockages were intentionally perpetrated by another player. These blockages were short-lived in duration. Usually, the blocking player would quickly lose interest in blocking the other player and cease his or her actions. The merit of this strategy is also questionable, since it draws the player's attention away from the game itself, leading to a highly increased chance of dying in the game.

On the other end of the spectrum, many smaller movements occurred to aid a participant's vision. These movements were recorded in the video analysis as view adjustments. The larger movements discussed above highlight the extreme side of this spectrum. However, there were numerous small motions, such as craning a neck, that were performed in the interest of getting a better view of the screen.

As seen in the results above, view adjustments almost never occurred in the four-player version of the game. However, in the twelve-player variant, they happened approximately twenty times per round. View adjustments serve as an example of players moving as part of playing PyBomber.

2) *Verbal Interactions*

The volume of time filled by social interactions in the twelve-person version of the game is much higher than in the four-person variant. This is evidenced by the significantly lower amount of time between each type of interaction. It is also demonstrated in the timelines of utterances provided in the results.

It was noticed while analyzing the video of the user trials that the social interactions were bursty in nature. This means that something of note would happen in the game, triggering a brief period filled with utterances, physical reactions, and possibly full conversations. These triggers were often several players dying simultaneously.

The crucial difference, though, was that these bursts occurred much more frequently in the larger games. The most likely reason for this is that the larger number of players involved in the game led to a larger number of interesting events, which in turn triggered a larger stream of outbursts. Together these increased the volume of social interactions considerably.

Four-player games of PyBomber had frequent and lengthy periods of quiet. The bursts of activity were still present, but they occurred much less often, leading to these long periods of quiet. In contrast, the twelve-player version of the game had almost nothing in the way of quiet periods. Between so many players, something interesting would happen often enough to trigger a burst of activity such that the social interactions were often a constant throughout a given round.

This phenomenon is backed up by the significantly lower number of seconds between utterances and conversations in the twelve-player games. Further evidence of this is the percentage of a round that is filled with conversation or trash talk. Both of these events comprised significantly larger portions of the time. In the case of conversation, the percentage of a round made up from this type of interaction jumped from about 7% during four-player games to over 13% in twelve-player ones.

An interesting occurrence in the user trials is the huge disparity between the number of utterances and the number of conversations. It is to be expected that the number of utterances is higher, since a conversation is by definition made up of at least two utterances. However, the vast majority of utterances provoked no response. Very few statements by one player solicited a response from another. In some of the trials, this became so severe that it was like seeing twelve people have conversations with themselves. Players would constantly be talking, but none of the talking was ever directed at another player.

A notable link can be drawn between physical reactions and utterances. In a very large number of cases, a physical reaction was accompanied by an utterance. Physical reactions were very strongly associated with dying in the game. After being killed, on many occasions the player would shout some kind of expletive and then react physically. Common reactions included: turning around and walking a few steps away, throwing their hands up, and punching the air.

V. DESIGN OF GOOD HIGH-RESOLUTION GAMES

The design, construction, prototyping, and user trials of PyBomber have provided a sizeable amount of insight into the characteristics of a good high-resolution game. The following points are broad design criteria that should be considered as part of the design in any enjoyable high-resolution game.

A. Single gameplay area or split gameplay area

The primary strength of high-resolution displays is their ability to display large volumes of data at the same time. There are two broad methods of utilizing this ability: a single, shared gameplay area or the use of split views.

Split views on a large high-resolution display allow multiple players to have their own unique views of the game space. Due to this, the size of the gameplay area can be larger than any of the views would be capable of displaying without loss. However, the use of unique views may limit players to a single portion of the display.

As a consequence of unique views, there is the possibility of non-global data. In the case of a shared gameplay area, all information can be seen by all players. When the view is split up, there is a possibility of displaying different information in different views. However, the co-location aspect of the game would still allow "screen watching" by other players.

The use of a single shared gameplay area has several benefits associated with it. The first of which is that the size of the game area scales directly with the resolution of the display. Because of this, increasingly large displays will get an increasingly large gameplay area free of virtual navigation. This area can also support a larger number of game objects simultaneously.

Another benefit of a single shared gameplay area is that a player will be able to utilize the entire display, rather than being limited to a specific portion like they would be with split views. In addition, the single, shared view of the game space will provide a common focus amongst all of the players. This singular focus is expected to provide a greater level of collaboration [15] and allow for richer social interactions.

As a tradeoff, the use of a single shared gameplay area does not support the ability to show different data to different players. Since the entire view into the game space is global, so is all of the information that it displays. Also, problems may arise if and when players cluster in the game space. This clustering may lead to a clustering in the physical space close to that specific part of the display, leading to an uncomfortably crowded portion of space.

Both types of gameplay areas have their tradeoffs. It is important for the designer of a high-resolution game to weigh the benefits and negatives of each approach and choose the method that is best suited to the game in question.

B. Use of physical space

There are several new paths opened up by the physical dimensions of a large high-resolution display. It is important for high-resolution games to take advantage of this space one way or another.

One of the simplest ways to use this space is to increase the number of players that share the space in front of the display. PyBomber uses this approach to allow a dozen players to play simultaneously. Without this space it would not have been possible for so many players to coexist comfortably.

