

**TANGIPLAY:
PROTOTYPING TANGIBLE ELECTRONIC GAMES**

by

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ABSTRACT

Tangible electronic games currently exist in research laboratories around the world but have yet to transition to the commercial sector. The development process of a tangible electronic game is one of the factors preventing progression, as it requires much time and money. Prototyping tools for tangible hardware and software development are becoming more available but are targeted to programmers and technically trained developers. Paper prototyping board and video games is a proven and rapid means of testing game mechanics, and requires minimal technical skill. However, paper prototyping is unable to reproduce the experience of interacting with a physical object. This thesis explores development issues regarding tangible electronic games and then introduces and analyzes an environment for conceptualizing tangible electronic games. Finally, the thesis discussed the outcome of the project and future implications.

Keywords: tangible electronic game; prototyping process; game prototyping; prototyping tool; tangible user interface; augmented token

DEDICATION

To my wife, Stephanie, and my family for all their support.

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1: INTRODUCTION

“There is a growing trend in today’s games to bring more physical movement and social interaction into games while still utilizing the benefits of computing and graphical systems” (Carsten Magerkurth, Adrian David Cheok, Regan L. Mandryk, & Trond Nilsen, 2005, p. 2). A current example of this trend is the Nintendo Wii, a gesture based gaming console, the result of which is a transition from buttons to actions. Users can now swing a controller instead of mashing button ‘A’. But, what if you could physically interact with tokens that are directly related to a game?

Board games utilize physical tokens while “...[emphasizing] the direct interaction between human players. ... On the other hand, playing computer games introduces many highly interesting possibilities that enhance the playing experience. Game presentation is enriched with audio and visual support and game content is limited only by the imagination of the developers” (Carsten Magerkurth, Timo Engelke, & Grollman, 2006, p. 1).

Game designers have experimented with digitizing traditionally analogue games. Ping Pong Plus is a version of ping-pong that has been electronically augmented to include the social and physical, while exploiting the power of a computer. The system keeps the traditional paddles, ball and table, while a computer system knows where the ball lands and digitally displays feedback at the point where the ball strikes. (Wisneski, Orbanes, & H. Ishii, 1998) In this

version of ping-pong, Ping Pong Plus has been rendered a tangible electronic game, a type of game designed to combine the physical and social aspect of board games with the computing power and immersive abilities found within computer games.

1.1 Tangible Electronic Game's Foundation

Tangible electronic games are situated in an innovative field and there are no standards since few examples exist. For this thesis, I define them as a game augmented with a display surface and tangible electronic tokens; most often the outcome is a board game. Due to the early period of development, tangible electronic games rely on related fields of study: board games, video games and tangible user interfaces (TUI). “[T]angible interfaces give physical form to digital information, employing physical artifacts both as representations and controls for computational media” (Ullmer & H. Ishii, 2000a, p. 2). A genre within the TUI category is surface games and is the closest field of study to tangible electronic games; however, they are defined as a board game augmented with a display surface. Surface games, like tangible electronic games, are not common within our society, nor are prototyping tools for supporting them.

1.1.1 Tangible Dilemma

Generating tangible electronic games requires three distinct skill sets: game development, user interfaces and tangible electronics. Current video game designers are familiar with software development; however, tangible electronics are not part of the video game industry. Board game developers have more

experience with tangibles, but not electronic tangibles. Pairing game designers with people who can create tangible objects would most likely produce entertaining tangible games, but the process would be lengthy, tedious and costly. For game designers without access to a specialist of tangibles, developing tangible games is complicated, as not being able to analyze the tangibility of a game, a game designer would not know the particulars of the game until it was developed. This technical burden needs to be removed, thus freeing designers to create, play and refine, all within a very short amount of time, while not requiring any knowledge of how to create tangible electronics. Ullmer and Ishii echo this concept:

“Obviously, the development of [tangible electronic] gaming applications involves the integration of physical, social and virtual aspects, thus introducing a new dimension of complexity to the entertainment applications of the pre-pervasive computing era. Hence, it is crucial to be able to quickly prototype and tweak game rules as well as the involved user interfaces and interaction devices” (Ullmer & H. Ishii, 2000a, p. 2).

1.1.2 Research Question

Tangible electronic games are not well developed and there is no simple way to prototype these games, but they are a growing trend in the gaming market. Time, money and particular knowledge are hindering their development and the lack of prototyping tools is delaying game designers from experimenting in the field. In order to better understand tangible electronic games, more knowledge is needed. One particular focus is on how can we support game designers. This led to the research question motivating this thesis: How can a tangible computing and interactive surface environment support designers to

conceptualize new tangible electronic games? In order to answer this question, an objective was identified: To develop and assess a conceptualizing environment for the new field of electronic tangible games in which a ready toolkit of tangibles and an interactive surface are used to conceptualize a range of tangible games.

1.2 TangiPlay

TangiPlay is the physical outcome of this thesis, and it is a prototyping environment for tangible electronic games. The concept for TangiPlay was envisioned in a large network of schools referred to as CATGames (Creativity Assistive Tools for Games) Network. Within the group, there were a variety of projects, one of which spawned the development of TangiPlay. CAT Games identified a need for a “Gesture and Tangible Prototyping Tool” and called for “... a coherent environment that allows for fluid experimentation and prototyping” (“CATGames: Creativity Assistive Tools for Games,” 2007). Specifically, the physical project was to be “... composed of a software system, sensing and display software system, and a hardware installation of large shared displays and spatial audio, plus prototyped tangibles” (“CATGames: Creativity Assistive Tools for Games,” 2007). Even with a detailed explanation of what the project would include, it was not defined how it would work or what kind of games the system would make. This brought about the need to simplify and ground tangible electronic games within a familiar framework, thus the production of TangiDice, a proof-of-concept. By way of TangiDice, I explored electronic dice to see if there

was value in such a prototyping project. From that point, TangiPlay was developed.

This thesis includes more detailed information regarding TangiPlay, but it first begins with a literature review, where related fields of study are discussed. The methodology follows and outlines the project requirements and how studies were conducted. TangiPlay is then thoroughly discussed, regarding exactly what it is and the user testing sessions. Finally, the future of TangiPlay is envisioned along with a discussion of larger issues regarding tangible electronic prototyping.

2: LITERATURE REVIEW

Games cannot exist without interactions, whether it be between individuals or between the player and an interface. People interact; cards are dealt; dice are rolled; tokens are moved; timers are activated; buttons are pressed; all are completed to progress a game. Of course the interface varies from game to game and as technology advances, so do the interfaces. Tennis for Two was the first computer game, developed by Willy Higinbotham in 1958. The game used a custom-made control box that included a knob and a button. In 1961, Spacewar! was designed to run on PDP-1 (Programmed Data Processor-1), and used five switches (Cummings, 2007, p. 2). Early video games such as these relied on digital input and buttons that were either on or off. They converted a player's toggling of switches into gestures displayed on the screen. For example, Nintendo's Tennis video game, which was released in 1984, equivocated hitting button A or B to the act of serving and returning the ball. This type of interface in video games has lasted even until today. There has, however, been an evolution to game controllers as they have transformed from simple knobs and buttons to "...computer vision, touch and motion control" (Cummings, 2007, p. 7). In 2006, Nintendo released Wii Sports, which utilize Nintendo's Wii console and Wii Remote, a tangible gesture interface. Included in the Wii Sports is a revolutionized version of Nintendo's Tennis, in which the Wii technology allows players to mimic the actual motions of tennis; contrary to its predecessor,

gestures in the game are not abstracted to button pushing. The Nintendo Wii, which relies on a tangible interface controller that interprets user's gestures for playing games, has proven to be a commercial success.

Video games have evolved to incorporate more tangible elements, as physically mimicking interactions with objects makes the game experience more realistic. Currently, the Nintendo Wii sits commercially as the standard; however, game designers aspire to attain even greater forms of technology. Heritage Canada funded a project that allowed researchers in the video gaming field to discover new grounds, thus the development of the technology found in TangiPlay – a prototyping environment that supports the emergence of new types of tangible computing games. There are very few tangible computing games and no prototyping projects in this field; therefore, TangiPlay is a unique system. Even though TangiPlay is a niche project, there are partially related fields of study, such as surface computing, tangible prototyping and augmented reality. Consequently, these areas were studied to inform the development of TangiPlay and to provide the groundwork required to understand tangible computing games.

2.1 Tangible User Interface

TangiPlay falls under the broad category of Tangible User Interface (TUI), a “user [interface] employing physical objects, instruments, surfaces, and spaces as physical interfaces to digital information” (Ullmer & H. Ishii, 1997, p. 223). This type of technology manifests itself in a variety of forms ranging from workspaces to music, narratives to games. Since the late 1980's, people have been

experimenting with means to make computing a tangible process, something that is more intuitive to users than TUI's forerunners – the graphical user interface (GUI) and the command user interface (CUI).

TUI's have continued a trend of rendering interactions more natural as compared to the abstracted interactions one would have with GUI and CUI. When computers were first developed using a CUI, users had to memorize text-based commands in order to interact with the interface, such as DOS (Disk Operating System). This was later simplified with the development of the GUI, which enables users to employ a physical pointing device that is graphically represented on a screen and designed to carry out desired operations. TUI's "...give physical forms to digital information. The physical forms serve as both representations and controls for their digital counterparts. TUI makes digital information directly manipulatable with our hands, and perceptible through our peripheral senses by physically embodying it" (Hiroshi Ishii, 2008, p. xvi).

2.1.1 History of TUIs

Pierre Wellner was one of the early developers of a TUI system, a term later coined by Ishii and Ullmer (H. Ishii & Ullmer, 1997, p. 2). Wellner's goal was to combine the advantages of both an analog and digital workspace. This led to the construction of DigitalDesk, a system that could project electronic images on the surface of the desk or paper, detect and respond to a user's movements and his/her interaction with pens or pencils, as well as share documents between multiple locations (Wellner, 1993).

Following this early form of TUIs, Fitzmaurice, Ishii and Buxton experimented with TUIs or what they called “Graspable User Interfaces” at the time. Their project named “Bricks” involved “physical handles” to control electronic or virtual objects and marked the shift from using pens and fingers as pointing and writing devices to attaching digital information to physical objects (Fitzmaurice, H. Ishii, & Buxton, 1995). The utilization of physical objects by Bricks underlines certain goals and advantages: two-handed interactions, objects with specific physical and digital properties, multi-user capabilities and relatively natural means of interaction (Fitzmaurice et al., 1995, p. 443).

GeoSpace, a navigating map system, was designed in 1997 specifically for the project “MetaDESK”. By putting a building block on a particular spot of the surface, the map would orientate itself to the positioning of the physical model. This example, where digitized objects meet an interactive surface, solidified the previously mentioned goals of TUIs (Ullmer & H. Ishii, 1997). A project used for urban planning called “Urp” utilized the same type of user interface, only more physical objects were incorporated for richer interactions. Urban developers used Urp to determine urban planning issues, specifically building shadows, wind flow and reflections, and proximities between buildings and roads (Underkoffler & Hiroshi Ishii, 1999, p. 387).

2.1.2 Digital Augmentation of Everyday Objects

“Tangible User Interfaces...augment the real physical world by coupling digital information to everyday physical objects and environments” (H. Ishii & Ullmer, 1997, p. 2). There are two notable projects that bring social environments

to a new level. The first, FishPong, is an interactive tabletop with a fish theme. In a social setting such as a coffee shop, the users have magnetically tagged coffee cups that allow them to interact with the table. Not only is it a great conversation piece, it also serves as an “icebreaker” for patrons, even between those who may not know one another (Yoon, Oishi, Nawyn, Kobayashi, & Gupta, 2004, p. 374). The Drift Table is a coffee table intended for the home and operates in a similar way; however, interactions between the table and its objects are not limited to coffee cups. In this case, it is the distribution of weight provided by objects placed on the table that manipulates an aerial photograph. Through a combined effort of people positioned around the table, the display of the aerial image slowly and constantly moves in the direction where the heaviest objects are situated (Gaver et al., 2004, p. 895).

Ping Pong Plus is an example of a computer supported collaborative play system, a category under which TangiPlay can be classified. Ping Pong Plus digitally augments the game of ping-pong through adding a digital display on top of the table along with corresponding audio (Wisneski et al., 1998). Players use the customary ping-pong ball, table and the ping-pong paddle but in an unlit room as the interactive surface’s projection provides the light. Microphones underneath the table triangulate where the ping-pong ball strikes the table and that information is used by one of several different programs to control the audio and visual display. For example, “Water Ripple” generates a water ripple wherever the ball hits the table. While this example changes the visual perception of the game, how players mentally approach the game remains unaffected. Other

programs make ping-pong more collaborative, such as “Painting” and “Comets”, two modes that require the players to work together to generate a painting and musical tones. “Spots” removes light from the ping-pong table wherever the ball lands and a thunderstorm is generated by a rally in the “Thunderstorm” mode. These last two examples change how players approach ping-pong. In “Spots” mode, it becomes more difficult to see the ball because light is removed from the area where the ball hits. With “Thunderstorm”, as the storm’s visual and audio feed become more frenzied, players tend to reflect that state by hitting the ball harder and faster (H. Ishii, Wisneski, Orbanes, Chun, & Paradiso, 1999, pp. 4-5). Ping Pong Plus demonstrates how a traditional game can be transformed into a different experience through digital augmentation.

2.1.3 Surface Computing

TUIs often require two main elements: “tokens...the physically manipulable elements of tangible interfaces, and [interactive surfaces]...the physical interaction spaces in which these objects are used” (Ullmer & H. Ishii, 2000b, p. 6). Tangible Viewpoints uses an interactive surface and a combination of tokens, specifically called “pawns” in this project, to facilitate an exploration of a narrative (Mazalek, Davenport, & H. Ishii, 2002). Pawns represent characters within a narrative and when a particular one is placed on the surface, corresponding story segments appear around the token. Through using a selection token, individual segments can be activated and are displayed on an adjacent screen. When two pawns come together, the story segments only

involving the two characters come into view. Through these interactions between physical objects and the surface, a tale is told.

