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The Effect of Tangible and Multitouch Interfaces on Game Performance

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The Effect of Tangible and Multitouch Interfaces on Game Performance

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by
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Abstract

Over the past few years, the video game industry has seen an explosion of innovative new interfaces. From touch-based mobile games on the Apple iPhone and Nintendo DS to console titles on the Nintendo Wii and Xbox Kinect requiring players to physically move around their living rooms, the definition of 'video game controls' has expanded far beyond the traditional controller. Although such novel control schemes have been met with unarguable commercial and critical success, little research has been done to explore the effectiveness of these interfaces from the standpoint of user performance: we do not know if touch- and tangible-based interfaces make us better gamers, or to what extent they might. This paper explores this question, specifically looking at how such interfaces can improve player performance by providing a more natural and direct means of interacting with the game and by enabling players to multitask more efficiently in-game. To accomplish this, a game was developed for the Apple iPad that was designed to be controlled in three different ways: a traditional joystick interface, a multi-touch interface, and a tangible interface with a physical game piece, each with optional multitouch gestures. A custom automated analytics system was built on top of the game, allowing quantitative performance data to be gathered from user testing sessions held with Bard students.

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Dedication

This senior project is dedicated to the memories of all of the orange and pink squares that bravely gave their lives for the sake of this project.

Acknowledgments

Major thanks are in order to Keith O'Hara, my senior project advisor, as well as all of my teachers, friends, family, and everyone else who doesn't fit neatly into one of those groups but who nonetheless deserves acknowledgement for all the support they've given me.

1

Introduction

Until relatively recently, video game controls had been largely unchanged since the proliferation of the first generation of video games in the early 1980s. The number of buttons had increased, and the ergonomic shape of controllers had certainly improved, but with a few notable exceptions the fundamental paradigm of a plastic controller with buttons and a directional pad or joystick remained a constant.

The past few years, however, have seen an explosion of new game interfaces depending on tangible and multitouch input. The wild commercial success of Nintendo's DS and Wii consoles and the increasing popularity of Apple's iOS App Store as a gaming platform - as of December 2010, the Wii has sold 84.64 million units worldwide[1] to the Playstation 3[2] and the Xbox 360's[3] 50 million each, despite the Xbox 360 having been released a full year earlier than the Wii - are clear indicators that these new interfaces have been widely accepted by gamers of all kinds.

[1] http://www.nintendo.co.jp/ir/library/historical_data/pdf/consolidated_sales_e1012.pdf
[2] http://www.gamespot.com/news/6308755.html
[3] http://www.gamespot.com/news/6285921.html

Despite this surge in popularity, little to no research has been done on the effectiveness of these new interfaces; while there is a wealth of user interface research on tangible and multitouch interfaces in traditional computing, it has yet to be shown that moving away from a traditional game controller has a practical effect on gaming beyond attracting consumer interest.

This project explores the effect these new mechanisms of controlling games have on player performance. In short, it is trying to answer the question of whether the way a gamer physically interacts with a game affect their ability to succeed at the game. Specifically, this project uses a twin-stick shooter developed for the Apple iPad to target two facets of this question: the ways in which traditional, multitouch, and tangible controls each affect player performance, and how each of these interfaces affects usage of multitouch gestures designed as a simultaneous secondary input. Through qualitative interviews and quantitative in-game analytics data gathered from test sessions, this project aims to provide an increased understanding of how players respond to different levels of tactility and direct manipulation in game interfaces, with the hope that it will aid game designers to come up with more successful innovative game interfaces in the future.

1.1 Tangible Game Interfaces

The best-known example of tangible interfaces in gaming today is the Wii gaming console, released by Nintendo in 2006. Instead of using a standard video game controller, the system features a wireless remote control-like device outfitted with accelerometers and an infrared sensor. Although it can be modified using its expansion port to gain the same number of buttons and joysticks one would find on a more standard modern game controller, many games take advantage of the motion sensors to provide what could be described as tangible game experiences. In Nintendo's title *Wii Sports* (bundled with the Wii hardware), players are asked to swing the Wii Remote as one would a tennis racket while playing the Tennis game, or mimic the actions of throwing it like a bowling ball in the Bowling game. The Wii has been both a critical and commercial success for Nintendo. However, it is difficult to show decisively that the success of the Wii is due to its more physically engaging control scheme than to one of a multitude of other factors (Nintendo's aggressive marketing campaign, a library targeted at a wider audience of 'casual' gamers, etc).

The Wii games considered to use motion-based controls the most effectively are, generally speaking, not playable using a conventional control scheme. Their closest non-motion competitors tend to differ greatly in feature sets and core game mechanics. Conventional tennis games, for example, allow the player to move around freely and to accurately aim each shot with precise button controls, almost as if they were programming the outcome. Since it is so easy to control where your shot lands, the challenge comes largely from moving your player around the court appropriately. *Wii Tennis*, in contrast, controls the characters for the player, but the outcome of each shot is determined by the manner and timing in which the player swings their Wii Remote. The basic challenge of the game comes not from moving to the ball, but in hitting the ball the precise right way. The same can be said of touch-based interfaces; the most commercially successful iPhone and Android games tend to be the ones whose controls focus on direct manipulation of the game elements using multitouch.

1.2 Touch-Based Interfaces

Touch-based interfaces have been around for decades, although they have traditionally been used primarily for mobile devices. Perhaps popularized with the Apple Newton in 1994 and then the PalmPilot in 1997, the first generations of touch-based devices relied on pressure-based resistive touch detection, and almost universally relied on a stylus for input.

Although the Palm platform found some minor success as a game device, the Nintendo DS was the first mainstream success using this sort of technology for gaming.

More recently, Apple's iOS devices and other touch-based smartphones have gained popularity as gaming devices. The iPhone and iPad detect touches using electrical capacitance, rather than pressure. This has two practical effects. First, a stylus is unwieldy, as all touches need to come from an organic source or capacitive material connected to an organic source. While this has not proved a major technical issue for stylus manufacturers (in South Korea, frozen sausages have skyrocketed in sales recently as iPhone users found they were effective in controlling their phones in the cold weather), this design decision encourages a model of direct manipulation, with users touching user interface elements on the screen directly rather than using an intermediary object such as a stylus.

Secondly, capacitive-based touchscreens allow for multitouch. Each iOS device can detect up to 11 simultaneous unique touch points, as opposed to the one allowed by resistive screen technology. Research studies have suggested that multitasking using multiple hands (as in a multitouch iOS device) is more efficient: a 1986 study found that asking users to multitask with a two-handed input system resulted in better performance from both novice and advanced users, as well as a lessened skill gap between novice and advanced users[2]. Furthermore, a 2009 study conducted at the University of Massachusetts Lowell found that 100% of test participants asked to perform gestures to control robots used multi-hand gestures without any prompting; while users with iPhone experience were significantly more likely to use gestures found in iOS such as the pinch gesture, this propensity towards multitasking was universal among test participants[7].

Given the prevalence of studies such as these, it would appear that there is something inherently appealing about multitouch interfaces. While such research has not previously been performed in the field of gaming specifically, it is not hard to see how multitouch interfaces might be used to make interfaces that allow gamers to perform better without an increase in innate skill.

1.3 Twin-Stick Shooters

The game designed for this project is a 'twin-stick shooter', a genre that originated in 1982 with the arcade title *Robotron: 2084* but has since seen a comeback on the iOS platform. While most arcade games in the early 1980s featured large scrolling levels, Robotron placed the player inside a fixed game space with unlimited incoming waves of enemies. Instead of the then-standard control scheme of a single joystick for movement and a fire button, it featured two joysticks, allowing the player to fire in a direction other than the one the character was moving in. These design considerations became the hallmarks of the genre: nearly all twin-stick shooters place the player in a fixed space with the goal of killing as many enemies as possible before either the player dies or a fixed amount of time elapses, and give the player the ability to independently control their character's movement and direction of fire.

Recently, twin-stick shooters have become one of the most heavily represented genres on both the iPhone and iPad App Stores, an impressive achievement given that games are arguably the largest emerging market on the iOS platform. With a few notable exceptions, almost all of these iOS twin stick-shooters share a common control scheme: two on-screen 'virtual joysticks' that players manipulate as if they were physical joysticks (a la *Robotron*). It is interesting that, despite the range of expression possible with Apple's multitouch interface, twin stick shooter developers have chosen to closely emulate an interface developed for a 1980s arcade game.

2
Design Considerations

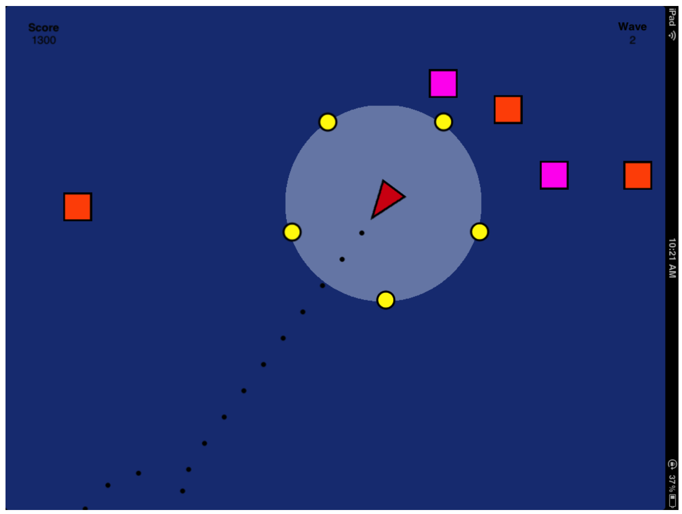

Figure 2.0.1. *Trigonometry Wars*, a twin-stick shooter for the iPad.