The physical space could also be used with physical navigation to provide a modified version of the overview plus detail design pattern [7]. This approach would be well-suited to strategy games. It would allow a player to move further from the screen to gain an overview of the game world, or to move closer to the screen for detailed information on a localized portion of the world.

Physical interactions with the game, or with other players, are another good use for the physical space in front of a large high-resolution display. This space provides enough of an area for players to physically interact while minimizing the possibility of collisions– either with each other or with the display itself.

C. Localized feedback

Due to the large size of these displays, in terms of both physical size and resolution, normal feedback mechanisms will not always work. It is typical for a video game to put feedback on the periphery of the display. This design pattern scales poorly to large high-resolution displays, since the periphery of a high-resolution display is not necessarily within the periphery of a player's vision.

It is imperative that games provide localized feedback to the players. This type of feedback "follows" each player around in the game space. Because of this, the players will not have to look far away from their position to gain feedback.

A large portion of the changes that were made to PyBomber throughout the course of play-testing involved the localization of feedback. It turns out that in general, players will be unwilling or unable to look around for feedback. An example of this is the scoreboards on both sides of the screen in PyBomber. These display each player's score in gigantic letters that can be read from far away, yet many players never even noticed their existence. The problem was that they were not localized, and because of that they were simply ignored.

It is important for high-resolution game designers to consider what information should be localized and what information can be pushed to the periphery. The amount of feedback that can be localized has limits, so it is important that only the most important information is localized.

D. Appropriate use of input devices

As with many other constructs, input devices do not necessarily do a good job of scaling up to high-resolution displays [8]. It is vital to evaluate the possible input devices in the context of the game that is being designed. In the case of PyBomber, this was as simple as choosing commodity wireless controllers.

Other games may need to take this consideration a step further. The previously mentioned high-resolution gaming study involving strategy games spent a significant amount of time modifying the user interface to retain its usability when scaled up to a large display [4].

This characteristic also includes any physical interactions that are incorporated into the high-resolution game, since the actual players become another input device. Whether through motion tracking or another method, it is important for the game to design the physical interactions in such a way that they are appropriate to the game at hand.

VI. Conclusions

As seen in the results above, the social dynamics in a co-located high-resolution game shift when the number of players increases. The time in a large game was filled to a much greater extent with social interactions. Most of these social interactions took the form of utterances. Interestingly, few of the utterances were part of an actual conversation.

These utterances, along with many of the social interactions, were triggered by the game itself. Because of this, they were bursty in nature. The triggering events, such as several people killing each simultaneously, occurred more frequently in the larger games.

It is interesting that we observed the virtual aspects of the game to be too involved in some ways. This tended to lead to people being completely focused on the game while neglecting the social interactions around them. This was evidenced by the large volume of talk contrasted with the limited amount of true conversation.

The exception to this occurred between rounds, where players would gather and talk. We were able to see some initial aspects of rich social dynamics, such as people moving around each other and talking often. There is an opportunity to reduce the intensity of the virtual game and bringing more physical-social interactions into the fold. These interactions would involve both a social and a physical component, such as blocking another player's view, tagging another player, or moving to a special physical location to trigger an in-game effect.

In this study, a small number of physical-social interactions took place. These were mainly limited to occasions where a player purposely blocked the view of another, or when someone pushed someone else. There was a high level of variation between the groups. In the future, it may be possible to study why that is, and if there are any ways to encourage it.

Instead, the movements typically seen throughout the trials, especially with twelve players, revolved around viewing. Many of these were simple reactions to a view blockage. However, about 10% of a twelve-player round had at least one player moving a significant distance, usually with the goal of getting a better view.

There were no measurable differences in the social interactions between the team and free-for-all versions of the game. The reason for this is likely that PyBomber's team-based mode had no over-arching team goals that encouraged collaboration.

CONTRIBUTIONS

This study has served to provide a base upon which other high-resolution and/or many-player games can build. A goal was to demonstrate the feasibility of this new type of gaming. In many ways it was a success.

This study has also shown that when so many people are playing together in the same space, they will move around and interact verbally. It will be possible for future studies to use this as a foundation when looking at the dynamics of large groups of players.

The characteristics of good high-resolution games are something that can be applied during the design phase for any future high-resolution games. They should help to maximize the potential utilization of the large high-resolution displays that the game will run on.

FUTURE WORK

There are two primary directions in which future work could head. The first direction would focus on many-player games. Work would involve creating (or modifying) a game to take even greater advantage of the large gameplay area. This could also involve the incorporation of a higher level of support for team-based gameplay. This work would segue into running more user trials on high-resolution, many-player gaming. The goal of this work would be to gain a greater understanding of group dynamics in large games.

The other possible direction would be to put more focus into individual social interactions. This work would still involve multiplayer gaming, but it could work on a smaller scale than twelve players. A focus would be placed on forcing interactions in the physical sense, in addition to the already-present game interactions. This could be accomplished through any number of methods. The physical space in front of the display, along with the tracking system installed above it, could be incorporated into the game in a more pervasive manner.

Future studies could look at people playing multiplayer games and the interactions between them at a greater level of depth. A focus could also be put on the players' level of engagement in the game and its effect on the social dynamics. The analysis in this paper was fairly high-level in nature.

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