Many TUIs create entirely new experiences through combining interactive surfaces and tokens. They lend themselves well to the creative process, specifically audio (Schiettecatte & Vanderdonckt, 2008, p. 3). AudioPad is designed for musicians to mix audio samples; this is accomplished through token-surface interactions (Patten, Recht, & H. Ishii, 2002). This work has been continued by such projects as reactTable (S. Jordà, Geiger, Alonso, & M. Kaltenbrunner, 2007, p. 139) but rather than manipulating existing music, it is capable of modulating sounds and rhythms. It also pioneered a tracking technology called ReactIVision, which uses fiduciary markings being tracked beneath the screen. This will be discussed in more detail in the Prototype chapter. AudioCubes, palm-size cubes housing LED lights, is a similar audio interactive interface but they do not require an interactive surface; rather, the cubes themselves are the interface and can be coupled to create and mix audio tracks (Schiettecatte & Vanderdonckt, 2008).

2.1.4 The cube as an interface

The cube lends itself well in TUIs because its attributes suggest how it is used. This idea that users know how to interact with an object based on its characteristics is called affordance (Sheridan, Short, Van Laerhoven, Villar, & Kortuem, 2003, p. 1). Therefore, “the affordance of the [cube] is known to every potential user. [It] can be picked up, rotated and played with, it can be thrown and shaken, and be put down again. ...Additionally, relying on the experience with

dice games, people expect to find different information on each side of the cube” (Terrenghi, Kranz, Holleis, & Albrecht Schmidt, 2005, p. 154). Many examples exist illustrating the popularity of using tangible cubes as an interface in diverse ways. The Learning Cube, as the name suggests, is a tangible interface for the purpose of learning. Each side is made up of an LCD screen; together, the sides offer multiple-choice questions and answers to quiz students on a predetermined subject. It offers a “playful interface...to embed and integrate technology into children’s everyday context and activities” (Terrenghi et al., 2005, p. 153).

Smart Blocks is an interface designed for children to learn about volume and surface area of three-dimensional objects through physical manipulation of cubes. When students interact with them, their properties are updated in the program, allowing the student to receive “continuous feedback for reinforcing learning” (Girouard et al., 2007, p. 183). RoBlocks is another environment intended for learning, in this case, tangible programming for constructing robots. Each block is attributed a specific element ranging from light sensors to movable tracks for propelling a robot (Schweikardt & Gross, 2008, p. 167). Like RoBlocks, each block in AlgoBlock is assigned a command. Each one is designed to control a cursor in some way. By connecting blocks, specific programming sequences are carried out (Suzuki & Kato, 1995, p. 351). Because of the cube’s familiar affordances, it was a natural choice to include cubes in TangiPlay along with an interactive surface and tokens.

2.1.5 Tangible User Interfaces and Board Games

It is no surprise that TUIs have made an impact on games. As explained earlier, TUIs are used to make learning more enjoyable through blending knowledge, interactivity and play, as illustrated in the Learning Cube. It has allowed, though not commercially, for a new type of games that some call “surface games” (Kirton, Ogawa, Sommerer, & Mignonneau, 2008, p. 953), a term I will continue to use in this thesis. The nature of such games is a blend of analog and digital, as was the case with MetaDesk.

With games, board games are situated within the analog realm. Chris Crawford defines board games as such:

“These games consist of a playing surface divided into sectors populated by a set of movable pieces. In the most common arrangement the pieces are directly associated with the players, while the playing surface represents an environment beyond the players’ direct control. Players maneuver their pieces across the playing surface in an effort to capture other players’ pieces, reach an objective, gain control of territory, or acquire some valued commodity. The player’s primary concern in these games is the analysis of geometrical relationships between the pieces.” (Crawford, 1984, p. 22)

Many game designers agree upon the fact that board games provide a context for meaningful social interactions between players while video games provide immediate feedback through audio and graphics. With a computer system that referees game play, users can become immersed in the game experience (Kirton et al., 2008; C. Magerkurth, T. Engelke, & Memisoglu, 2004; C. Magerkurth, Memisoglu, T. Engelke, & Streit, 2004; C. Magerkurth, A. D Cheok, R. L Mandryk, & T. Nilsen, n.d.; Regan L. Mandryk & Maranan, 2002, p.

640; Mazalek & van den Hoven, 2007; Zhou, A. D Cheok, Chan, Pan, & Y. Li, n.d.). Additionally, video games channel a user's attention exclusively to the screen from which the immediate feedback is delivered and little physical social interaction is achieved (Zhou et al., n.d., p. 1). However, video games "...provide for complex simulations, evolving environments, impartial judging, the suspension of disbelief, and the ability to save the state of the game" (Regan L. Mandryk & Maranan, 2002, p. 640). While this might seem like some game designers are rivalling board games against video games, the goal of TUI game designers is really to bring together the advantageous elements of both analog and digital games to create surface games. This is iterated by Mandryk & Maranan in their article about exploring board and video games: "In order to develop technology that promotes social interaction rather than isolation, we are exploring the space between board game and video games. We created a hybrid game that leverages the advantages of both physical and digital media" (Regan L. Mandryk & Maranan, 2002, p. 640).

There are a wide variety of surface games. In terms of interface, these games take on the form of game boards as all include tokens and a surface, which is interactive. PINS is a surface game that requires strategy and to be played on a multi-touch surface. Though it does not involve a grid, it is a blend of Chess and Checkers. In order to win the game, a player must eliminate all of his/her opponent's pieces or be the first to reach a predetermined score. Unlike the games by which it is inspired, PINS is played on an interactive surface that provides feedback reflecting each move (Kirton et al., 2008, p. 954). The

interface is able to give such feedback because a TUI plays referee, akin to video games. W41K is a miniature based war game, which is a TUI form of Warhammer 40K™ (W40K) that benefits from the computer's ability to instantly calculate complex algorithms because this type of game incorporates many tokens per player, each with unique attributes such as health, armour and weapons, all of which change constantly throughout the game. "The idea of W41K is not to simply replace a rule book with a computer screen but [to allow] the players to focus on strategic decisions and social aspects by relieving them of cumbersome tasks and providing them with relevant and up-to-date information about all game objects" (Hinske & Langheinrich, 2009, p. 104). Due to the intricate nature of war games, TUIs are well suited for harnessing the power of a computer since they impartially and consistently calculate player interactions and follow rules. As a result, TViews, a game based on the popular combat game Dungeons and Dragons, utilizes the computing prowess of TUI technology while being able to keep the game tangible.(Mazalek, Mironer, O'Rear, Van Devender, & Herder, 2008).

Dungeons and Dragons also inspired another TUI game called KnightMage. This game was developed on a platform called STARS specifically designed for creating surface games (C. Magerkurth et al., 2004, p. 15). STARS has been used to develop two additional surface games: Candyland and Monopoly Adaptation (C. Magerkurth et al., 2004, p. 16). Candyland is a surface game that designers created to examine children's interactions with a TUI. It guides children through a small village by means of an adventure/storytelling

game engine. Monopoly Adaptation, as suggested by its name, is an adaptation of the board game Monopoly, and is valuable for evaluating the digital version compared to the analog game. Shuffling, stacking cards and money handling are fulfilled automatically with the TUI; furthermore, game rules are enforced by the system. STARS has proven to aid in developing surface games and may even be groundbreaking; creating surface games is a time consuming and an expensive process as there are no kits available. Thus, the software and hardware for existing TUI games are generally consumer and custom-made parts pieced together to engineer desired projects. For TUI game designers this is daunting, as the skill sets required includes knowledge of electronics, engineering and programming, in addition to having the creativity to generate an entertaining game.

2.2 Prototyping

TangiPlay aims to provide a ready toolkit of tangibles and an interactive surface to aid TUI game designers with conceptualizing new electronic games. While STARS is a platform for developing new games, it does not allow rapid game development. “The STARS platform consists of a specialized hardware setup that allows integrating different kind of devices with a game table that each have the potential to enrich the gaming experience in one way or another...[but] the actual gaming applications are built on top of a STARS software layer” (C. Magerkurth et al., 2004, pp. 73-74). The three games that were developed using this system had unique tokens, graphics and game rules that had to first be created and programmed before the systems could be tested. Because STARS

is so specialized due to its technological nature, it requires someone with a profound understanding of the platform to aid game development. In other words, STARS specialists are the only ones who can create games or designers need to work along side a specialist through the whole game developing process. Generating games, finding solutions and adjusting concepts would require extensive teamwork, much time and good communication. So the only existing tool for creating surface games right now – STARS platform – is not ideal for rapid game development. “Creative ideas rapidly evolve during the early stages of a design but the lack of tools available that supplement and support traditional sketching and prototyping skill means that effective exploration of integrated design concepts becomes a major challenge” (Culverhouse & Gill, 2009, p. 363). While the STARS platform is designed to create unique and robust, playable surface games, it does not enable rapid game development; therefore, the need for prototyping tangible games quickly and easily remains.

2.2.1 Defining Prototyping

STARS is only one of a handful of tangible prototyping platforms that exists and each project approaches the process of prototyping in a different manner, as designers have various interpretations of what constitutes a prototype. Even within the established video game industry, what a prototype comprises of is not standardized. As Ian Schreiber put it, “[t]he word prototype is a tricky word because it means different things to different people. I’ve seen some people who, to them, what prototype means is “first playable”; it’s an alpha version of the game. It’s not fully working; there’s lots of bugs but most of the

functionalities are there and you can sort of see what the game's going to be like. But it's still production code and we're going to use it. Other people see a prototype as a very unfinished but complete game. Other people would see it as a single system within a larger game" (Schreiber, 2009). A specific genre of prototyping is paper prototyping "[a]nd basically, it implies using paper but it's also using little knick-knacks and you might use, checkers or chess pieces or little army men or dice or whatever you would normally use, sort of like basic game pieces to just figure out a basic rule system. The interesting thing about paper prototyping is that obviously it's not prototyping the whole experience; it's usually prototyping one specific part of the experience" (Weise, 2009).

Prototypes, as Ian Schreiber described, vary in how complete they are, but the goal is to test a concept before committing an idea to production. Producing a game to the point where it can be published ranges from months for smaller independent games to years for large titles. "So prototyping in paper is a lot faster and so it is very practical for a video game designer to be able to use non-digital materials in order to prototype as many systems as is practical for a project. Just because you can figure a lot of things out very fast and very cheaply before programmers get involved and things start getting very expensive to build and to change" (Schreiber, 2009).

2.2.2 Paper prototyping

Paper prototyping is a developed practice used for designing, testing and refining UIs. A designer would build a paper version of the desired UI, specifically different screen shots for each task a user could complete. Then a user would

interact with the paper prototype, having a person act as the computer, another as the facilitator and finally one who observes by examining what happens.

(Snyder, 2003) Paper prototyping is popular as a UI can be quickly mocked up for a lot less money than actually coding a UI. Additionally, both users and developers can evaluate and modify it.

With board and video games, paper prototyping is often "... a crude model whose purpose is to allow you to wrap your brain around the game mechanics and see how they function" (Fullerton, Swain, & Hoffman, 2004, p. 157). When Ian Schreiber prototypes a video game, he uses items found in his 'prototyping box'. The kit includes, for example, a variety of dice, random game bits, glass beads, zip lock baggies for organizing pieces, index cards, sticky labels in different shapes, wooden cubes, pennies, pens and coloured markers (Schreiber, 2009). These tools lend themselves to prototyping board games, as a designer can very quickly mock up a game like Battleship by simply drawing out a grid and having a few tokens. However, Schreiber says "... if you were talking about a game like...Sid Meier's Civilization, a very wonderful video game, a lot of the systems in there could be prototyped on paper in about fifteen minutes with just taking a pencil and drawing a bunch of squares on a game board and sitting down a couple cardboard tokens saying, 'This is a tank. This is a knight. Go'" (Schreiber, 2009).

2.2.3 Prototype Samples

Prototyping can be used to examine a specific game mechanic, complex attack calculation or even how to interact with a tangible interface. Robert

Madsen uses C# and sometimes the XNA platform as those are the languages he feels comfortable prototyping with. “[T]he key idea is to develop some goals so that I can come up with an as-fast-as-possible and playable version of this prototype because ... we don’t want to invest a lot of time into it so we just want to get the prototype done as quickly as possible and into people’s hands to see if it’s a feasible concept” (Madsen, 2009). At a video game workshop, Matt Weise in a group prototyped an aspect of Resident Evil using Excel. Resident Evil is a first person shooter, so the dynamics of moving through a space was not replicated, instead an algorithm was developed. “So rather than actually modelling the space and then having the user’s experience of being in that space ... we took that experience and then abstracted it out to a level of sheer probability and then basically said well, there’s this many enemies in a room based on how many bullets you have and how close they are to you. There’s some mechanic and some sort of algorithm or some sort of mathematical equation that determines whether you get out of the room or not” (Weise, 2009). At Carnegie Mellon, Seth Sivak was developing a tangible user interface for an exercise game. “We were doing something totally new; we were designing totally a new interface to play so we had to test it as much as possible and just iterate on it many times. We went through, I would say, probably over a dozen iterations just on the dance pad itself. We started with it just being the standard DDR dance pad set up and then we ended up tilting it on a 45-degree angle so that it made a diamond because we found that more ergonomic. Then we changed over and over again what buttons went where, what their interactions were and just tried to

make it comfortable, ergonomic and feel cool, not feel forced or gimmicky, like feel it was interesting and fun” (Sivak, 2009).