2.1 Overview

Trigonometry Wars is a twin-stick shooter developed for the Apple iPad. Both the genre of game and the 'virtual joystick' control scheme described in the previous section are well-established in the iOS gaming community, serving as strong reference points to base the study on. Furthermore, the wide possibilities afforded by the multitouch surface of the iPad mean there are a number of possible interfaces that can be explored that vary greatly from each other and from the traditional 'virtual joystick' method.

The game places the player in control of a red triangle surrounded by a series of yellow circle base points representing the players health. As enemies (colored squares) enter from all sides of the screen and attempt to attack the players base points, the player is tasked with destroying the enemies while evading their attacks.

Specifically, there are two kinds of enemies: pink squares and orange squares. The orange squares are slower, but have more health and deal more damage. All enemies select one base point to attack, and continually move towards that base point, damaging it when they touch. When the base point being attacked is destroyed, the enemy randomly selects a different base point to attack.

Enemies are spawned in ten-second waves. Within a wave, the game tests every 0.7 whether it should spawn an enemy; the spawn probability increases with each wave, meaning that later waves have more enemies than earlier ones. When an enemy is to be spawned, it is randomly chosen whether it is a pink or orange enemy. Each subsequent wave also increases the speed, total health, and damage dealt by each enemy at a linear rate. Once a player destroys all the on-screen enemies for a given wave, the player is given a brief (three-second) break before the next wave begins spawning.

To destroy the enemies, the player has two attacks. In the twin-stick shooter tradition, the players avatar shoots a continuous stream of bullets that can damage the enemies. Furthermore, the player can drop a bomb by drawing a circle anywhere on the screen. The bomb damages all enemies within the circles radius; the amount of damage dealt is inversely proportional to the size of the circle, forcing players to balance the trade-off between the number of enemies targeted versus how much they are damaged. The use of bomb gestures is unlimited, with their relatively large damage compared to the weak bullets encouraging players to use them as much as possible.

When an enemy or a base point is damaged or destroyed, the damaged object flashes red and a sound effect is played. There are five of these sound effects in total (one each for damaging and destroying an enemy or base point, and one for a successful bomb gesture), all in a lo-fi electronic style evoking early arcade games. For further feedback, the player's current wave and score is displayed at all times. Score is accumulated by killing enemies: a pink enemy is worth 200 points and an orange enemy 300.

Overall, the visual and aural aesthetic of the game is intended to be as nondescript as possible to let the controls be the more noteworthy part of the experience. The particularly large size of the players avatar (the area made up of the red triangle avatar and the circle of base points amounts to a relatively significant portion of the total screen size) is designed to encourage the player to move frequently, as the large size makes the player a particularly easy target for the increasing number of enemies. The sharp difficulty curve that progresses from wave to wave is intended to overwhelm the player to some extent, encouraging them to make use of both their bombs and bullets to keep the enemies at bay if they were not in the earlier levels. The unlimited use of the bombs is anotherkey point in guiding player strategy, with all of these factors collectively hoping to encourage players to multitask as much as possible by moving and using the gestures simultaneously.

The game's control interface can be divided up into two aspects: the movement, and the secondary multitouch 'bomb' gesture.

2.2 Movement

As described in Section 1.3, a defining characteristic of twin-stick shooters is the ability to control the direction of firing independently of the direction of movement. Three control schemes were developed with these considerations in mind: a traditional dual-stick interface, a multitouch interface, and a tangible interface.

It is worth noting that creating a game designed to be played with three very unique interfaces is problematic; as mentioned in Section 1.1, the games generally considered to use tangible and multitouch interfaces most effectively are ones that use them in such a way that the game would not be playable with a traditional controller. Such an approach to design, while useful for creating interesting new game experiences, does not easily allow for a quantitative comparison of interfaces. Subsequently, *Trigonometry Wars* has been designed such that each method of movement appears well-suited to the twin-stick genre, even if it is perhaps not the most innovative use of each interface.

2.2.1 Dual Stick

The first control scheme is the dual stick interface traditionally found in the game genre. Two virtual joysticks are present on-screen at all times, one on the bottom-left corner of the screen and one on the bottom-right. Figure 2.2.1 shows the location of each of these joysticks on the game screen, as well as a visual demonstration of how each functions.

The bottom-right stick controls the attack angle: placing ones finger anywhere in the circle causes the player avatar to turn and face the angle equivalent to where the finger lies relative to the center of the circle.

The left joystick controls movement. After setting a finger down inside the circle, moving in a direction causes the player avatar to move in that direction with a speed relative to how far the finger has been moved. This is meant to more closely emulate an analog joystick, where pushing harder in a direction causes more of an effect.

The chief benefit of this control scheme is its familiarity, as it is a control scheme that most players who would consider themselves gamers should be instantly at home with. It also provides a clear distinction between movement and rotation, as the two axes of movement are spatially differentiated. One potential weak point with this control scheme is its higher level of abstraction – other than by gaming convention, manipulating virtual joysticks would appear to have little relation to moving the on-screen character. Additionally, it requires two hands to fully operate, meaning that performing secondary gestures requires temporarily giving up some level of control.

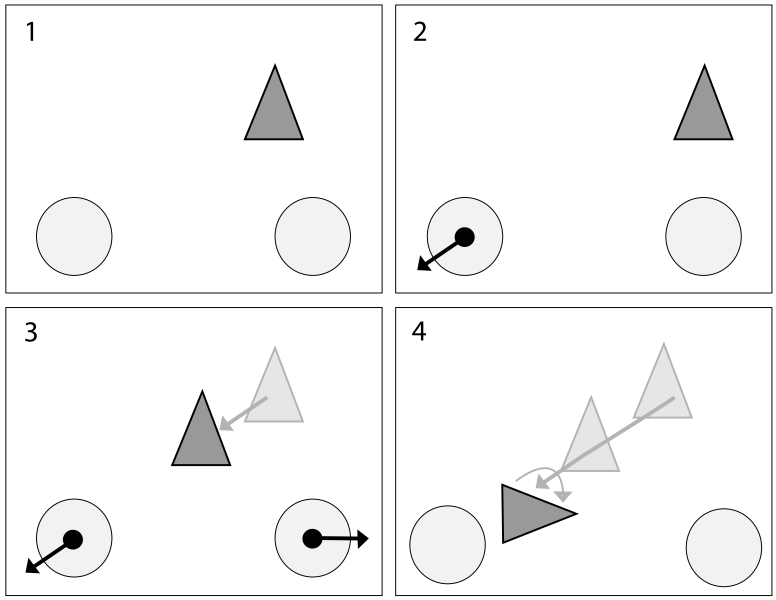

Figure 2.2.1. Movement and rotation are controlled independently by two virtual joysticks.

2.2.2 One Finger

The second control scheme, as seen in Figure 2.2.2, is still based on touching the screen, but does not rely on virtual joysticks. Tapping within the circle surrounding the player avatar and then moving one's finger controls both rotation and movement. Moving the finger within a small radius of the triangle character results in the triangle turning in the direction of the finger while staying stationary. Dragging the finger farther away from the triangle results in it moving in the direction indicated by the finger, as if it is following the finger.

This control scheme both offers more direct manipulation of the avatar than the dual stick control scheme and requires only one hand, allowing the player to perform gestures with their secondary hand while still controlling movement and rotation. The clear limitation of this control scheme is that it does not allow simultaneous independent control of movement and rotation. While it is possible to rotate without moving, one cannot move in one direction while firing in a different direction, a common tactic in twin-stick shooters.

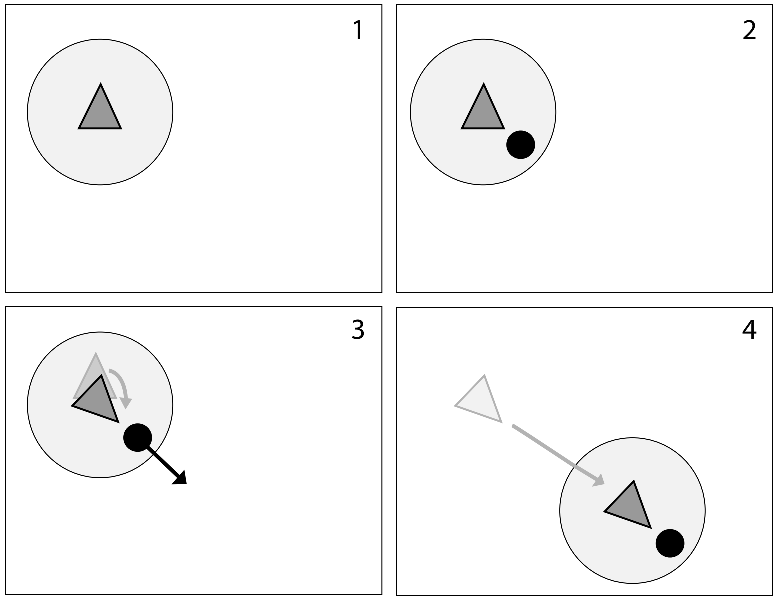

Figure 2.2.2. Both rotation and movement can be controlled with a single finger.