2.2.4 Tangible Prototyping Environments

Due to the nature of TUIs and the lack of standards for input and output in this particular field, there are a wide variety of designers attempting to make environments to address the issues of prototyping for TUIs. Designers keep in mind the following: “In creative sessions, it is crucial to have an intuitive interaction for not distracting the user from the task to be solved” (Hofer, Naeff, & Kunz, 2009, p. 317). As such, they identify an audience and create a system catered to that audiences’ skill level and needs. Papier-Mâché (Klemmer, J. Li, Lin, & Landay, 2004) and PhidgetLink (Jung, Schrader, & Carlson, 2005) attempt to address tangible prototyping issues, each taking a different approach. Papier-Mâché is a prototyping kit that supports tangible interfaces. It incorporates computer visions, electronic tags and barcodes and is programmed through a code-based environment using Java. The following is a sample of coding for controlling the vision system:

```
1 PhobProducer prod = new VisionPhobProducer
  (new CameraImageSource());
2 AssociationFactory factory = new
  VisualAnalogueFactory(new PMacheWindow(
  gen, CALIBRATE), JPanel.class);
3 AssociationMap assocMap = new
  AssociationMap(factory);
4 gen.addPhobListener(assocMap); (Klemmer et al., 2004, p. 403)
```

This is only four lines of code; nonetheless, it requires programming knowledge to implement this device for conceptualizing a tangible interface. PhidgetLink is designed to incorporate existing hardware, in this case Phidgets and it acts as a bridge to connect sensors to an interface kit and then outputs to a client application (Jung et al., 2005, p. 4). Once again, it is required that designers have suitable understanding of necessary elements in order to make a functional TUI. Yet, this system is a step towards better facilitating game designers as it simplifies the prototyping process.

All programming requires some level of language. Any programming done in the TUI field is generally considered high-level. In other words, little knowledge of programming codes, specifically machine codes, is necessary for program development. However, within the field of TUI prototyping environments, Papier-Mâché and Phidgets are low-level programming environments as compared to projects similar to iStuff (Ballagas, Ringel, Stone, & Borchers, 2003) and CookieFlavors (Kimura, Okuda, & Nakajima, 2007). The latter two are high-level programming environments and are considered such because they permit quick and easy development of large programs. Computationally, it is less efficient but as a prototyping environment, this is not a concern. What is important is that the physical devices are “simple enough so that developers can concentrate on the overall use, modification and recombination of devices into a physical user interface instead of low-level device construction and implementation” (Greenberg & Fitchett, 2001, p. 215)

CookieFlavors and iStuff are two research examples of prototyping environments for developing TUIs that are both in early stages of development. CookieFlavors is designed to help developers omit the implementation stage of TUI development. In 'iStuff: A Physical User Interface Toolkit for Ubiquitous Computing Environments', Ballagas, Ringel, Stone and Borchers explain how there is no guide on how to apply affordances to TUIs and that the process takes a great deal of time and money. Therefore, the goal of CookieFlavor is to use existing objects in which small sensors are applied as a rapid way of mocking up a TUI. For example, one may take a sensor that looks similar to a large quarter, and attach it to a coffee mug to detect its rotation. Other various sensors included in the project measure acceleration, galvanic skin response, ambient light and pressure. In the end, it was suggested that CookieFlavors effectively supports the trial and error process and helps developers design visualization and exteriors for TUIs.

iStuff is a toolkit that includes physical devices and a software interface designed to work in the Stanford iRoom. The iStuff toolkit combines lightweight wireless input and output devices, such as buttons, wands, speakers and microphones. Each of the iStuff components "can be dynamically mapped to different applications running in the iRoom through a software intermediary called the Patch-Panel" (Ballagas et al., 2003, p. 537). This setup facilitates users to rapidly prototype unique TUIs. For example, most users in about 30 seconds can take the iButton and program it to open a computer application, or turn on a light. "[iStuff] has led to more adventurous, innovative, and outside-the-box user

interfaces in the research projects created by our group and visiting project students than before” (Ballagas et al., 2003, p. 543).

3: METHODOLOGY

This thesis is an exploration of tangible electronic game development and its goal is to produce a prototype that can be tested to generate future iterations and to start envisioning future tangible electronic games. A protocol study was developed to evaluate a prototype from a technical perspective, but more importantly to assemble games designers' view on the project and what an effective prototyping system would be for tangible electronic games. This chapter begins with the technical conditions TangiPlay was designed to meet, then outlines the details of user testing and finishes with how the prototype was conceptualized.

3.1 Technical Prototype Requirements

Tangible electronic games currently do not exist in the commercial market so there are no sample projects one can use to understand the potential of tangible electronic games. Without a common understanding, asking users to guess or envision how a prototyping environment for tangible games would function is not pragmatic. As such, a working prototype for user testing was necessary to generate understanding of the potential in tangible electronic games. The prototype would need to allow users to physically interact and provide feedback on what would be generated during the conceptualization process. None of the output generated by the prototyping environment would use the Wizard of Oz method that some other tangible systems employ for testing

(Hartmann et al., 2006). Rather, the project would have to completely interpret user input to provide accurate and instantaneous response in order for the project to be realistically evaluated by users. TangiPlay was the outcome of these specific requirements.

TangiPlay is a prototype itself designed for game designers to conceptualize tangible electronic games. The analysis of this prototype demanded user-testing sessions that required a minimum of thirty minutes of operation as testing included an introduction to the project, a demonstration, a development of an original game and finally an evaluation of the outcome. During this process, the complete system had to continuously communicate within itself, which consists of three major components: an interactive table, responsive tangible tokens and a programming environment. Because these elements rely on an assortment of experimental and consumer technology, there was no expectation for the final project to be entirely flawless; minor faults were acceptable, assuming they would not affect user's development of a tangible electronic game.

3.1.1 Prototype Components

TangiPlay consists of multiple smaller components to constitute the complete prototyping environment. These components are an interactive table, responsive tangible tokens and a programming environment.

The interactive table performs two functions; it first registers the token's presence on the display surface and then it displays the associated feedback.

There are two kinds of responsive tangible tokens – Simple and Smart. The Simple tokens are physical objects with a unique identification on the bottom. The much more complex Smart Tokens use a gyroscope and an accelerometer to sense movement and current orientation respectively. The information is wirelessly transmitted to the interactive table so that the information can be interpreted, then displayed on the Smart Token and the interactive table. The programming environment ties the interactive table and tokens together through a collection of programs that track user input, computes the data and then outputs a display on the interactive surface.

Because TangiPlay is a prototype, occasional malfunctions were expected throughout user testing and considered acceptable as long as it did not impact the user testing process. Simple tokens have little to cause errors; the only way these tokens can fail is if their identification becomes obscured. On the contrary, the combination of consumer technology including wireless parts and sensors soldered together, limited battery life and the physical act of rolling the Smart Tokens on a hard surface has meant that there have been frequent occurrences of malfunction. To be considered completely functional, the Smart Tokens needed to last the duration of the user test, display their correct orientation through the LED's on each face and stay in communication with the interactive table. However, this was not realistic, so the goal was for the Smart Token to be functional 80% of the time, or in terms of the project, four of out every five rolls must work. Nonetheless, the programming environment had to operate

impeccably as the hardware portion of the project was the only part where errors were acceptable.

3.1.2 Prototype Goals

When I designed TangiPlay, the requirements were generated purely to produce a system that could be analyzed. The prototype had to be functional enough to enable users to reproduce existing games such as Snakes and Ladders, and then formulate an entirely new game with the tangible tokens and an interactive surface. Once made, the games needed to be playable and then amended as needed. TangiPlay had to facilitate this cyclical act, as one of my goals for the project was to compare TangiPlay to paper prototyping and its unbound, iterative process.

Game designer's familiarity with paper prototyping provided a common foundation for understanding, comparing and suggesting how to improve TangiPlay. Building TangiPlay was an iterative process itself so early feedback from users was built into the system, assuming the suggestions were feasible under the scope of the project. When suggestions were not feasible, I evaluated and incorporated them into the Future Directions and Discussion chapter, where I forecast what tangible electronic games can become. TangiPlay is the first tangible prototyping environment and it may not be continually as a project, but an analysis of it can help mould the future of tangible electronic prototyping tools.

3.2 The Study

Tangible electronic environments do not exist outside of TangiPlay, so there is no standard means to analyze the project. The objective of this thesis was not to completely dissect TangiPlay as would be done in a case study; instead, through user testing, I designed TangiPlay as a proof of concept to generate inferences about the future of tangible prototyping environments and the games they can make. The most suitable study for my project is a protocol study, which was developed through the process of building TangiPlay to extract implications. A literature review, which was conducted throughout the whole project, and a first generation of tangible prototyping tool was developed and analyzed to aid in the creation of TangiPlay; however, I gained the vast majority of insight from phone interviews and the testing of TangiPlay that was conducted with game designers.

3.2.1 Phone Interviews

Phone interviews with game designers were conducted to provide insight into their prototyping practices, which led me to better understand how to develop TangiPlay. I sent an email to the International Game Developers Association asking for volunteers. The message included an introduction to the project and stated the goal – to learn about prototyping practices. I set up a date and time with those who volunteered and, for ethical reasons, asked if the conversation could be recorded. Seven people participated in the phone interviews including two students and five professionals in the game industry, three of which are also instructors. All were male and located around North America.

The phone interviews followed a predefined script (found in the Appendix), which began with another brief introduction about the project and once again, I confirmed their approval to record the session. If an interviewee answered “no”, the interview would be terminated at that point. Thankfully, all who volunteered permitted the recording. I began the interview by asking about the participant’s education and background in the game industry, and then continued with specific questions about prototyping experiences, practices and tools. It was important to first evaluate the interviewee’s knowledge and experience of tangible games so that I would know how to interpret the rest of the interview. In the case of knowing very little about tangible games, I defined the concept in relation to my project.

While very few participants had worked with tangible games, all of them had paper prototyping experience and used various tools to aid their prototyping process. In every phone interview, we discussed the programs and strategies they employed and whether they felt that there is insufficiency in paper prototyping. Creativity also played a role in their designs but I wanted to learn how and when it did. Often, many ideas surface when creating a game so it was important for me to understand how game designer selected ideas to carry forward and what they do with the so-called unsuccessful ideas. Drawing from what was discussed about what they saw lacking in paper-prototyping, I then inquired about what they would like to see to aid the process of prototyping. I finally explained my vision of TangiPlay, specifying my desire to create a tool that would facilitate the future of tangible game prototyping.

When all my questions were answered, I invited the interviewee to ask questions and provided them with my contact if future correspondence was desired. The audio files were logged and pertinent sections were transcribed for use in this thesis. Having had no industry experience in building a tangible prototyping tool, their answers provided guidelines for the development of tangible tools and solidified what I hypothesized as a suitable process. Furthermore, I came to understand how to approach the protocol study.

3.2.2 Testing TangiPlay

The user testing of TangiPlay required a more complex structure. Once again an email was sent to the International Game Developers Association and game companies in the Vancouver area that specialize in Wii Games asking for volunteers, the latter in particular because Wii game designers have experience with tangible based controllers. When this process was done for the phone interviews, I was able to acquire seven participants; however, testing of TangiPlay needed people to physically come out to Simon Fraser University Surrey to be part of the study. In two weeks of asking for volunteers, I had no confirmed game designers. The email and subsequent correspondence followed the same structure laid out for the phone interviews; except it now included a twenty-dollar gift card incentive. Eight professionals from game industry were tested.

Parallel to the phone interviews, I drafted a script to guide the user testing sessions (found in the Appendix), which began with an overview to the project, followed by a demonstration of how the physical project worked and then

transitioned to users creating a game and final comments. In order to refine the script and determine how user testing would progress before asking game designers to volunteer their time, I conducted two rounds of preliminary testing, each with three different users. Examination of the two rounds of testing led to simple changes with TangiPlay - adjusting how questions would be asked and adding the step for gathering background information from participants. The result was a prior experience sheet designed to learn about participant's educational history and experience within the game industry. Another one of the most significant changes was the recording process, as I found the quality of the recording technology in the first round was very poor and audibly irritating during the session because the camera constantly went in and out of focus.

The script was specifically designed to enable users to build and play a tangible game, and retrieve feedback on the overall process, all in roughly thirty minutes. In order for users to be able to conceptualize a game, they needed to be familiar with the technology. The script utilized a scaffolding process to give users sufficient information to enable them to construct a game within approximately ten minutes of being introduced to TangiPlay. The user testing employed by Topobo (Raffle, Yip, & Hiroshi Ishii, 2006) inspired this scaffolding process. Topobo is a 3D construction kit with kinetic memory and uses a scaffolding process as the project also needed to teach users how to use the tool quickly.

User testing began with an introduction to the general research project and again I asked participants if the session could be recorded and used for

research purposes. An overview of the prototyping system was designed to highlight the specific elements with which users could interact and an explanation of how all the pieces related to each other. I then worked with the participant to reproduce Snakes and Ladders, a simple and generally well-known game. This collaboration got participants building a game board, determining rules, selecting game pieces and playing the game. Equipped with the concept of the project and how it functioned, users were asked to continue exploring the table and tangibles, and then to make a game. This was, however, preceded by going over my goals of analyzing the session, as it provided an explanation to the user about the questions that would be asked at the end of the session. While the participants made their game, I avoided providing suggestions unless asked for, but once the game was made, I played through their game with them, as their games required an additional player. After the game had been played and edited, I posed three questions, which were designed to find out the user's thoughts on their finished game, the conceptualizing process and how it compared to previous prototyping experiences. The session concluded with an opportunity for the users to ask questions. I also gave them my contact information for any other possible questions or comments.

Time was spent watching the recording of user testing sessions to interpret notable behaviours and to discover answers for generating implications about the project and tangible prototyping in general. Patterns, suggestions and comments were extracted from my interactions with the users throughout the introduction, the demonstration, the game development and testing, and from

feedback on the process and technology of TangiPlay. The duration of each section was also noted.

3.3 TangiPlay Conceptualization

TangiPlay began as one project of a larger research group referred to as CAT Games (Creativity Assistive Tools for Games), funded by Heritage Canada. CAT Games was a research network with a vision to produce tools for game production. TangiPlay was conceived from the “Gesture and Tangible Prototyping Tool” concept, which was envisioned by CAT Games “... to enable designers to quickly conceptualize and create physical, tangible and virtual game prototypes based on physical gestures and manipulation of ‘smart’ objects” (“CATGames: Creativity Assistive Tools for Games,” 2007). TangiPlay materialized from this concept as first TangiDice and in its second iteration, as TangiPlay.

3.3.1 Explored Technology

The proposal defined by CAT Games was quite vague, so the project began by narrowing the scope of games down to dice games and an exploration of technology that could support the application. ReactIVision, blob tracking, Arduino and the Nintendo Wii controller were four types of technology studied to make an electronic tangible dice. ReactIVision is open source computer vision software designed for tracking fiduciary markers. In the initial stage of testing, a camera was mounted above a table to track the fiducials that were printed on the sides of a wooden block. This setup was cumbersome; the camera had to be

fairly close to the table in order to read the fiducials, but that prevented the camera's viewing angle from covering the whole table. In addition, a user's hand or body often obscured the face of a die, causing the system to lose track of it. Blob tracking, which was a program written in Max/MSP, required a similar physical setup but rather than using fiducial markings, it tracked coloured dice on a table. It identified first the colour and then the number of pips. However, it suffered the same issues as the ReactIVision setup because it still required an above-mounted camera. Arduino is an open source platform for electronics, and the goal was to make a wireless system that would know its orientation and communicate to the computer. While the concept resolved the visual concerns of ReactIVision and Blob tracking, this technology was temporarily abandoned once it was determined that a stock Nintendo Wii controller could do the same – determine one's own orientation and communicate to a computer.



Figure 1: ReactIVision, blob tracking, camera setup, Arduino with accelerometer and Nintendo Wii circuit board

3.3.2 TangiDice

Having the ability to communicate with a Max/MSP patch, the Nintendo Wii controller enabled the creation of TangiDice, a proof of concept for a tangible prototyping environment. Each physical die is a cardboard box housing a Wii controller's circuit board. Due to the ability to program the Nintendo Wii controller

through a Max/MSP patch, users are able to modify rules and compare the game results of two players.

The ability to be creative in altering rules exists thanks to the make-up of the Nintendo Wii controller, which uses Bluetooth to communicate and includes a three-axis accelerometer. When I was developing TangiDice, it was approximately the same price to purchase a controller or an individual accelerometer. Working with a Wii controller was far less complicated since the communication protocol and sensors were already built; even a plug-in had already been produced for programmers using the controller with Max/MSP. However, the circuit board for the Wii controller is as long as the physical housing and is not meant to be modified. Consequently, a very large die housing was necessary to accommodate the long circuit board. TangiDice employs Max/MSP for communicating with the physical dice and as a user interface. It displays which side the dice are facing up, variable rules, score and a load/saving mechanism. A keyboard and mouse are used to interact with the interface, which is displayed on a forty-inch monitor and the dice are rolled in a felt lined rectangular box.



Figure 2: TangiDice as a system and the dice

A significant aspect of the project is how the computer compares and computes the players' rolls. When a game designer makes a game with TangiDice, they begin with all of the rules turned off, but available. For example, if selected as a rule, the system can record how many times a die rotates after hitting the table, and the game designer would select if fewer or more rolls were desired and attach a numerical value to the preferred outcome. A specific rule could be to compare player one and two's rolls to determine who had the most amount of rotations and reward that person five points. In addition to rotation, face value, distance apart and acceleration, there could be combinations of these rules and how points are calculated. For example, one can set an initial value where the game commences and a winning score that players try to achieve. It is through the computation of the rules that generates the score but comparing rolls achieved by two players requires that the computer knows when the dice's

movements are actually intended for the game. This can be done by pressing '1' or '2' to indicate the respective player and his/her readiness, after which Max/MSP knows to calculate the roll for the selected player.

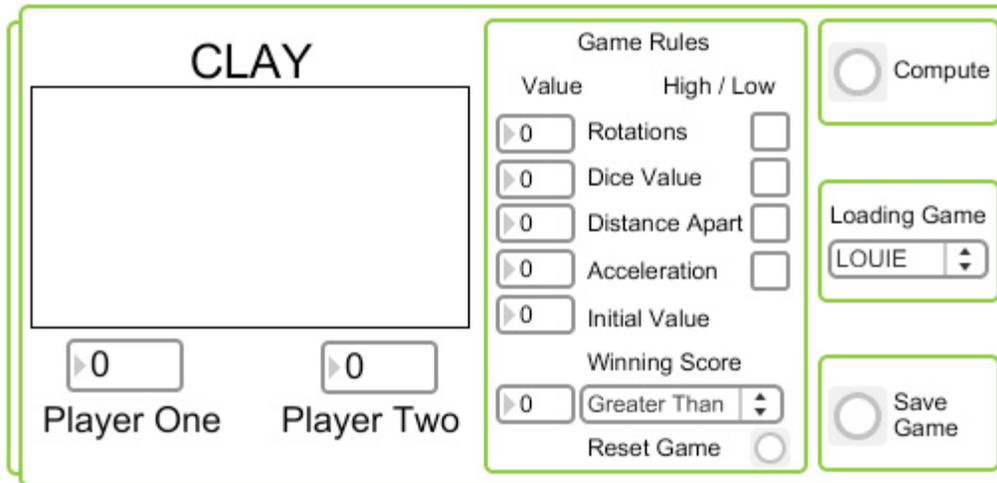


Figure 3: User Interface for TangiDice

I ran an informal testing procedure to evaluate TangiDice. User testing began with an explanation of the project and how it fit into the larger CAT Game's network. The UI was explained and then I gave a short demonstration on how to set rules. Extra time was spent clarifying the rolling sequence. After an introduction to the project, users were given the opportunity to make and play their own games. I took notes throughout the process about the user's thoughts and his/her final game. Six participants, consisting of undergrad and graduate students were the sample used for testing TangiDice.

TangiDice was a successful proof of concept as the user testing was able to demonstrate the prototyping concept and reveal both positive and negative aspects. The user interface became the apparent weakness, as multiple users

had issues understanding how to make rules even after a demonstration. The information beside the buttons was unclear to users and how points were added or subtracted was concluded to be overly complicated. The playing sequence became another confusing aspect for users. The need for the computer to compare player's rolls required the computer to know who rolled and when, but the sequence became awkward with users having to indicate via a key press before each roll and often forgot, causing the system to compare the wrong results.

At the point when users were capable of freely exploring TangiDice, many began by ensuring the system worked the way it was explained to them. Users played around with the dice to see if the system really knew who rolled, what the results were and which player should get points. By the end of the session, a few users had managed to make games that included skill by employing more than one rule and assigning often both positive and negative values to them. One such game scored points for the player with the most rotations when the dice was rolled, while also awarding points for the slowest acceleration. This was completely a skill based rolling dice game. The outcome was significant, as users were able to utilize the prototyping system to generate skill-based game with dice, traditionally chance based objects, and thus, highlighting the value of TangiDice.

TangiDice has proven to be a successful proof of concept, as it was able to both show the worth of a tangible prototyping tool, and shaped the outcome of TangiPlay, the second version of the project. TangiDice uses dice with

electronics inside to enable new means of play with a dice. Unfortunately, this was challenging because many people focused on the aspect they could see – the pips on each side denoting the face value. The die is an iconic object with specific uses known to almost any individual making it difficult for users of TangiDice to ignore and override pre-existing perceptions of a cube with notations on each side. Accordingly, users wanted to make dice games with dice, making it quite hard to push people to envision what other types of dice games could be generated. For example, one user wanted a matching face value rule, as it was a common rule he found with dice games. A temporary solution for testing was to provide users with samples of games that could be made with the technology. This scaffolding process used by Topobo (Raffle, Parkes, & Hiroshi Ishii, 2004) was later utilized in the user testing of TangiPlay. The goal was to build the user’s knowledge base to the point of being able to use the tool at its greatest potential. The perception of dice was also addressed in TangiPlay by means of stripping away the pips from all sides of the cube. As Matt Weise suggested, “You can help shape people’s perception of what “dice” means by the context you put the dice in” (Weise, 2009). The goal was to change the display format, thereby stopping users from bringing their preconceptions to the dice token. TangiDice also influenced how I approached the testing procedure as it underlined the need for a script to steer the interview and how detailed documentation can help with analyzing a session after the fact.

3.3.3 TangiPlay's Goals

Building on TangiDice, TangiPlay evolved from using dice to board games as a structure. Through the development of TangiPlay, other goals were built into the project. Initial iterations of TangiPlay's user interface was a combination of RCX Code and Adobe Photoshop. The concept was for game designers to program their tangible game using a mouse and keyboard with the UI, and then test the system with the tangible tokens. Preliminary explorations revealed the programming and testing stages were distinctly separate, so a new UI was created that only used tangible tokens. This new UI combined programming and testing, so a game in development could be modified during any stage. The tangible interface was designed to be completely intuitive for game designers, requiring minimal technical expertise. Development of tangible electronics is a time consuming process, but through supplying predefined tangibles, the speed of development for an electronic prototype was to go from days to minutes. Through the development of the display surface, the concept was born to combine digital information with the ability to draw directly on the screen with whiteboard pens, thus mixing digital and analog. Finally, TangiPlay's overall mood was to promote a sense of play for both development and testing of tangible electronic games.

3.3.4 TangiDice's Influence

In prototyping games, rules are developed and then tried. Often with paper prototyping, the tester must keep track of these and, should the game require it, calculate the results. TangiDice was programmed to implement the rules and

process the input, thus relieving the tester from having to act as referee, allowing them to focus on evaluating game play. However, there were only four rules from which users could choose to develop a game by combining one or more of these boundaries. Consequently, this limited toolset confined users to make very specific types of games.

More elements were necessary to allow for greater variety and broader rules to encourage creativity. With this in mind, my thesis question was generated: Can tangible electronic games be prototyped through using a ready toolkit of modifiable tangibles and an interactive surface? The outcome from TangiDice suggested that even electronically modified dice by themselves could support some level of new tangible electronic games.

In its final iteration, I was able to determine that TangiDice was successful in fulfilling its purpose; it was a reliable tool for users to prototype games. Through user testing, the value of the project became apparent when games were more than simply chance based; skill actually played a roll in the newly developed games. The concept of converting dice from a chance-based object to a skill-based object thus highlighted the potential of tangible electronic games. As such, I saw the power in facilitating the prototyping process in developing tangible electronic games with a ready set of tools. It was then a matter of figuring out what tools were necessary to make the system useful.

3.3.5 TangiPlay

TangiPlay was the next iteration of tangible prototyping tools after TangiDice. The concept was to build on the project by making a more complex toolset now that the proof of concept had been tested and shown to be successful. My goal was to evolve the underlying structure from dice games to board games with dice, tokens and a surface that is interactive. As previously stated, what I learned through TangiDice shaped multiple aspects of TangiPlay, even utilizing two key types of technology originally explored for TangiDice: ReactIVision and Arduino. I began designing TangiPlay with a wish list of functions that the final project could perform. Elements were suggested, evaluated and then kept if proposed technology seemed plausible.

3.3.5.1 Smart Tokens

TangiDice was successful with the exception of the size of the dice, which was rather large because it was housing a ten centimetre long Wii circuit board. Since this size was not practical for playing game, a dice of manageable size was designed for TangiPlay. Secondly, to prevent users from seeing the dice as purely numerical cubes, each side of the cube was designed without pips. Instead, a distinct colour emitted by LED lights differentiated the sides. Functionally, the dice were designed to have the same capabilities as TangiDice – the ability to determine which side is facing up, acceleration, rotation, good battery life, and reliable wireless communication. Finally, the name needed to reflect greater functionalities than an ordinary die and move people away from seeing them as simply that. To fit into the overall theme of the project, these new

dice became known as “Smart Tokens”, which in its first iteration was an accelerometer mounted on a large Arduino board and wired to the computer. As continual testing revealed flaws in the custom design, new iterations of both electronics and the physical housing were made. The final product is a six and a quarter centimetre cube printed from ABS plastic, which houses all the electronics including the accelerometer, gyroscope, wireless communication, LED lights and a 9V battery.

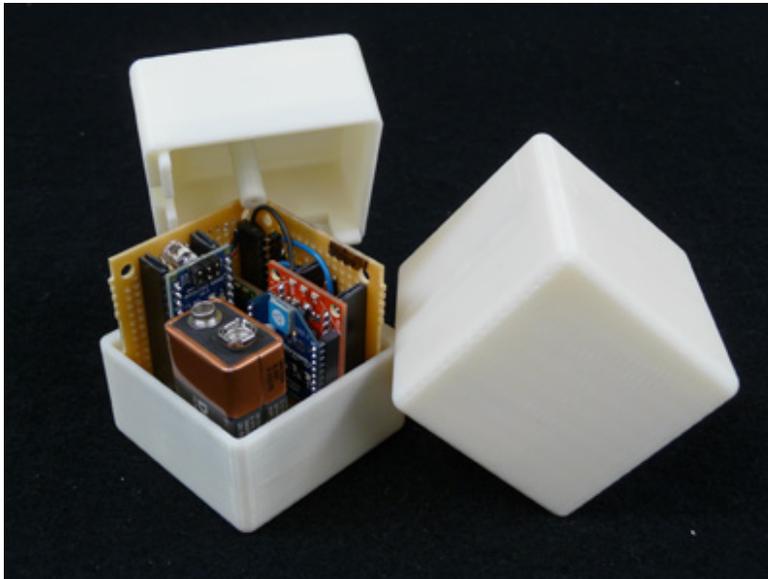


Figure 4: Smart Tokens Version 1.0

3.3.5.2 Simple Tokens

The progression from dice games to board games necessitated a need for new tokens, in addition to the revamped Smart Tokens. These tokens are named Simple Tokens since they lack the electronics housed inside, and instead use ReactIVision to gather information. ReactIVision is an open source computer vision program designed to track fiducial markers, in this case the markers on

found on the bottom of the tokens, and the program is able to identify each token individually, know its location and orientation. After completing a taxonomy of board games, I identified common game tokens and concepts. This led to the design and production of Simple Tokens, Programming Tokens, a Proximity Token and a Stamp Token, all of which rely on ReacTIVision.