2.2.3 Tangible Game Piece

The third and final control scheme is a tangible one. Rather than interacting with the multitouch screen, the player moves around a physical game piece on the screen, with the on-screen avatars location and rotation directly mirroring that of the game piece. Technically, this is accomplished using capacitive foam and fabric glued to a knob-like plastic cylinder approximately one inch in diameter (see Figure 2.2.3). On the base of the piece are three pieces of capacitive foam arranged in an isosceles triangle formation; all other visible surfaces of the game piece are covered in two large pieces of capacitive fabric, with each piece of foam connected to these large pieces via smaller strips of fabric. When the player moves the game piece, the capacitance in their fingers transfers through the fabric and foam, causing the multitouch screen to register each foam piece as a touch point. From there, it is trivial to calculate the position and angle of the game piece using triangulation. A red triangle has been drawn on the top of the piece, showing the player which direction the game piece is facing while providing an aesthetic link to the player's in-game avatar.

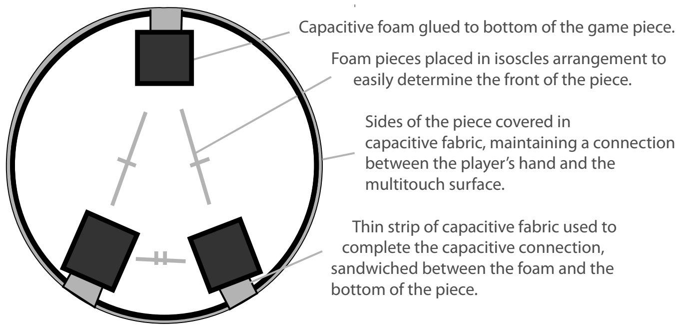

Figure 2.2.3. Construction of the tangible game piece.

A potential advantage of this control scheme is the increased range of control afforded by the physical piece. It offers the distinction between movement and rotation that the dual stick controls offer, but with the gestural freedom and sense of direct manipulation afforded by the second control scheme. It is also hypothesized that interacting with a tangible object, rather than the flat screen, will cause players to be more engaged in the game experience.

The drawbacks of the physical piece are also clear. The piece being used is relatively large, and it is possible that it will obscure the players view of the screen. Additionally, with a real-world object, real-world restrictions come into place; it is possible that the player could knock over the piece and lose precious game time reorienting themselves in the game, something that is not an issue with the previous control schemes.

2.3 Gestures

At the time of testing, *Trigonometry Wars* has one possible multitouch gesture: at any time, the player can draw a circle on-screen and all enemies within the radius of the circle will be damaged. An example of this can be seen in Figure 2.3.1, where two enemies are killed with a single gesture.

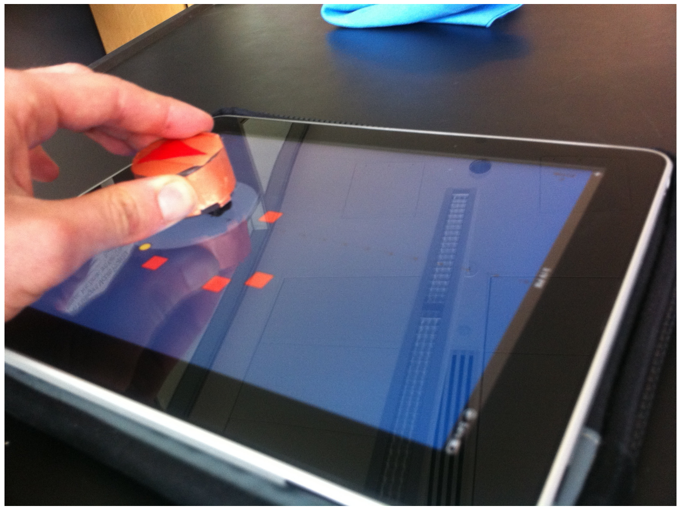

Figure 2.2.4. The tangible interface in action.

Furthermore, the effect of the gesture is affected by the nature of the circle drawn. The larger the radius of the circle, the less damage is dealt to enemies, forcing the player to make a decision: a small focused circle can kill a weaker enemy in one attack, but drawing a larger circle can do more widespread damage across many enemies (the number of enemies affected has no bearing on how much damage is dealt to each enemy). This is designed specifically to take advantage of the nature of multi-touch interfaces, as the way the gesture functions makes it impractical to implement on a game controlled via traditional gamepad or keyboard and mouse.

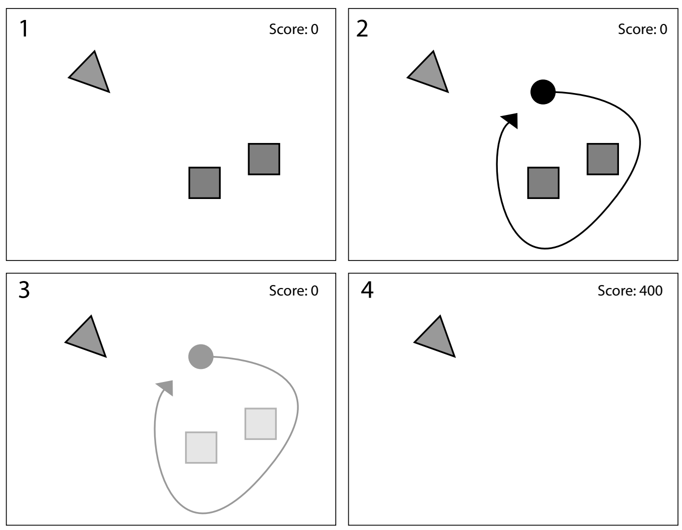

Figure 2.3.1. Drawing a circular gesture triggers a powerful targetted attack.

3
Research Methodology

Testing participants were solicited from within the Bard community. Although the test pool was limited to current Bard students at least 18 years of age, no effort was made to specifically target participants who would or would not identify as gamers, with the expectation that the final group of participants would naturally contain members of both demographics.

Participants underwent the test process individually, scheduled in half-hour time slots. Each participant was asked a few preliminary interview questions, and then played the game three times, spending five minutes on each control scheme, and being asked a series of questions after each play. The sessions were video recorded, allowing interviews to be conducted without any distraction caused by note-taking.

3.0.1 Pre-Play Interview

The following questions were asked of each participant before having them play the game. The aim of these questions was to establish a basic profile of the participant to take into consideration when assessing their game performance.

1. Would you describe yourself as a gamer? If so, what genres of games do you like to play?
2. What sort of experience with games do you have?
3. Any experience with twin stick shooters / tower defense?
4. Do you own an iPhone or an iPad? How about another multitouch smartphone?
5. Do you have any experience with iPad or iPhone gaming?
6. If so, can you give a few examples of your favorite game interfaces?
7. Are you left- or right-handed?

3.0.2 Explanation of the Game

After this first interview session, each player was given a brief description of the games rules: each was told that they were playing as a red triangle, surrounded by a series of yellow circles that represent their life points. They were then told that orange and pink squares were going to come onto the screen and try to attack the life points. If a life point was attacked enough times, it would die. If they all died, the participant would lose. The participant was told to attack and kill the red squares with their gun to get points, and the gun was always firing. Enemies would spawn indefinitely, only stopping if the player died or when five minutes had elapsed.

After this, the first control scheme was explained to the participant, followed by the gesture. They were told that at any time they could draw a circle on the screen to drop a bomb, damaging everything inside the circle. It was explained that the larger the radius of the circle, the less the damage, so they would have to deal with the trade-off between attacking a large number of enemies weakly or dealing a more focused amount of damage to

Event	**Data Collected**
Stopped moving/rotating	Location and angle
Base point damaged for the first time	Location and angle
Base point was destroyed	Location and angle, base points remaining
Damaged an enemy for the first time	Location and angle, enemy location and type
Destroyed an enemy	Location and angle, enemy location and type
Successfully made a gesture	Bounding rectangle of the circle
Drew an unrecognized gesture	
Damaged an enemy with a gesture	Enemy type
A new wave was started	Wave number
Score increased	Total score
The player has lost	Final wave number and score

Table 3.0.1. Events and data collected by analytics system

a smaller number of enemies. They were encouraged to end the circle gesture at roughly the same point they began it, as a means of helping the gesture recognizer function properly.

3.0.3 Playing the Game

They then spent five minutes each with the remaining two control schemes. The order in which the interface methods were presented varied from participant to participant, chosen in such a manner so as to ensure even distribution for each possible order combination; with six possible configurations and thirteen test participants, this means that each arrangement was presented to two different participants, with one arrangement being presented a third time. Furthermore, the games random number generator was set to a fixed seed, ensuring that each player experienced the exact same enemy spawn rate pattern.