3.3.5.3 Interactive Surface and User Interface

TangiDice uses a monitor for display, a separate area to roll the dice and a keyboard and mouse for interaction with the user interface. This configuration separates the tokens from the display and requires users to switch between token interaction and a position in front of a mouse and keyboard. One of the conditions for TangiPlay was to combine the display and the region where tokens would be used, and to limit keyboard and mice interaction. An interactive display table was selected as it enables users to have their tokens recognized by a computer from below the surface while also having a projector display on the same surface.

The user interface is a key focal point that ties the whole project together, yet there are few examples of software designed to incorporate tangibles and, furthermore, act as a prototyping environment. Lego Mindstorms (Baum, 2003; Resnick, Bruckman, & Martin, 1996) is a Lego robotic kit, which includes RCX Code, a drag-and-drop programming software. RCX Code is designed to enable children to rapidly program a robot and is a distant cousin to what a tangible prototyping user interface could be. For TangiPlay, the software is targeted for game designers, who often have limited programming experience and would not

want to spend hours coding a concept only to abandon the idea. Initial user interfaces designed for TangiPlay were a combination of TangiDice's interface, RCX Code and Adobe Photoshop. This user interface included a traditional menu system with ways to save and open existing projects, as well as a place to get help. The first focus of the UI was in setting up the interactive surface, for example player names, score and background pieces. The second focus was attaching rules, such as comparing acceleration and rotation to both the Smart and Simple Tokens. The graphics and layout for this interface were completed; however after much evaluation, the interface was found to be focused on guiding game designers through a predefined process. In addition, the tokens were only being utilized in the testing of the game, creating a distinct boundary between programming and testing.

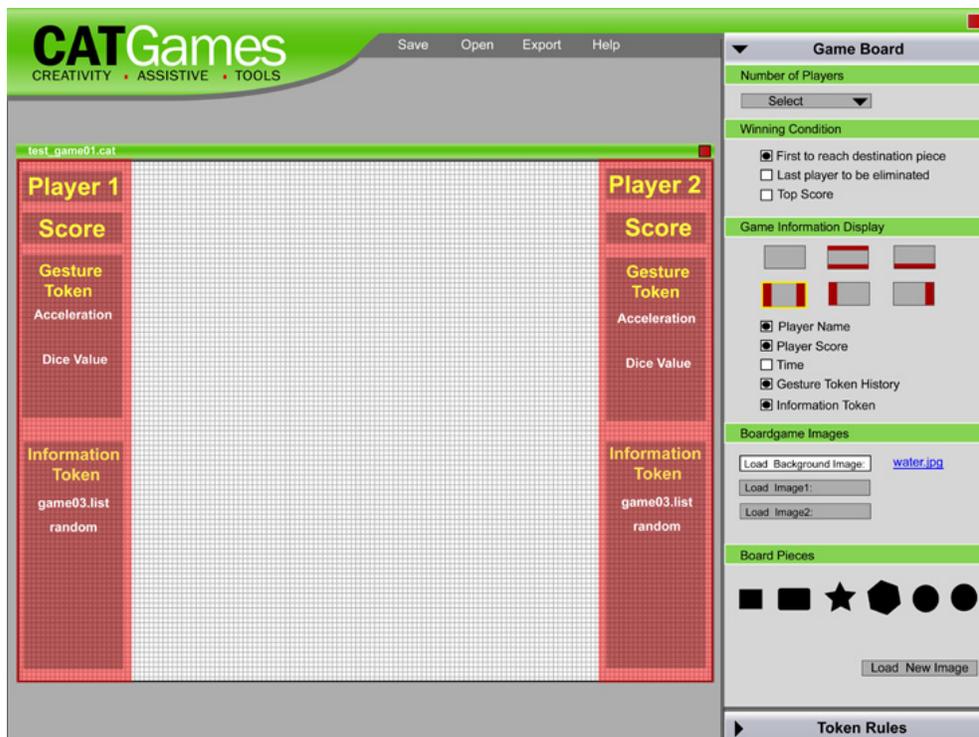


Figure 5: Early version of TangiPlay's user interface

A new user interface was developed which enabled complete token interaction without any keyboard or mouse. The interface was refined to remove the structure originally designed to guide game designers. Instead, the new user interface focused on a completely open prototyping process, one more comparable to paper prototyping than using a software wizard.

4: THE PROTOTYPE

One ambition of this thesis was to develop and assess a conceptualizing environment for the new field of electronic tangible games in which a ready toolkit of tangibles and an interactive surface are used to create a range of games. After a long development process, TangiPlay is the result of this objective. This chapter details the techniques and specific technology used to accomplish this goal and includes a scripted user scenario of how TangiPlay is designed to be used by game designers.

4.1 Technical Overview

TangiPlay consists of four main components, the interactive surface, Game Tokens, Programming Tokens, and a user interface. Each of these elements relies on different technology, yet they all work together and are designed to share a common aesthetic.

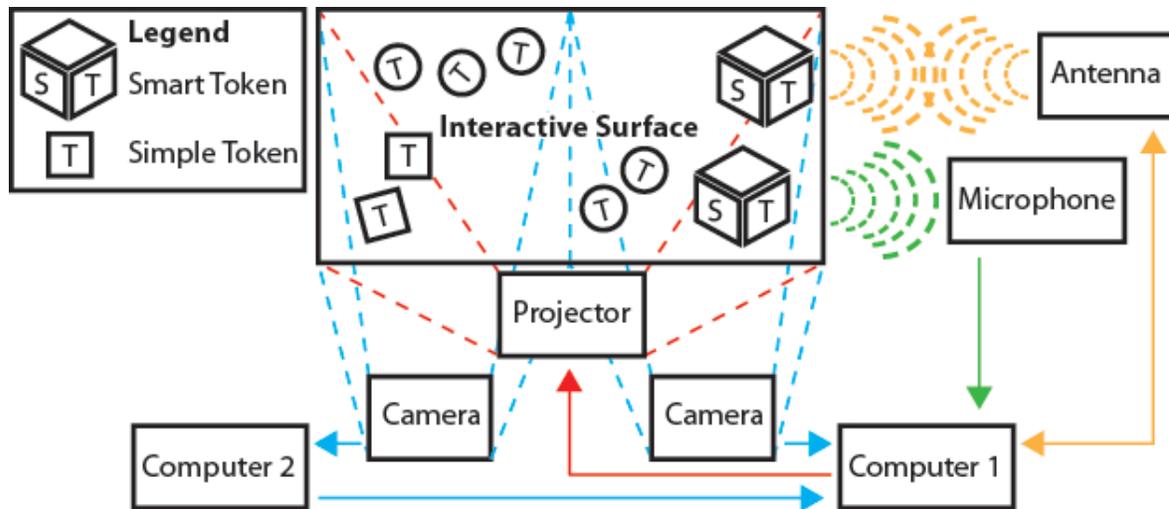


Figure 6: Schematic of components

4.1.1 Interactive Table

The interactive table began life as a fifty-inch LCD projection HDTV. A projection TV utilizes a projector built into its base and bounces the generated image off of a mirror at the back of the encasement to the bottom side of the display screen. The procedure of reflecting an image off a mirror before it meets the screen permits the projected image to expand in size, a technique many other computing surface projects employ (Gallardo & Sergi Jordà, 2010; S. Jordà et al., 2007; Wakkary et al., 2009; Couture, Rivière, & Reuter, 2008; Bakker, Vorstenbosch, van den Hoven, Hollemans, & Bergman, 2007; C. Magerkurth et al., 2004; Regan L. Mandryk & Maranan, 2002; Kirton et al., 2008). This technique is popular, as without using a mirror, a projector would have to be directly perpendicular to the screen, and the distance between the surface and projector could be twice the distance. With the amount of space in the TV, there is room inside for two cameras, eight infrared light sources and a microphone, all

of which are contribute to the functionality of TangiPlay, but will be explained later this chapter.

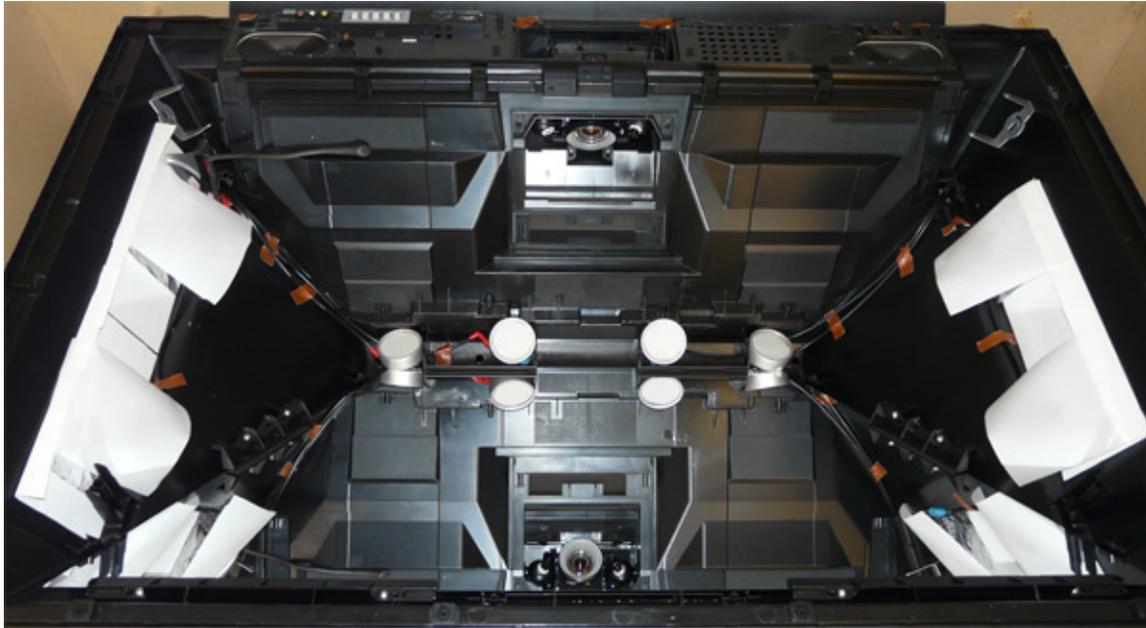


Figure 7: Inside a projection TV with two cameras, IR lights and microphone

TangiPlay's interactive surface sits just over sixty centimetres above the ground and fills a screen 62 by 110 centimetres. The projection TV is angled on its back and is held in a custom built casing. The case balances the TV on rails and houses the additional electronics under a twelve-centimetre border that wraps around the screen. The table was designed to keep the focus on making games, so the table is a simple black box with the surface resembling a framed television screen. A fold out shelf at the front is designed to hold a keyboard and mouse for debugging the two Mac Minis mounted inside. Hidden underneath the shelf are two USB ports, designed to quickly enable a keyboard to be setup to the concealed computers. Unseen in the table is a network hub, which splits

Internet to the two Mac Minis and allows them to communicate to each other. Within the table, a great deal of heat is generated by the two MacMinis and the projection TV, so a filtered air-conditioning setup has been fitted to keep the system cool. Even with plenty of technology on the inside of the table, only one power cord and network cable exit the back of the unit. The design of TangiPlay focuses on the interacting with the tokens and user interface, not the table nor technology that supports the system.



Figure 8: Mac Mini #1, TangiPlay housing, Mac Mini #2, power and network cable

Projection TVs are meant to stand vertically and present viewers an image from the projector through the screen. The screen diffuses the light in an equal pattern, so there are no hotspots and viewers situated around the screen all get the same image. These screens have no supportive strength to them and had to be changed to a surface that could support users interaction on top. The interaction included both the tokens and using markers to write and erase on the surface. The screen was replaced by an eight millimetre thick piece of acrylic glass, designed to support tokens being placed on the screen, Smart Tokens rolls and users drawing their game prototype. To protect the acrylic glass, a clear

protective film covers the surface, which is originally intended to protect the front of cars from rock chips, but in this case it stops the Smart Tokens from scratching the surface when being rolled. The piece of acrylic glass and protective film are completely transparent, so as a screen they did not diffuse the light from the projector. Reusing the projection screen on top of the acrylic glass was not possible due technology required to track the tokens on the surface. Consequently, the top layer of the screen was evenly sanded with an orbital sander to rough up the surface, providing an area that would diffuse the projected image.



Figure 9: Both cameras' view from within the TV

A key aspect of the interactive surface is the ability for users to write directly on the board. Coloured whiteboard markers are provided for users to mix the digital display with their analog work. Unique game boards, pictures, rules or notes can quickly be sketched out on the surface in addition to the hotspots that are digitally tracked by the system. TangiPlay is unable to compute a game score or keep track of complex rules, as it is only a prototyping environment; however,

the ability to write these elements on the surface helps designers develop their games.



Figure 10: Writing on the surface of TangiPlay

4.1.2 Simple and Programming Tokens

TangiDice only used two large physical dice as prototyping tokens and through a combination of rules, a variety of games were developed. TangiPlay was designed to provide more tangible opportunities. Simple and Programming Tokens are a group of tokens that rely on unique barcodes marked on the bottom of each object, as compared to Smart Tokens, which house electronics inside.

Table 1: TangiPlay's Tokens

Category	Name	Image	Details
Game Tokens	Smart Token		<ul style="list-style-type: none"> - Chance and skill token - Glows one of six colours; each side is assigned a colour
	Simple Token		<ul style="list-style-type: none"> - Multipurpose marker token - When on a hotspot, the spot will flash - When the Proximity Token is present, a number will indicate how many pixels the Simple Token is from the Proximity Token
Programming Tokens	Hotspot Token		<ul style="list-style-type: none"> - Used to stamp hotspots on the interactive surface - Hotspots are one of six colours, which can be selected by turning the token - Hotspots can be removed by re-stamping an existing spot
	Proximity Token		<ul style="list-style-type: none"> - Used to indicate how far Simple Tokens are from the Proximity Token's location
	Smart Display Token (bottom side displaying fiducial marker)		<ul style="list-style-type: none"> - Used to turn on or off detailed information regarding how the Smart Tokens are rolled - Either 'abstract' or 'numerical' output can be selected by turning the token like a dial

All of the tokens are grouped into either of two categories, Game Tokens or Programming Tokens. Game Tokens are the pieces used as game play

elements, and include Smart Tokens, which will be explained later and Simple Tokens that are round puck shaped pieces designed as a multipurpose tokens. The Programming Tokens are used to draw on the game board or gather more information during a game. The Programming Tokens include the Smart Display Tokens, Hotspot Token and Proximity Token. There are three Smart Display Tokens, each has the same square surface area as the Smart Token, since they relate to each other and turn on one of three parameters; acceleration, face value or rotations. Each token is connected to one of the parameters, so when the token is present on the screen, the information is represented on the board. Further, the information can be toggled between an abstract or numerical setting by rotating the Smart Display Token. The Hotspot Token is modelled to mimic a large square stamp, as its function is to stamp hotspots on the interactive surface. Rotating the Hotspot Token enables users to make different coloured hotspots. The Proximity Token is a round puck shaped object, larger than the Simple Token, with a ripple effect designed into its surface. This token interacts with the Simple Tokens and therefore is round to indicate to users the token's relationship.

The Simple Token and all Programming Tokens were designed to keep a common minimalistic aesthetic. Again, similar to the table, the tokens' design is not meant to be distracting from the objective of making tangible games. Each object is printed using a 3D printer, and the surface is left unmodified, hence the objects are ivory in colour and exhibit the weave pattern from the printing process. All tokens have a common centimetre and a half thick base with

bevelled edge on the topside to indicate proper orientation. Moreover, the tokens have been engineered through the printing process or filled with foam to provide a relatively comparative weight to the Smart Tokens which house electronic.

TangiPlay employs ReactIVision, open source computer vision software, to track the unique barcodes found on the bottom of the Simple and Programming Tokens. These barcodes are referred to as fiducial markers and enable the system to individually track each token present on the interactive surface. The system outputs the identification number of each token, along with x and y coordinates and the rotational orientation. A basic ReactIVision setup uses a camera to track fiducials and then simply exports the information to another program. TangiPlay uses this straightforward structure; however, to work with an interactive screen that is fifty inches, many adjustments had to be made.

Keeping TangiPlay uncluttered from a user's perspective meant all the technology needed to support tracking fiducials would have to be hidden within the TV. When a token with a fiducial is placed on the screen, the screen needed to be opaque enough to allow the image of the fiducial to be seen through the screen, yet the screen also had to capture the projected image for the interactive surface, so a concession had to be made to support both needs. Further, due to the thickness of the eight millimetre acrylic glass, only the topside could be opaque, otherwise the gap of acrylic glass between the opaque side and token caused the fiducial image to be blurry.

Below the screen, two PlayStation EyeToy cameras are used to track the fiducials. Most interactive screen systems employ one camera (Wakkary et al.,

2009; Gallardo & Sergi Jordà, 2010; Martin Kaltenbrunner & Bencina, 2007; Couture et al., 2008), but due to the large fifty inch screen and how shallow the TV encasing is, two cameras are required, each to track half of the screen. When TangiPlay was being developed, ReactIVision only supported one camera, so an additional computer was added to operate the second EyeToy camera. The second computer receives the information from ReactIVision and then packages it up and streams it over the network to the main computer, which combines the information with the first camera and interprets it. Because the system uses two cameras, calibrating the two cameras was a key step for being able to combine the information. A calibration grid made with minimal overlap allowing the whole system to function as if there is only one camera operating. Since TangiPlay was completed, ReactIVision has been modified to support multiple cameras to cover greater surfaces in higher resolution (Wang, Bevans, & Antle, 2010).

A key element of TangiPlay is the interactive screen that responds to the tokens being placed on the surface. However, the projection for the interactive surface projects on the bottom of the screen and any tokens placed on the surface. This projection causes the fiducials on the bottom of the tokens to be obscured by the projected image. Other interactive surfaces such as ReactIVision (Martin Kaltenbrunner & Bencina, 2007) utilize infrared light in order to enable the cameras to clearly observe the tokens. Infrared light (IR) is not visible by humans as it at a different wavelength than visual light. The two EyeToy cameras have been taken apart to fit a custom housing for a new lens and a IR filter that lets a specific range of IR light in. To match that range, eight

forty-eight LED emitting units are mounted inside the TV encasing. The IR lights illuminate the tokens on the interactive surface and the modified EyeToy cameras only see the fiducials on the bottom of the tokens and completely ignore the projected image.

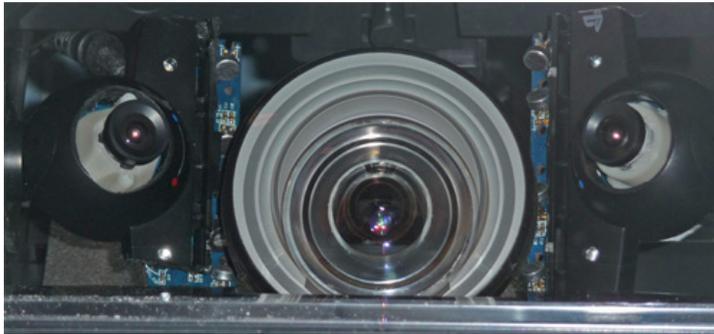


Figure 11: Modified EyeToy cameras mounted beside the projection bulb

4.1.3 Smart Tokens

Ten centimetre square dice are not practical for playing games, as one die is all a user can hold in one hand, and unfortunately that meant the dice from TangiDice had to be redeveloped for TangiPlay. In addition, the dice were renamed to Smart Tokens to avoid user's preconceptions. The final iteration of the Smart Tokens are six and a quarter centimetre square cubes, printed through the same process used to make the Simple Tokens. The aesthetics match, as they have the same ivory coloured surface and weave pattern from the printing process. The only visual difference is each side has two recessed holes for screws to hold the token together. Each face holds a piece of electronic prototyping board with electronics on the inside, two recessed holes for screws and two brass barb inserts on the sides that lines up with the recessed holes. This setup creates a die when screwed together can hold all its electronics in

place while being rolled and not break, and still allow easy access to adjust electronics or the battery on the inside by simply removing one of the die face.

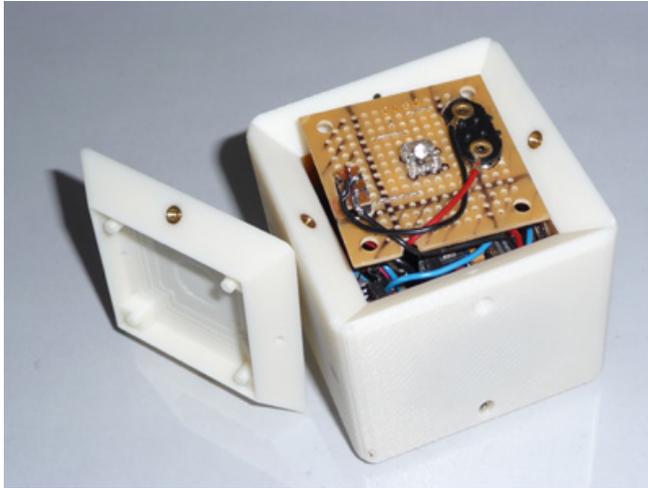


Figure 12: Smart Token Version 2.1

When the Smart Tokens are off, their appearance does match the rest of the tokens; however, part of changing user's perspective, in addition to the name, was to remove the pips on each face and replace that information with coloured LEDs. The Smart Tokens have a multi-coloured LED behind each face and generate one of six colours. The sensors inside the token know which side is up and that information is used to then change the whole die to the corresponding colour, producing a glowing effect.



Figure 13: TangiPlay displaying six different colours

The large die from TangiDice used a WiiMote circuit board, something that could not be made smaller for the next iteration. This meant the die for TangiPlay had to use electronics specifically built and programmed together for the die. An accelerometer and gyroscope are hooked up to an Arduino Nano board and are used to sense which side is facing up, how many times the token has rotated and average acceleration. To communicate to the main computer, the Smart Tokens are using XBee hardware and a Zigbee communication protocol. The information gathered using the sensors is streamed to the computer, where the data is interpreted. These elements, in addition to the six LEDs are powered via a nine-volt battery.

The Smart Tokens along with the large dice from TangiDice were used to gather information about a user's roll. The sensors in both iterations were able to sense any movement made, however the computer was unable to determine what was a 'throw', as compared to 'shaking in a users hand' or even just being 'passed between users'. Two key assumptions were made for the computer to know when the dice were being rolled, the first was users would roll the token on the interactive table, and second, that the interaction of when the Smart Token first met the surface when being rolled would generate a louder than usual noise. For both TangiDice and TangiPlay, a microphone listened just above or below the surface for a specific noise threshold to be met, at which point the computer would assume the dice were being rolled.

4.1.4 Software

TangiPlay's user interface is a large interactive screen that users interact with through physical tokens. From a user perspective, the interface is very minimal, as there is a limited amount of tokens, and a handful of designed interactions between the tokens and interface. However, behind the surface, TangiPlay employs ReactIVision for tracking fiducials, Processing for programming the Smart Tokens, Pure Data for information sharing, Max/MSP as a backend, and finally Adobe Flash as the interface.

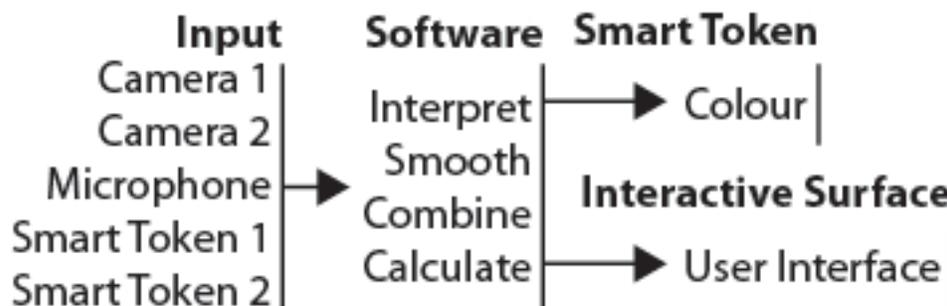


Figure 14: Flow of information from input to output

The information channel begins with ReactIVision, open-source software for tracking fiducials. ReactIVision uses a web camera to identify fiducials and then outputs a list of data generated by that specific fiducial, such as if the object was just added, the session number, the fiducial number, x and y axis position, angle, and many more. At the time of development, ReactIVision only supported one camera, so two computers were employed to operate a camera each. The goal was to direct the information to Max/MSP where the data would be analyzed and passed to Flash. However, two computers meant one stream of information had to be forwarded onto another machine before this could happen. Pure Data,

a visual programming language, was used on the second machine to receive the information from one camera utilizing ReactIVision, and then to package that data and forward it onto Max/MSP on the main computer, which would now be receiving two ReactIVision signals.

The Smart Tokens are programmed using Processing, another open-source programming language, but specifically an integrated development environment for electronics. Similar to ReactIVision, Processing instructs the Smart Tokens to gather all related information and pass it onto Max/MSP with out any filtering or computing.

Max/MSP is a visual programming language that is often employed by sound and multimedia artists. TangiPlay uses Max/MSP to combine input from ReactIVision, wireless hardware and a microphone, and then computes and outputs the information. The two streams of information coming from ReactIVision are sorted by source, altered to fit the display screen and smoothed to eliminate the jittering found with raw data. Finally, the two sources are combined back together and sent off to Flash for display. The Smart Tokens send a wireless steam of data regarding the status of the three-axis accelerometer and two-axis gyroscope. The information is smoothed and interpreted to find out acceleration, face value and rotations. Then all value outcomes are transmitted to Flash for display, while the face value is also converted to an instruction set and communicated back to the Smart Token where the LEDs turn on to the corresponding face value. The microphone is the final source of information Max/MSP tracks. The volume is converted into an

integer and the system waits until a specific threshold is met before it informs the system. For the microphone, the trigger indicates a Smart Token has just begun its roll.

The collected and analyzed information ends its journey in Flash, where it controls the user interface. Max/MSP sends out a stream of information that Flash decodes and then turns on or off images that correspond to the present token or output from Smart Tokens. The user interface visual design follows the same design aesthetics that guided the look of the interactive table structure and token appearance. The interface's goal is to be intuitive and functional, while not being flamboyant. To support whiteboard markers being seen on the screen, the background of the interface is plain white.

When the tokens with fiducials on their bottom are placed on the interactive screen, the UI attaches a relevant image. There are three Smart Display Tokens, and each one is assigned to different information about the Smart Token; acceleration, face value or rotations. As soon as the token is present on the table, an image appears surrounding the token. With the Smart Display Token, the top of the image is the information that the token controls and on the bottom indicates how the information is displayed, either numerical or abstract. For example, one Smart Display Token controls the acceleration information displayed about the Smart Token. When this token is not present on the interactive surface, this information is not displayed. When the token is present, the information is displayed on the side of the interface in red dialog boxes. The acceleration information can be changed by rotating the Smart

Display Token, like a dial, on the surface to toggle between numerical and abstract output. Numerical means the information is presented as a number, where abstract converts the number into word value, in this case 'slow', 'moderate' or 'fast'. Face values are displayed as either numbers or colours, and rotations as number or 'few', 'moderate' and 'fast'.