The analytics system created for the game tracked any notable in-game events, allowing me to review each game session after the fact and analyze each players performance. Whenever a notable game event occurs, the event was logged into a database, along with the time it occurred (as a Unix timestamp), which control method was being used, a key uniquely identifying the participant, and various pieces of pertinent data. Table 3.0.1 details the events logged and the data collected.

The game sessions were video recorded, so that the analytics data could be cross-referenced with the video footage of the physical interaction between the participant and the iPad; it was assumed that such data would prove useful in situations where correlating physical movement with in-game performance could be useful, such as if a participant appeared to be having difficulty moving the tangible piece.

3.0.4 Post-Play Interview

After each game trial, the participants were asked about the easiest and most difficult elements of the control method they just used. After the third five-minute session, a further series of questions were asked of the participants:

1. Which control format did you prefer? Why?
2. Which control format felt more natural?
3. How did you feel about the items that used multitouch gestures?
4. What aspects of the game were the most difficult?
5. What aspects of the game were the easiest?
6. Was the game fun? Why do you think you enjoyed it?

The intent behind these questions was to provide insight into the players qualitative experience playing the game; the in-game analytics would provide ample quantitative data about how game performance varied from interface to interface, while this interview would serve to explore the participants emotional reactions to the different control methods.

It was suggested at this project's midway board that the post-play questions be revised to generate more numerically quantifiable answers, including more pointed lines of inquiry and an introduction of Likert scale ratings. A more specific set of questions was re-submitted to the IRB, but a response was not received prior to testing.

4
Results

4.1 Interviews

Tables 4.1.1 and 4.1.2 aggregate the quantifiable interview questions asked of each participant before playing the game and after completing all three game sessions.

4.1.1 Prior Gaming Experience

While an overwhelming majority of participants did not describe themselves as 'gamers', each participant reported having experience with multiple games of different genres and platforms. 10 of the 13 participants mentioned having played Pokemon, Nintendo 64, or Playstation games when they were younger. 11 of the participants reported owning a multitouch phone, and all 13 reported familiarity with at least one smartphone game (with 9 participants specifically mentioning the iPhone and Android game *Angry Birds*).

4.1.2 Preferred and Most Natural Interfaces

Table 4.1.3 displays the user-reported numbers for which interfaces were preferred and which were considered the most natural, as well as how many participants scored highest on each interface out of the three. While only one participant preferred the dual stick interface, four described it as the 'most natural'; when pressed, the four participants each indicated that their choice was based on it being the most familiar of the control schemes, since it was also the most conventional. Interestingly, three of these four participants did not list any experience with the sort of games that would use a dual-stick control scheme, and none of these three self-identified as a gamer.

4.2 Analytics

4.2.1 Data Analysis Methodology

The SQLite database containing all of the analytics data gathered during the testing sessions (see Table 3.0.1) was entered into a custom-built statistical plotting application written using JavaScript with the jQuery framework, the graphic library Flot, and HTML5 Local Databases. This allowed simple generation of tables and charts based on any pieces of data taken from an individual participant or taken in aggregate over the set of participants.

4.2.2 Overall Performance

Table 4.4.1 shows the final score and number of gestures for each control scheme for each participant, as well as the mean across all participants. Recall that points are rewarded when enemies are killed, with the easier enemy type worth 200 points and the more difficult one worth 300. This punishes players who lost and had to restart the game partway through a five-minute session, as the earlier waves have less enemies, making it more difficult to rack points quickly. Subsequently, the final cumulative score for a player represents roughly how successful they were at an aggressive offense, with a built-in penalty for failing to play defensively enough.

Although it is clear in Table 4.4.1 that the mean final score for the tangible interface was higher than that of the one finger interface, and both were in turn higher than the dual stick interface, performing a one-way repeated-measure ANOVA test on the data

Participant	Interface Order	Identifies as a Gamer	Multi-Touch Experience	Dominant Hand	Preferred Interface	Most Natural Interface
1	Dual Stick, Tangible, One Finger	No	Android	Left	One Finger	One Finger
2	One Finger, Dual Stick, Tangible	No	None	Right	Tangible	Tangible
3	Tangible, One Finger, Dual Stick	No	iPod touch	Right	One Finger	Tangible
4	Dual Stick, Tangible, One Finger	No	None	Left	One Finger	One Finger
5	One Finger, Tangible, Dual Stick	Yes	Android, iPhone	RIght	One Finger	One Finger (Dual Stick for aiming)
6	Tangible, Dual Stick, One Finger	No	Android	Left	Tangible	Dual Stick
7	Dual Stick, One Finger, Tangible	No	iPod touch	Right	One Finger	One Finger
8	One Finger, Dual Stick, Tangible	No	iPhone	Right	One Finger	One Finger
9	Tangible, One Finger, Dual Stick	No	iPhone	Right	Dual Stick	Dual Stick
10	Dual Stick, Tangible, One Finger	Yes	iPhone	Left	One Finger	Dual Stick
11	One Finger, Tangible, Dual Stick	Yes	Android	Right	One Finger	Tangible
12	Tangible, Dual Stick, One Finger	“Moderately”	iPhone, iPad	Right	One Finger	Dual Stick
13	Dual Stick, One Finger, Tangible	No	iPhone, iPad	Right	Tangible	Tangible

Table 4.1.1. Demographic interview data and preferred interfaces

Participant	Reported Prior Gaming Experience
1	Online/phone games: mostly Angry Birds and Tron. Used to play Playstation action/adventure/platformers
2	Mostly board games. As far as video games go: Call of Duty: Modern Warfare, Modern Warfare Zombies (iPhone), Angry Birds.
3	Pokemon, Super Smash Bros, Starcraft 2, Halo, Doodle Jump (iPhone)
4	Nintendo 64, Mario, The Sims, Angry Birds
5	Nintendo 64, Game Boy, RPGs, Construction-based sims such as Roller Coast Tycoon, Age of Empires, Alchemy (Android game)
6	Zelda on SNES, Pokemon, Bejeweled, Angry Birds
7	Nintendo 64, Game Boy, Boggle on iPhone
8	Angry Birds, an iPhone labyrinth game (occasionally), prefers PC to console
9	Super Smash Bros, anything multiplayer, Angry Birds
10	World of Warcraft and other MMOs, Magic: The Gathering, Pokemon, Angry Birds, lots of iPhone twin-stick shooters. Reads gaming webcomics.
11	RPGs, platformers, games with good story elements, Angry Birds, Playstation emulator on Android
12	Lots of iPhone and iPad games. Does not like Angry Birds.
13	Civilization, Sim City (iPhone, iPad and PC), Pokemon

Table 4.1.2. Reported prior gaming experience

Interface	# Preferred	# Most Natural	# Actual Best
One Finger	9	5	6
Dual Stick	1	4	1
Tangible	2	4	6

Table 4.1.3. Interface preferences for all participants, reported and actual

found the interface used to have no significant effect on the mean final score ($F(2, 24) = 3.07, p = 0.08$, partial $\eta^2 = 0.87$). For this ANOVA test, Mauchly's test did not show a violation of sphericity against interface ($W(2) = 0.93, p = 0.86$). An alpha level of 0.05 was used for all statistical tests.

4.2.3 Performance Over Time

To paint a more complete picture of the relationship between each interface and the participant's scores, Figures 4.2.1 and 4.2.2 show how the mean score and number of gestures used for each control method increased over the five-minute game period. Figure 4.2.3 shows the score over time for each individual participant.

4.2.4 Performance Over All Three Play Sessions

The bottom three rows of Table 4.4.1 show the average score and gestures for each interface grouped by what order the participant played the game in. This corroborates a common-sense claim: as a participant plays the game, their skill will improve over time.

A one-way ANOVA test was performed on the final score for each play session grouped by whether it was the first, second, or third play session for a participant. Mauchly's test did not show a violation of sphericity against play order ($W(2) = 0.72, p = 0.16$). With one-way repeated-measure ANOVA, a significant effect of play order on final score was found ($F(2, 24) = 8.21, p = 0.01$, partial $\eta^2 = 0.87$). However, running a pairwise t-test with Bonferroni correction on the data yielded $p > 0.05$ for all permutations.

Table 4.4.3 displays each participant's set of final scores grouped both by interface and order played, allowing easy comparison across any of these metrics. To help contextualize this data, Table 4.4.2 shows the difference between a participant's final score for a given interface and the score they received on the first interface they played, with a value of 0 indicating that was the first interface the participant played.

The negative values that appear in Table 4.4.2 represent play sessions where the player actually performed worse in that interface as their second or third play session than they did on their first play session. It is perhaps worth noting that out of the six participants who performed worse in a later play session than their first, only participants 10 and 11 scored worse using an interface that was not the dual-stick control scheme; those two participants also have the distinction of being the only two participants who performed better on their first play session than both of their subsequent sessions.

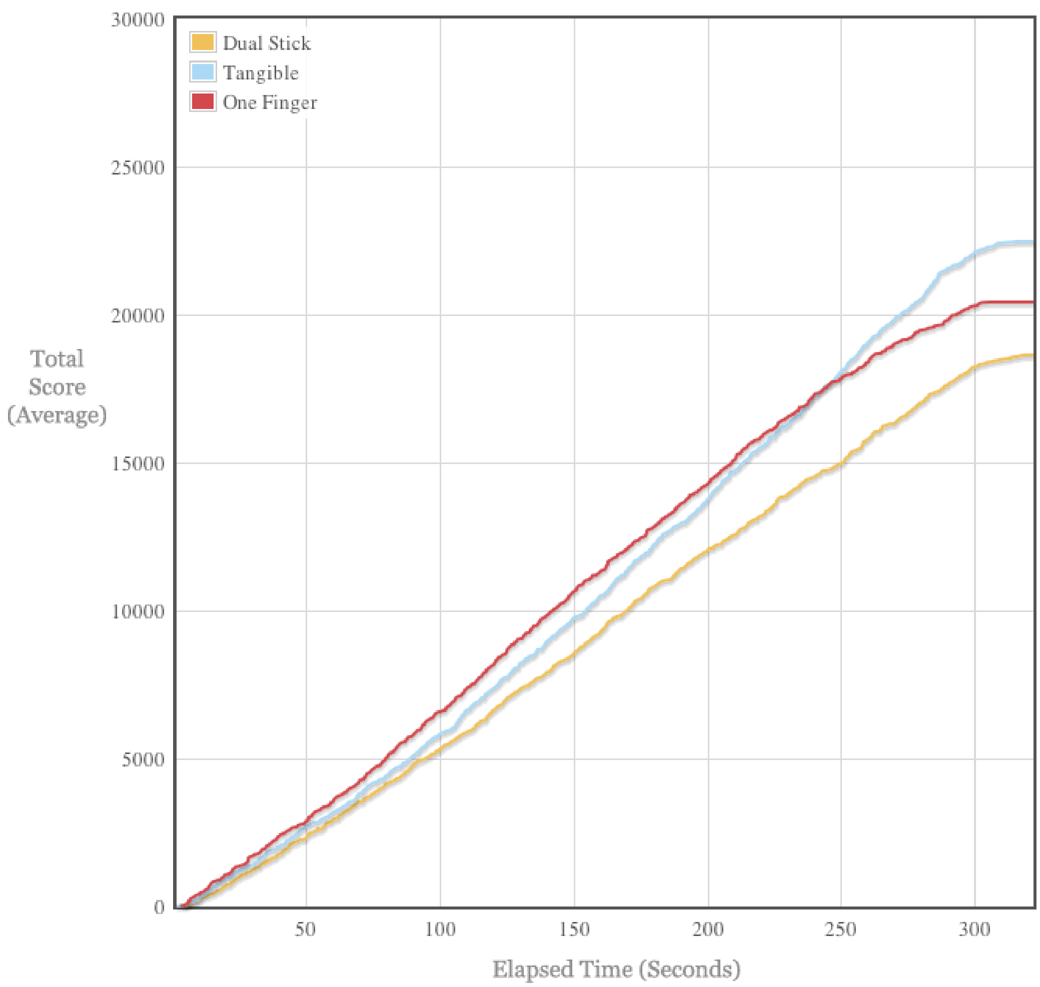

Figure 4.2.1. Average score over time

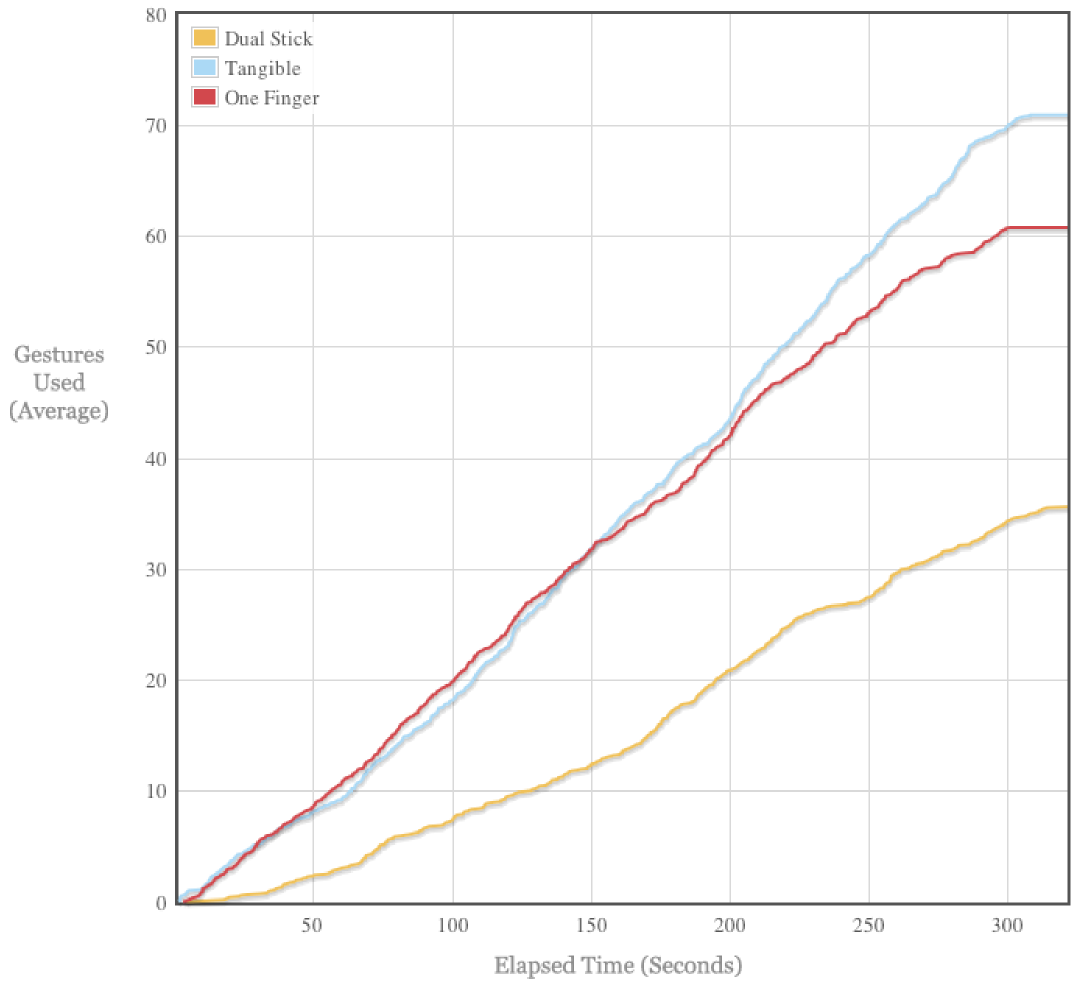

Figure 4.2.2. Average gestures used over time

4.2.5 Gesture Usage by Interface

Looking at the mean gestures for each interface in Table 4.4.1, it is evident that participants on the whole used more gestures with the one finger and tangible interfaces than with the dual stick control scheme. As discussed earlier, common sense would indicate this to be the case: the dual stick interface requires two hands to control movement and aim, making performing gestures difficult.

A one-way ANOVA test was performed on the number of gestures performed by each participant for each interface. Mauchly's test did not show a violation of sphericity against