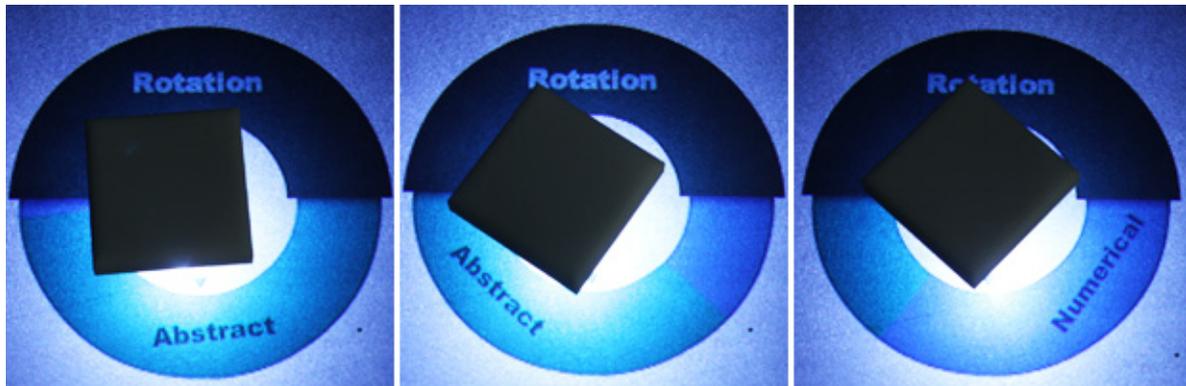


Figure 15: Smart Display Token being turned as a dial

The Hotspot Token is used to draw hot spots on the interactive surface. When the token is placed on the surface, an image is projected around the token, indicating its name and the colour of hotspot chosen. The Hotspot Token applies the same dial interface that the Smart Display Token employs. The token can draw one of six colours, all which match the colours the Smart Token can generate. To remove hotspot, a user only needs to re-stamp the existing hotspot and it disappears.

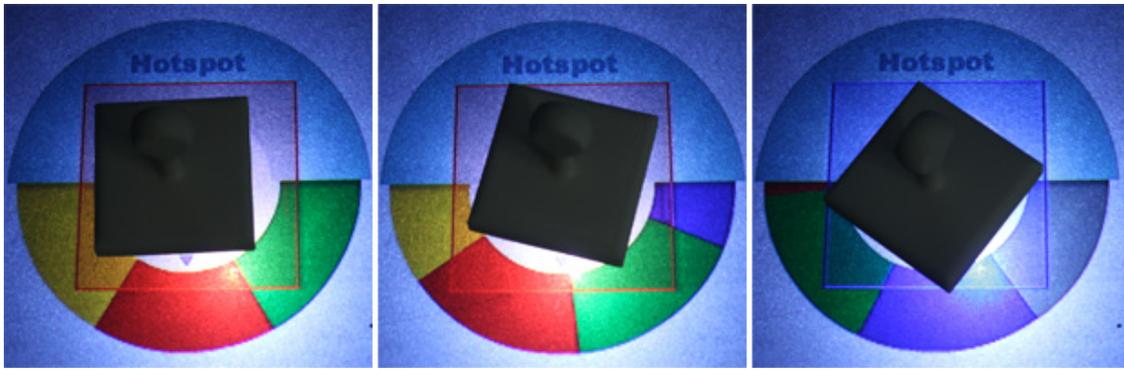


Figure 16: Hotspot Token interacting on interactive surface

The Proximity Token displays a target pattern when placed on the interactive surface. This token is designed to interact with the Simple Tokens. When the Proximity Token and Simple Tokens are present on the board, each Simple Token displays a number beside itself indicating how many pixels away it is from the Proximity Token. Without the Proximity Token on the surface, the Simple Token does not display information. However, when a Simple Token is on a hotspot, the hotspot will respond by flashing.



Figure 17: Proximity Token, Simple Token in relation to Proximity Token, Simple Token on a hotspot

4.2 User Scenario

This user scenario is designed to illustrate how TangiPlay is intended to be used by game designers. There are three main stages a user needs to work through: first exploring the project, second making a game and finally testing, debugging and evaluating. During the testing session, it is assumed users will test out all the different types of tokens on the interactive surface to find out how they interact and how their behaviours can be used to create a game.

As the designer of TangiPlay, I have tested out the project on many occasions to continually refine details. Due to designing the project, I have expectations of how users would employ of the project, as it is how I would used TangiPlay. I will outline a game I made and the process.

Already being familiar with the project, I skipped onto the development process, which can be daunting as there are no guidelines. TangiPlay is meant to be a prototyping environment, not a guided process such as a computer wizard. This openness enables a range of games, but it helps if users have a vague concept of an idea they want to explore. For this example, I wanted to make a chess-like game that incorporated the Proximity Token and Smart Tokens for more than just random number generation. I began by deciding the shape of the game board, by drawing hotspots. A few designs later, I had a diamond shaped pattern, where from the furthest left column is one tall, the second two, up until five were it works back down to one space tall and the very centre piece is the Proximity Token. The game is a two player game, each player had four tokens and start at opposite points of the diamond. At this point, I knew the winning

condition was when a player got one of their tokens to the opposite side. However, the movement conventions were unclear, so I began by rolling the Smart Tokens to find out what would fit the game and not just be a simple random number generator. Through trial and error, I decided upon setting rotations to abstract, and when a player rolled 'many' they could spawn a new token at their closest hotspot. When a 'moderate' was rolled, the player would then look at the face value and that would determine how many spaces they would move a token. The final rule was the Proximity Token, which would act as magnet and pull all active tokens one space closer to the centre at the end of the player's turn.



Figure 18: Game made during sample user scenario

Once the game was setup, I completely played through the game with a friend. By the end of the game we had found two rules to change that would improve game play and add more strategy. The first change was to not allow players to jump spaces occupied by a token; this enabled players to use their tokens to block a player's progression on the game board. Additionally, the dice value could now be split between tokens. If a player rolled a four, they could move one token four spaces, four tokens one space, or any other combination. A quick replay of the game found these rules added more strategy and we found made the game more engaging.

5: USER TESTING

In testing the prototype, I, being the producer of TangiPlay and having an in-depth knowledge of the project, was able to optimize the technical capacity of the interface. Though somewhat biased, the prototyping environment was able to support the development of an entertaining tangible electronic board game. In spite of this, to truly validate the prototyping environment, TangiPlay had to be put in the hands of game designers to determine whether or not it was successful in making games.

Before bringing official game designers in to do user testing, two preliminary rounds of user testing were conducted with graduate and undergraduate students: three individuals in the first round and four in the second. These sessions helped refine the script I had created to direct the final user testing sessions. While the scaffolding process of the script was not changed, it was determined that more background information about the users was needed to validate the data being collected. Further, some alterations were done to TangiPlay itself as a result of user suggestions, but not every idea was implemented. As Crawford puts it, "Playtesters' criticisms are difficult to evaluate. Most criticisms must be rejected for a variety of reasons. Some are incompatible with your goals; some are not achievable. ... Some are reasonable, but would require major software surgery incommensurate with the gains offered"

(Crawford, 1984, p. 16) Nonetheless, the input was valuable for preparing TangiPlay for game designers to test.

5.1 The Participants

As mentioned in the methodology, I sent e-mails out to game designers again much like I had done when looking for participants for the phone interviews. I also contacted game designers at companies such as Electronic Arts (EA) since they have experience developing tangible Wii games. After some time and adding a twenty-dollar gift card incentive, I managed to gather eight participants, each with varying years of experience in the industry. On the form used to collect background information, the years of industry experience are: 1-3, 4-6, 7-10 and 10+. Participant A was my first play tester. He is a game designer at United Front Games with four to six years of experience. Participant B, with four to six years of experience, is freelance game designer. She is not only a game designer but also a 3D character artist. Her current contract involves developing an iPhone game. In the past, she has worked for various clients providing art assets for video games. Participant C, who works for Participant B's personal company and has one to three years of experience, accompanied Participant B during the testing session. Participant D is a game usability researcher for EA and has been in the industry for one to three years. A designer/scripter at Rockstar Games, Participant E has working in the field for one to three years. Participant F and Participant G work for Ubisoft and offer over ten years of experience each. Participant F is currently a producer/manager while Participant G is a game designer for this Montreal-based gaming company. They

completed the user testing together. My final user tester was Participant H, a game designer at Electronic Arts with four to six years of experience. Each one of these play testers for TangiPlay went to Simon Fraser University Surrey, where the project is located and offered both positive and constructive feedback throughout their session.

5.2 Session Overview

I outlined in the Methodology chapter the scaffolding process for user testing. I will use this structure to explain how the sessions unfolded. I began with an introduction of myself, and the concept and components of TangiPlay. A detailed overview of the project included how the components work and interacted with one another. This explanation was followed by the second scaffolding step, which was to familiarize users with the project by making Snakes and Ladders, a simple game I assumed would be familiar to all. In the final stage, users were asked to make a game using the prototyping environment and this was concluded with a series of questions to learn about the user's experience throughout the process and how TangiPlay compared to previous prototyping experiences.

Up until the development of users creating their own tangible game, the sessions were more or less consistent. The intro, combined with the detailed overview, lasted no more than three minutes; the Snakes & Ladders session lasted on average nine minutes from building the game board to playing. Developing and playing the original games varied in length, from twelve to fifty minutes; however, it should be noted that the one lasting fifty minutes was only

ten minutes of game development and forty minutes of play because it was that engaging. As each user drew from his or her past gaming experiences and understanding of TangiPlay, six unique games were created. Most users did not name their games so for the purpose of this paper in referencing to each game, I have designated descriptive names for each one.

5.3 Testing Outcome

5.3.1 Games Made

Board games can be divided into three general categories: race, elimination and score, among which race was the most commonly developed during the TangiPlay user testing sessions. Participant F and Participant G worked together to create two games. The first game, “Fast! Slow! Go!”, is a two player game where players race from one corner of the predefined board to the opposite corner. The board is made up of three different colours, each corresponding to an acceleration speed: red is fast, yellow is moderate and green is slow. If the Smart Token is rolled quickly, the system feedback displays “fast”. A player’s token can only move one space at a time; therefore, the player can only move his or her token to an adjacent coloured space if it matches the generated acceleration. Fast! Slow! Go! utilizes the Smart Tokens as skill based objects. Users guide their tokens on the game board towards the goal by rolling the desired acceleration.



Figure 19: Fast! Slow! Go!

Participant D's "Rainbow Path" also employs the Smart Token as skill based objects. In this case, both the acceleration and rotations of a roll determine if and how far a player moves their token. The board structure is modelled after a rainbow and divided into three sections: 'up', 'across' and 'down' the rainbow. Each player is designated to one colour of the rainbow. They begin at the bottom the 'up' section, where their roll's acceleration must equal fast. If accomplished, the number of rotations indicates how many spaces a token will advance. When the players make it through the 'up' section, the acceleration of the rolls must be moderate in the 'across' section, then slow in the 'down' section. Rainbow Path was able to use the Smart Tokens as a skill based object. Similar to the previous game, "Rainbow Path" is a race game, in this case, a race to the end of the rainbow.



Figure 20: Rainbow Path

In the first two game examples, winning the game was based on the skill of interacting with the Smart Tokens. Participant B and Participant C utilized the Smart Token for both skill and chance. “Roll ‘n Attack” is a two-player elimination game where players start on opposite ends of the predefined board. Players move forward until they come together somewhere between their starting spots by rolling the Smart Token; the higher the number, the more spaces the player gets to move, hence, the element of chance. As for skill, the rotations of each roll is added to a players ‘attack’ points, which are tallied once the players meet and the one with the highest number of points wins.

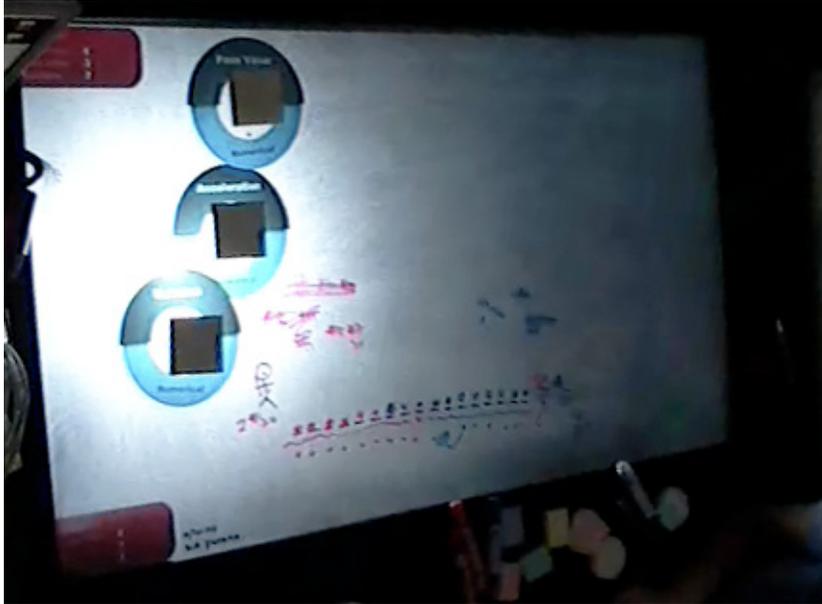


Figure 21: Roll 'n Attack

Participant E combined luck with strategy for his tangible game “Pave a Path”. A colourless grid makes up the game board and each player begins on a square outside the grid, opposite one another. Each player is assigned two colours and the remaining two colours are “neutral”. If a player rolls his or her own colours, a matching square for each colour can be placed anywhere on the grid. In order to move, a player must create a path using these squares. While a player might roll both his own colours and is able to create two squares, he or she can only move one grid space each turn. Should the rolls match the opponent’s colours, the player may eliminate his or her opponent’s squares. The neutral colours can be both added or taken away depending on what the player sees as advantageous, which is where the strategy lies. One may use colour placement to block or limit the movement of the opponent. Thus, the strategy is in how users create a board, or ‘pave a path’, based on the colours they roll.