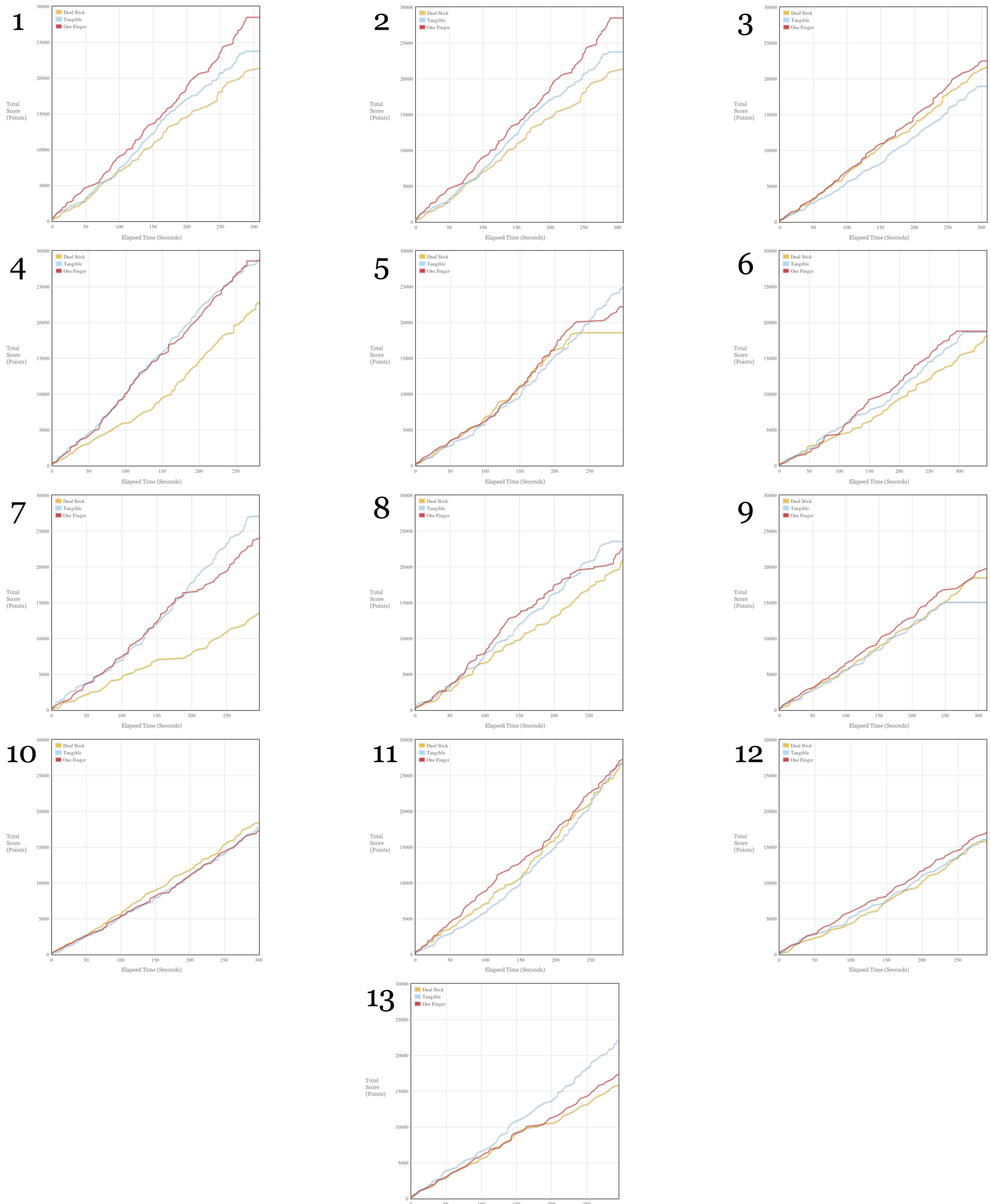

Figure 4.2.3. Score over time for each participant.

interface ($W(2) = 0.73, p = 0.18$). With one-way repeated-measure ANOVA, a significant effect of interface on the number of gestures was found ($F(2, 24) = 8.21, p < 0.01$, partial $\eta^2 = 0.89$).

Running a pairwise t-test with Bonferroni correction on the data yielded a p value of 1.00 for a comparison of the One Finger and Tangible interfaces. For the tests comparing Dual Stick versus One Finger and Dual Stick versus Tangible, $p = 0.08$ and $p = 0.01$, respectively.

Furthermore, running a similar one-way repeated-measure ANOVA test grouping the gestures by the order of the play session showed no significant effect of order played on the number of gestures ($F(2, 24) = 3.26, p = 0.07$, partial $\eta^2 = 0.75$). As before, Mauchly's test did not show a violation of sphericity against interface ($W(2) = 0.60, p = 0.06$).

What can be said based on this statistical data is that participants used more gestures using the tangible interface than the dual stick interface. Furthermore, the order of play did not affect the number of gestures used in a statistically significant way: that is, participants did not on the whole appear to increase their gesture usage as they became more experienced at the game. One noteworthy exception to this can be seen in participant 4.

4.3 Further Analysis

4.3.1 Participant 4

Of all the participants, Participant 4 was by far the most proactive user of gestures. The participant used 100 gestures with the dual stick control scheme, 209 with the tangible finger, and 230 with the one finger interface; only two of the other twelve participants used more than 100 gestures in any given play session, and no others even came close to using 100 gestures with the dual stick interface.

Looking further into Participant 4's play habits reveal a number of other interesting statistics. The participant's final scores for the tangible and single-finger interfaces were 28,800 and 26,600, respectively; compared to the 23,000 scored with the dual stick interface, this difference is relatively insignificant. The same can be said for the difference in the number of gestures used: while there was relatively little difference between the number of gestures used in the tangible and one-finger interfaces, fewer than half as many gestures were used with the dual stick control scheme.

Most telling, however, is Participant 4's behavior over time. Figure 4.3.2 shows the participant's gesture usage over the course of each play session. About 150 seconds in, there is a sharp increase in the rate at which the participant used gestures with the dual stick controls. After the 150-second mark, the participant uses gestures at roughly the same rate as the other two control schemes. This makes logical sense when considered with the participant's total gesture usage: the increase in use came approximately halfway through the dual stick session, and the number of gestures for that session is just under half that of the other two sessions. Looking at the participant's score over time (Figure 4.3.1) shows a similar pattern: shortly after 150 seconds, the participant's rate of score for the dual-stick scheme sees a marked increase, with the line roughly parallel to the lines representing the other interfaces.

The most likely cause for this pattern becomes clear upon considering that the dual stick control scheme was the first played by the participant. It would appear that about halfway through the participant's first game, the participant decided that using a significant number of gestures was a viable strategy. The participant then proceeded to use that strategy for the second half of the current play session and the entirety of the next two play sessions. The video footage from the play session gives credence to this theory: at a time about a third of the way through the first play session (roughly corresponding with the first marked increase in gesture use), the participant is heard commenting, "wow, it's so much easier!" immediately after killing a number of enemies with a series of gestures in quick succession.

Also interesting to note is the effect that the gestures had on the participant's base points in the dual stick control scheme. Looking at the participant's base point loss over time in Figure 4.3.3, the only time the participant lost any base points occurred while performing gestures with the dual stick control scheme. Looking at the video footage, the participant had difficulty juggling the two control schemes. The participant, who is right-handed, only performed gestures with the right hand while playing with the dual-stick controls, meaning that the participant was unable to move the character away from enemies while performing gestures. Interestingly, while the participant continued to perform gestures exclusively with the right hand when using the one finger interface (moving the character with the left hand), the participant switched hands regularly while using the tangible interface.

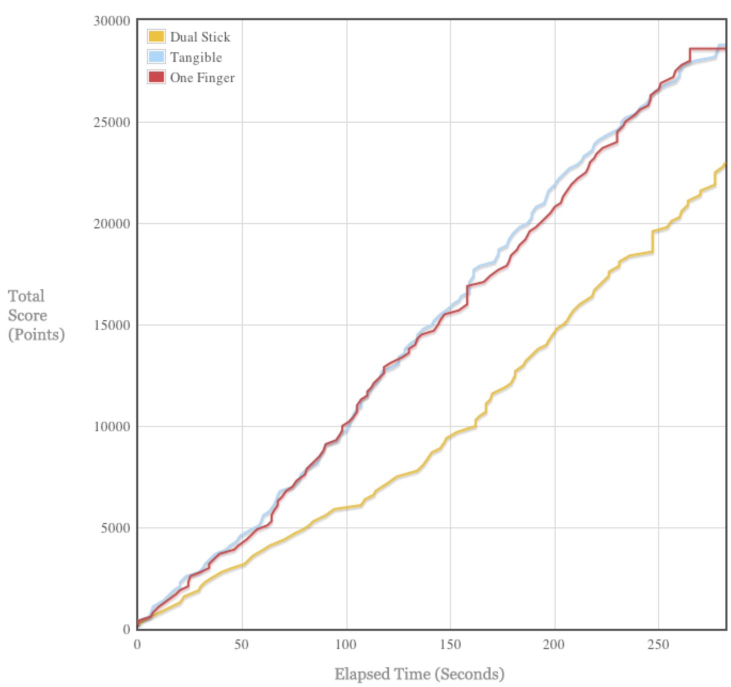

Figure 4.3.1. Score over time for participant 4

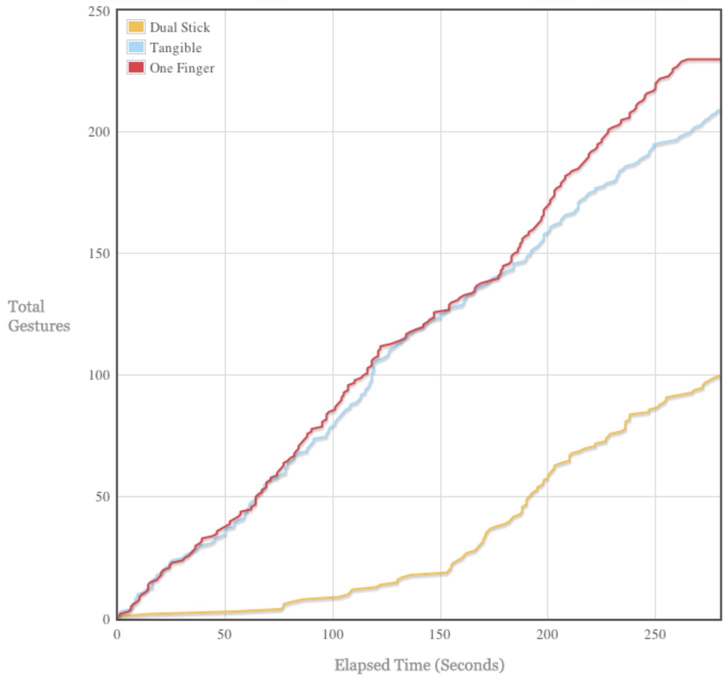

Figure 4.3.2. Gestures over time for participant 4

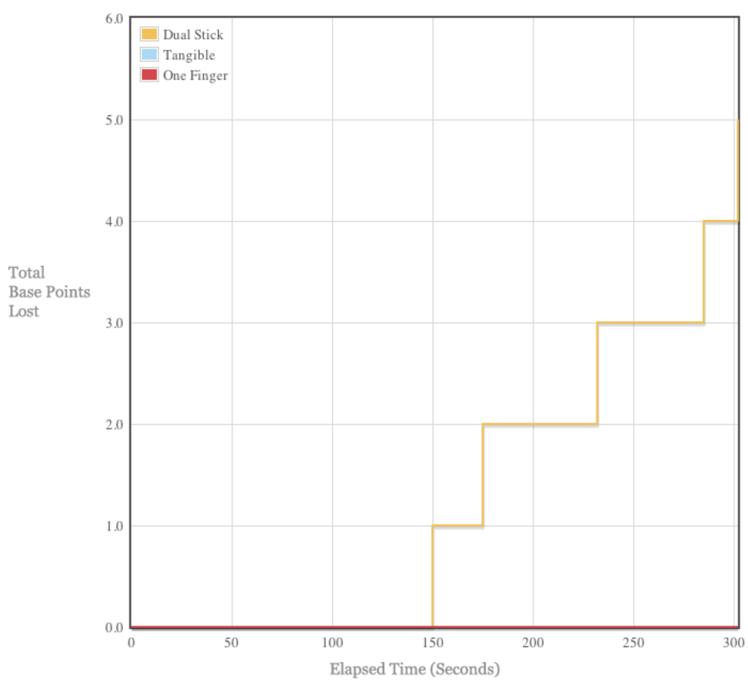

Figure 4.3.3. Base points lost over time for participant 4

4.3.2 Participant 11

Participant 11 was one of only two participants to score highest on the first play session; that is, rather than improving from play session to play session, participant 11 actually performed worse over time. The participant's three final scores were (in chronological order) 27,300; 26,900; and 26,600. While these scores are close enough that it is unlikely the participant got actively worse at the game, it is just as noteworthy that the participant's scores were all within 700 points of each other – as shown in Table 4.4.2, nearly every other participant saw a much wider score gap between play sessions.

One possible explanation is that the participant was one of the more experienced gamers in the study; out of the four participants who self-identified as gamers, participant 11 had the most experience with games similar to *Trigonometry Wars*. Although the participant claimed to be "bad" at twin-stick shooters, the participant was in fact the only one who was familiar with the genre terminology and did not require further explanation when asked about prior experience with twin-stick shooters. As such, the participant was more instantly familiar with the way the game functioned; instead of having to master the controls and the game system simultaneously, the participant was able to focus more of his attention purely on the presented interfaces.

Reviewing the video footage from the participant 11's test sessions reveals a few other factors at play. Using the dual stick control scheme, the participant had difficulty successfully performing gestures. A large number of attempts were made that were not recognized by the game as proper circles, almost certainly impacting the participant's performance and final score.

Perhaps most interesting was the participant's interaction with the tangible control scheme. Specifically, the participant consistently used the right hand to control the tangible game piece and the left hand to perform gestures; out of the thirteen participants, a total of four used this tactic rather than alternating hands based on the position of the game piece. Out of the four participants who used the same hands throughout, all three performed gestures with their dominant hand. Participant 11, however, used the dominant hand for movement and the non-dominant hand for gestures. While this did not appear to affect the participant's gesture usage in a negative way (the participant used more gestures using the tangible interface than either of the other two), it is still very much worth noting.

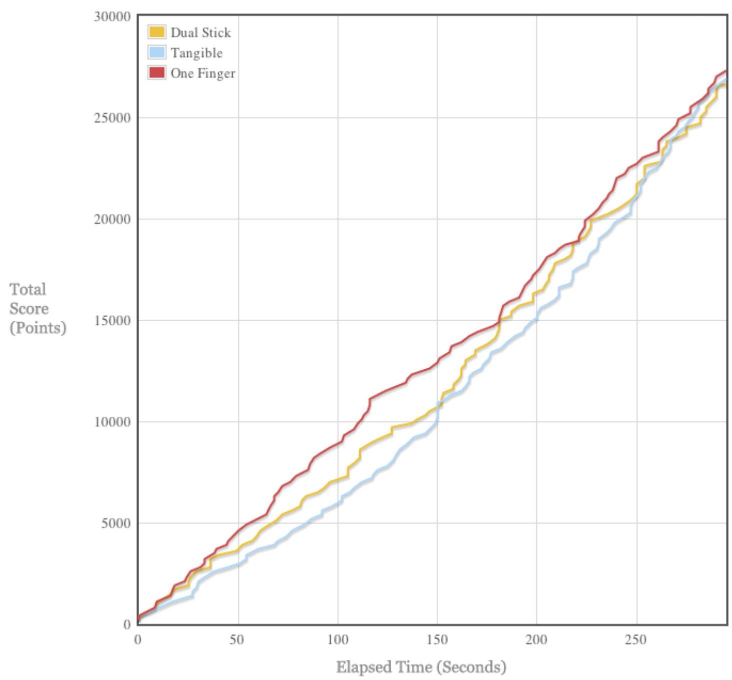

Figure 4.3.4. Score over time for participant 11

4.4 Future Research

After analyzing the results of the research presented in this paper, there are a number of clear actionable steps that could be taken to improve future work on this research.

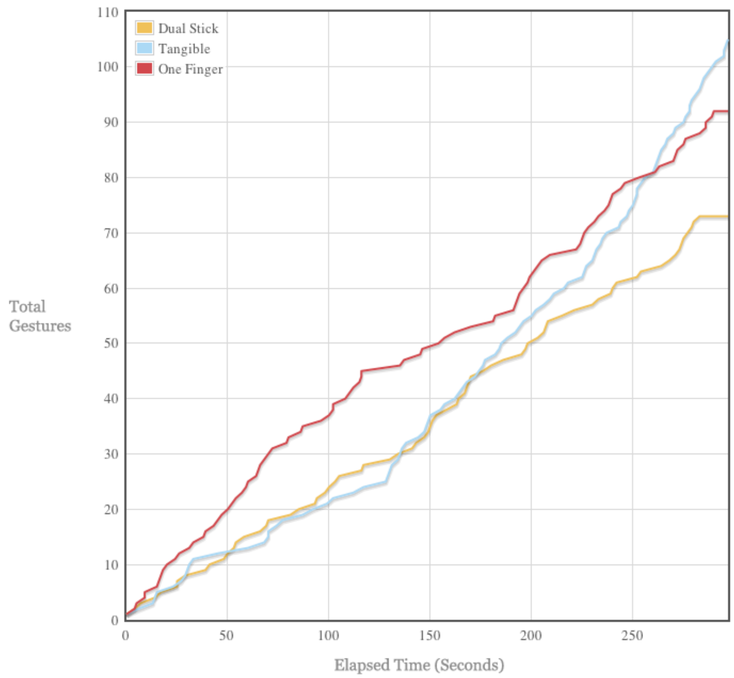

Figure 4.3.5. Gestures over time for participant 11

4.4.1 Improved Tangible Hardware

One of the most frequent participant comments about the tangible game interface was the lack of responsiveness of the game piece. Further explorations into tangible game interfaces designed to interact with a capacitive touch screen would do well to improve upon both the hardware and software used for this paper. Part of the responsiveness issues appeared to be caused by the low-density capacitive foam used, which often required players to exert significant pressure to get the screen to register the touch points. Upgrading to a higher-quality foam such as is frequently used in commercial iPad styli would be likely to greatly improve the responsiveness of the game piece.

4.4.2 Isolation of Gesture Components

A large portion of the ambiguity in the results of this study were due to being unable to ascertain whether or not differences in performance were caused by the way the interfaces encouraged or discouraged the usage of the multitouch gestures or rather a different factor present in the interface design. To more definitively determine causation, it would be to illuminating to hold play sessions both with and without the gestures enabled, to see how the relative performance between the interfaces varied whether or not the players were asked to perform the secondary simultaneous gestures.

Participant	**Final Score**			**Total Gestures Used**		
	Dual Stick	*Tangible*	*One Finger*	*Dual Stick*	*Tangible*	*One Finger*
1	21400	23800	28500	87	131	170
2	24400	27800	19500	48	86	27
3	21800	19000	22500	9	13	17
4	23000	28800	28600	100	209	230
5	18600	25400	22200	40	87	60
6	18200	18700	18800	29	39	53
7	13600	27100	24000	7	94	66
8	20900	23600	22500	67	90	97
9	18500	15100	19800	1	4	9
10	18400	17800	17300	2	30	0
11	26600	26900	27300	73	105	92
12	15800	16100	17100	1	16	3
13	15800	22100	17400	2	18	12
Avg	19769	22477	21962	36	71	64
Std. Dev.	3691	4693	4153	36	59	69
Played 1st	18440	17225	22875	40	18	69
Played 2nd	19825	24540	20925	37	112	26
Played 3rd	21375	25150	22060	31	72	92

Table 4.4.1. Final performance data by participant

	Dual Stick	**Tangible**	**One Finger**
1	0	2400	7100
2	4900	8300	0
3	2800	0	3500
4	0	5800	5600
5	-3600	3200	0
6	-500	0	100
7	0	13500	10400
8	-1600	1100	0
9	3400	0	47000
10	0	-600	-1100
11	-700	-400	0
12	-300	0	1000
13	0	6300	1600
Avg	338	3046	2531
Std. Dev.	2204	4297	3486

Table 4.4.2. Score difference from the first game played in each play session.

1

	1st	2nd	3rd
Dual Stick	21400		
Tangible		23800	
One Finger			28500

2

	1st	2nd	3rd
Dual Stick		24400	
Tangible			27800
One Finger	19500		

3

	1st	2nd	3rd
Dual Stick			21800
Tangible	19000		
One Finger		22500	

4

	1st	2nd	3rd
Dual Stick	23300		
Tangible		28800	
One Finger			28600

5

	1st	2nd	3rd
Dual Stick			18600
Tangible		25400	
One Finger	22200		

6

	1st	2nd	3rd
Dual Stick		18200	
Tangible	18700		
One Finger			18800

7

	1st	2nd	3rd
Dual Stick	13600		
Tangible			27100
One Finger		24000	

8

	1st	2nd	3rd
Dual Stick		20900	
Tangible			23600
One Finger	22500		

9

	1st	2nd	3rd
Dual Stick			18500
Tangible	15100		
One Finger		19800	

10

	1st	2nd	3rd
Dual Stick	18400		
Tangible		17800	
One Finger			17300

11

	1st	2nd	3rd
Dual Stick			26600
Tangible		26900	
One Finger	27300		

12

	1st	2nd	3rd
Dual Stick		15800	
Tangible	16100		
One Finger			17100

13

	1st	2nd	3rd
Dual Stick	15800		
Tangible			22100
One Finger		17400	

Table 4.4.3. Final scores for each participant and interface based on the order played.

Appendix A

Initial UML Diagram of Game Engine

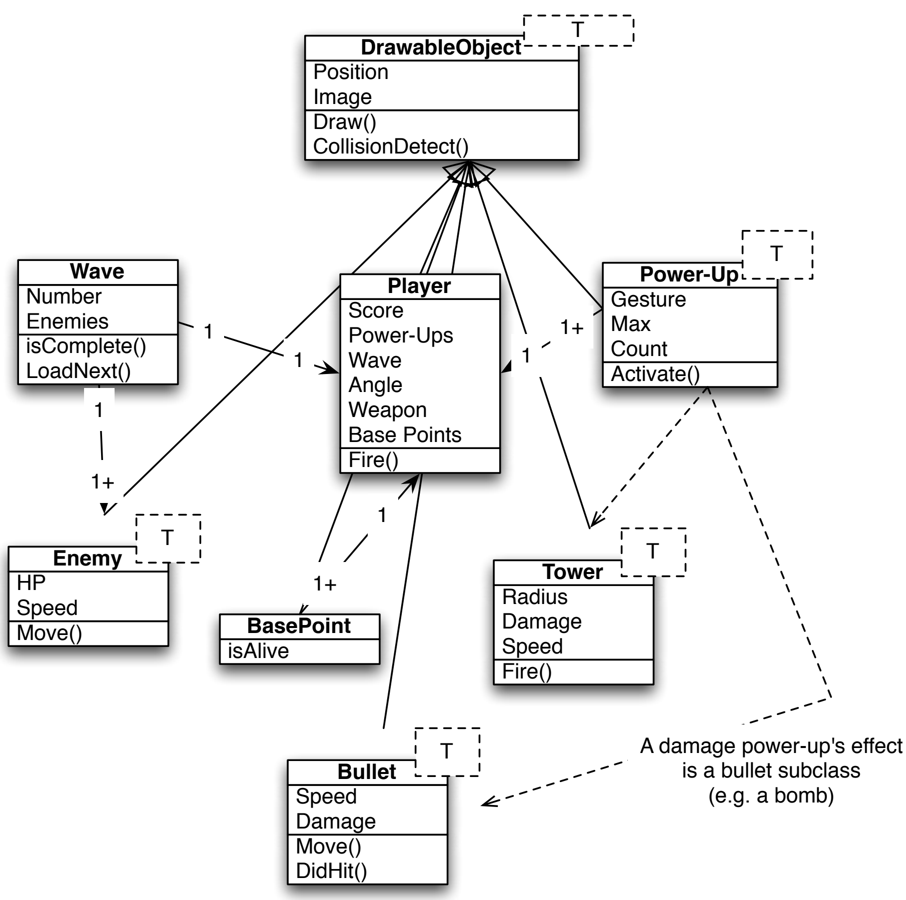

Figure A.0.1. High-level overview of the initial design of the game engine

Appendix B

Documents Submitted for IRB Approval

Recruitment Email (also to be used on Facebook / Bard Announce)

As some of you may already know, my senior project involves conducting usability testing on an iPad game I've designed. My research is involved with measuring the effectiveness of novel new control schemes versus traditional game interfaces.

It's testing time! I'm looking for people who want to come in and play the game and then answer a few questions about it. The entire process will only take about half an hour. Basically, you get to help out my project by having fun playing a game. What's not to like?

I'll be holding testing sessions at night on Wednesday, March 30, and all day Friday and Saturday April 1 and 2. If you're interested in participating, send me an email at mw562@bard.edu and we'll find a half-hour time slot that works for you.

Thanks! Invite your (Bard) friends!

Play test a new video game!

As part of my senior project, I am conducting usability testing on a new iPad game I have designed.

I'm looking for people to play the game and answer a few questions about the experience.

It'll only take about half an hour. Help out my project while getting to play a fun new game!

I'm holding testing sessions on Wednesday, March 31 at night and Friday and Saturday, April 1-2 during the day.

If interested, send an email to mw562@bard.edu and we'll find a half-hour time slot that works for you.

Thanks!

Verbal Description of Consent Process

Thank you for agreeing to participate in this study. Your participation is expected to take about 30 minutes. During this time you'll play a video game using an Apple iPad tablet. You will play the game using three different control interfaces. When you are finished, I will ask you a series of questions about your play experience and your background with gaming.

If you're ever uncomfortable for any reason and would like to stop participating, that is OK, just say so. Your data will be stored according to a coding number, so your responses will remain confidential.

Before we start you need to read this consent form carefully. Consent forms are necessary so that you are accurately informed about the research process and you understand your rights. If you have any questions, just ask me. Then, if you agree with the content of the consent form, sign at the bottom. If you'd like a copy of the consent form, you can take a copy with you.

Consent Form

Project Title: The effect of tangible and touch-based interfaces on game performance
Researcher: Michael Walker
Faculty Adviser: Keith O'Hara

I am a student at Bard College, and I am conducting game play test sessions as an experiment for my Senior Project. I am studying the effect that different novel interfaces have on the performance and experience of playing a game.

During this study, you will be asked to play a video game using a few different control methods and then answer a few questions about the experience. Please feel free to expand on the topic or talk about related ideas. Also, if there are any questions you would rather not answer or that you do not feel comfortable answering, please say so and we will stop the interview or move on to the next question, whichever you prefer.

This entire process was designed to be approximately thirty minutes in length, and is not expected to have any risk other than the minimal risks associated with playing any video game - eye strain, the opportunity cost of your time, etc. The potential benefits include playing a new iPad game before its release and helping influence its design, as well as contributing to video game development research to create more immersive gameplay experiences.

All information will be kept confidential. I will keep the data in a secure place. Only myself and the faculty supervisor mentioned above will have access to this information. Upon completion of this project, all data will be destroyed or stored in a secure location.

Participant's Agreement:

I am aware that my participation in this play test session is voluntary. I understand the intent and purpose of this research. If, for any reason, at any time, I wish to stop the play test session or interview, I may do so without having to give an explanation.

The researcher has reviewed the individual and social benefits and risks of this project with me. I am aware the data will be used in a Senior Project that will be publicly available at the Stevenson Library on the Bard College Campus. I have the right to review, comment on, and/or withdraw information prior to the Senior Project's submission. The data gathered in this study are confidential with respect to my personal identity unless I specify otherwise. I understand if I say anything that I believe may incriminate myself, the interviewer will immediately rewind the tape and record over the potentially incriminating information. The interviewer will then ask me if I would like to continue the interview.

If I have any questions about this study, I am free to contact the student researcher (Michael Walker, mw562@bard.edu, 858-353-3145) or the faculty adviser (Prof. Keith O'Hara, kohara@bard.edu, 845-752-2359). If I have any questions about my rights as a research participant, I am free to contact the chair of Institutional Review Board: Prof. David Shein (IRB@bard.edu; shein@bard.edu, 845-758-7454).

I have been offered a copy of this consent form that I may keep for my own reference.

I have read the above form and, with the understanding that I can withdraw at any time and for whatever reason, I consent to participate in today's interview.

__________________________ ______________________
Participant's signature Date

____
Interviewer's signature

Contact Information

If you have any questions about this study or your participation in this study, feel free to contact any of the following individuals.

Michael Walker
Researcher
mw562@bard.edu
(858) 353-3145

Keith O'Hara
Faculty Advisor
kohara@bard.edu
(845) 752-2359

David Shein
Chair, Bard Institutional Review Board
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845-758-7454

The Bard Institutional Review Board may also be reached at IRB@bard.edu.

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