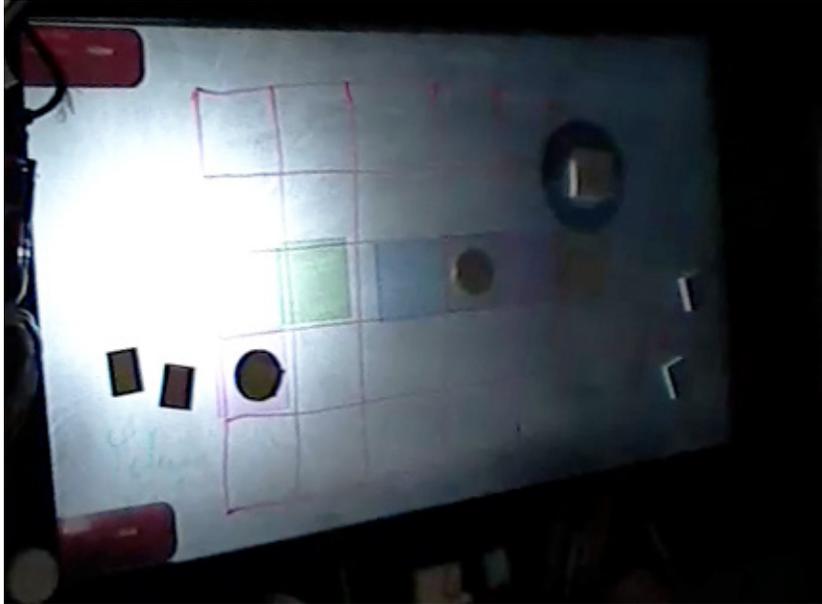


Figure 22: Pave a Path

Participant F and Participant G were very encouraging because after creating their first game, Fast! Slow! Go!, they recognized that it was too simple and that TangiPlay is capable of supporting a much more complex game. Because the first game did not take very long to generate, a second one was made, which I will call “Over Board”. It is a score based game where each player is in charge of four game tokens. Based on the face value of the Smart Token, the player moves one of their four tokens that many spaces forward (straight or diagonally) on a predefined grid. All four tokens can be on the board but only one token can be moved per roll. The name of the game encompasses the strategic goal, which is partly generated by luck. If a player’s roll causes him or her to land on the fringe of the board where a token already sits, whether it be his/her own or the opponent’s, the first token there is eliminated. When no more moves are possible, the end of the game is reached. Each square is worth a certain number

of points, and the points are added together to indicate a player's score once no more moves can be made.

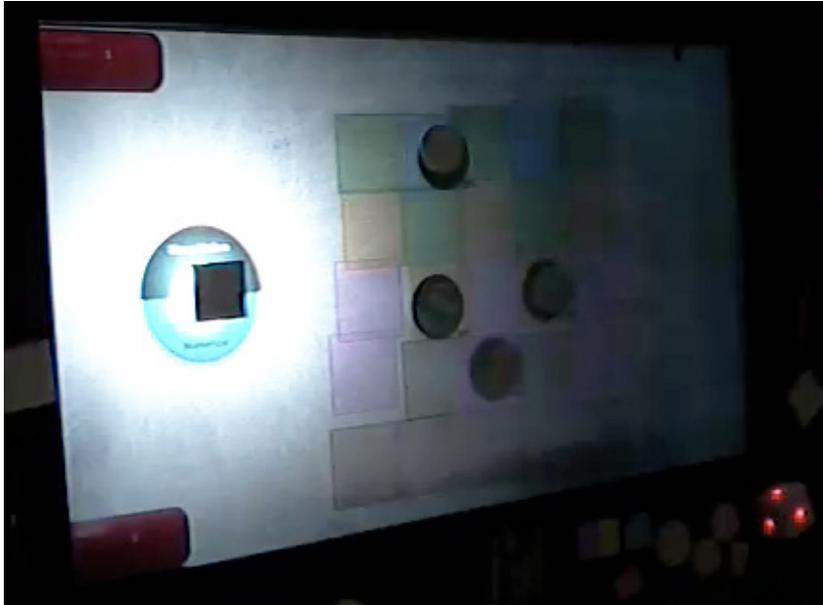


Figure 23: Over Board

“Tank, Plane, Anti-Air”, made by Participant H, is a strategy based race game and is inspired by a board game he is currently assembling. The goal is to navigate a commander, through a defined path that has a multiple routes, to the opposite side where the other player starts. In addition to the commander, players control a tank, plane and anti-air gun. TangiPlay doesn't include specific tokens such as a tank, so Participant C used the Simple Tokens and sticky notes on top to indicate what each token represented. These units employ dice to simulate fighting, but each element has a particular advantage or disadvantage. The system follows a rocks, paper, scissors premise, where the tanks have twice the probability of knocking out an anti-air, but half the chance of killing a plane. Planes have to advantage over tanks, but are weak against anti-air. Finally, the

anti-air is effective against the plane, but not a tank. In addition, units are limited to how far they can move by their characteristics: tanks are slow, anti-air are faster and planes the fastest. The Smart Tokens are used to indicate how far the pieces can move, which is purely based on chance; the strategy lies in how the pieces are controlled on the board. This game was a simplified version of a game Participant H is making; yet, it was still very balanced and engaging, so much so that we spent forty minutes playing.



Figure 24: Tank, Plane, Anti-Air

As users interacted with the table and conceptualized a variety of games, it became evident that TangiPlay is able to support users in the development of electronic board games. I was encouraged to see users employing the Smart Tokens for purposes beyond chance because it implies that there is great potential in tangible electronic games.

5.3.2 Technical Evaluation

TangiPlay is a working prototype and had to be fully functional for user testing in order to evaluate the concept. Due to the fact TangiPlay is a prototype, a certain level of failure was acceptable, up until the point where user testing was inhibited. Accordingly, during user testing, I kept record of how the system was functioning, specially focused on three sections: fiducials, Smart Tokens and software. The fiducial section was for how well tangibles were tracked and displayed on the surface. The Smart Tokens had to be able to communicate with the system and gather appropriate information without crashing or running out of battery life. Finally, the software included the user interface, which tied all the elements together, and needed to stay functional during the whole user testing session.

Participant A was the first game professional to be tested. During his session he was introduced to TangiPlay and was able to make Snakes and Ladders. Unfortunately, TangiPlay completely crashed at that point. Furthering the problem, the recording system failed to capture audio. For these reasons, there is almost no usable data from his session. The remaining sessions benefited from the initial issues being solved and didn't reoccur.

For all participants except Participant A, TangiPlay only displayed minor errors. The fiducial tracking wasn't overly robust close to the edges and often caused the Stamp Tool to not erase a hotspot immediately, but the fiducial system did not inhibit game development. The Smart Tokens had a few glitches with displaying acceleration and rotations, and this did hamper a few of the

games being developed. However, solutions were found, and the games being made didn't change because of the technology failing. The whole process of rolling electronics tended to be the cause of these issues. Finally, the software functioned seamlessly with the whole system and didn't cause any errors or problems for game designers. TangiPlay, from a technical perspective, met the goal of being a functional prototype and facilitated the ability to see if tangible electronic games could be prototyped through using a ready toolkit of modifiable tangibles and an interactive surface.

5.3.3 Evaluating TangiPlay's Goals

User testing confirmed that TangiPlay, united with skilled minds of game designers, is able to produce tangible electronic games. The final iteration of TangiPlay is a completely tangible interface on top of a display surface. Game designers used specific tokens for programming the system and other related tokens for playing their game. The user interface, being completely unique, is designed to be wholly intuitive; however, through user testing it became evident some explanation of the UI is required. The Stamp Tool is used to create hot spots on the display surface, and is designed to also remove and/or alter the hot spots by simply re-stamping the same location. This was not evident to the game designers, all of which asked how to remove hotspots they had created. Further, the Smart Display Token's purpose, to control the information being presented regarding the Smart Tokens, was not clear to users. The goal was for the similar shape of the Smart Tokens and Smart Display Tokens to indicate their

relationship; yet, users failed to notice this connection even with a brief demonstration.

Besides answering the same questions about the tangible UI, game designers required no additional instruction on how to program the system. Game designers, either by themselves or with another designer, were able to build a tangible electronic game without the need of someone who could program or build tangibles. This enabled the games to be modified or played at any stage of development and the vast majority of game designers realized they could adjust rules to balance a game or provide more strategy while they were testing their game. The process of removing the technical barrier of making tangibles, made prototyping tangible electronic games a relatively quick process, somewhere between twelve to fifty minutes for both development and playing through a completely new game.

The speed, of which a tangible game was created, was in part aided by the digital and analog combination. Game testers were able to write on the display surface with whiteboard markers, making TangiPlay comparable to the paper prototyping process.

All together, the tangible UI, minimal technical skill requirement, digital and analog display surface, and the quick development speed meant TangiPlay was a simple to use, rapid prototyping environment that employed a ready toolkit of tangibles and an interactive surface to prototype tangible electronic games. Matt Weise stated, "A computer based prototyping system using a tangible interface would have to be more convenient than paper prototyping. And if it weren't more

convenient, it would have to be so significantly more useful that learning it would be worth it”(Weise, 2009). TangiPlay is a rapid way to prototype tangible electronic games, requires minimal learning to operate, and offers the advantages of a digitally augmented tokens and an interactive surface.

5.3.4 Unexpected Findings

User testing of TangiPlay did reveal unforeseen ways users interacted with the system. First, the majority of users made grid based games. I believe this is because mainstream board games are grid based and that the Stamp Tool only created squares. Users merely worked with the tools provided and relied on their previous experiences to guide their games. However, Participant H, an avid board gamer, suggested the Stamp Tool should be a hexagon, as it would provide a greater number of spots a hotspot could be adjacent too. In particular, the game he made, “Tank, Plane, Anti-Air”, would have benefited from hexagon spots, as it would have enabled additional strategy when moving pawns.

When users were using the Stamp Tool, TangiPlay didn’t always recognize the fiducials when put on the screen. Users expected the token to provide a specific type of feedback, but when this didn’t happen, half of the users tried to solve the problem by pressing the Stamp Tool down harder on the table. In reality, pressing the tokens harder on the table did not help the system at all, but half of the users instinctively felt this action would help the token be recognized.

When users were first introduced to TangiPlay, the tokens were all laid out on the edge of the interactive surface and grouped together. I did this for aesthetic purposes and it made introducing the objects easier. What became apparent through user testing with all users was they continued the procedure of keeping all tokens, pens and paper off the interactive screen unless the objects were in use.

5.4 Smart Tokens

The Smart Tokens found in TangiPlay were carried over from TangiDice. The physical size of the dice shrank considerably, but the new dice kept the ability to know which side is up, how many times they rolled and their acceleration. Out of all the components of TangiPlay, the Smart Tokens are the only electronic tangible token. Their ability demonstrates how augmenting traditional objects can enable new behaviours and players are able to interact with games as never previously available. User testing of TangiDice and TangiPlay illustrated that users were able to make innovative games; however, users needed to be prompted to break the habit of using the dice objects as simple dice.

Through the informal user testing of TangiDice, I found that by providing users with examples of how the electronic information from the dice could be used, correlated to new games that used the information. Realizing users would need an example; TangiPlay incorporated this information into a demonstration when game designers were making Snakes and Ladders. Even with the demonstration not all users picked up on the ability to use the Smart Token as a

skill based object. Two of the games, “Fast! Slow! Go!” and “Rainbow Path”, used the Smart Token purely as a skill based object. “Roll ‘n Attack” used the Smart Token as both a skill and a chance based object. The remaining three games used the Smart Tokens as if they were traditional dice. Their games still included strategy, but it was not how the user interacted with the Smart Tokens.

6: FUTURE DIRECTIONS AND DISCUSSION

Tangible electronic games are becoming more common in our culture with consoles such as the Nintendo Wii. In addition, current explorations of tangible electronic games are happening in research laboratories around the world and vary from augmenting sports to board games. Along with a variety of finished products, there are a range of prototyping tools, each designed for a specific use and particular audience. Unlike video games, which have well developed genres and formulas for what constitutes a video game, tangible electronic games is not a developed field. The minimal boundaries of the field are exciting for developers as only technology and imagination limit what can be done; however, this lack of standards and guidelines is incredibly daunting. Furthermore, even within the video game industry, the concept of prototyping is quite varied among designers. All these elements are what led to a proposal for a tangible prototyping tool for game development from CATGames.

The first incarnation of the CATGame's proposal was TangiDice, and its concept was grounded within dice games. The strategy was to take a known tangible game, electronically augment it, and then evaluate it as a proof of concept. TangiPlay is the next version and this project is based on board games. Combined, TangiDice and TangiPlay are a stepping-stone towards future development in this very new field.

6.1 Future of Tangible Electronic Games

As stated above, tangible electronic games are still in their infancy, so there is no common genres, means of input or hardware; however, for this thesis, I will speculate and specifically suggest how a prototyping system like TangiPlay could be enhanced to further leverage the potential benefits of tangible electronic games.

6.1.1 Augmented Tokens

The Smart Tokens are the only digitally augmented tangible token for TangiPlay and as a result were a key element of the project. They took the longest to develop and caused the most amount of problems during user testing; yet, the Smart Tokens validated their augmented design the first time a game designer used the chance-based objects as a skill based one. The process of adding technology enabled supplementary forms of output based on user interaction. This concept can be applied to other tokens to also enhance their abilities. The question lies in which type and what will be enabled if they are digitally augmented.

At the beginning of this thesis, I completed a board game summary. Through reviewing a large number of board games, I was able to categorize all of them into three genres – race, elimination and score based. In addition, I organized them based on game elements including rules, tokens and displays. All games share the same four basic tokens: a turn indicator, player tokens, marker tokens and chance based tokens. The turn indicator often took the shape of a timer, as would be found in guessing games. Player tokens are used to

indicate a player's progress, such as the pegs used in cribbage to denote a player's score. Often more information is needed regarding a player's status, so marker tokens are used for supplementary information like game spaces owned in Risk or if specific types of question had been answered as found in Trivial Pursuit. The final token is the chance token, most often a die or a deck of cards. These four types of tokens have potential to be utilized in tangible electronic games if digitally enhanced, possibly even giving them new purposes.

Table 2: Board Game Summary

	Race	Elimination	Score
Rules	<ul style="list-style-type: none"> - Dice Roll - Token with Token Interaction - Token with Board Space Interaction - Chance Cards - Collecting/Eliminating of Resources/Tokens /Territory - Multiple Game Board Paths - Trading - Social Alliances - Finishing Condition (everyone on the space or just one) - Altering Game Board 	<ul style="list-style-type: none"> - Dice Roll - Token with Token Interaction - Token with Board Space Interaction - Chance Cards - Collecting/Eliminating of Resources/Tokens /Territory - Trading System 	<ul style="list-style-type: none"> - Dice Roll - Token with Token Interaction - Token with Board Space Interaction - Chance Cards - Collecting/Eliminating of Resources/Tokens /Territory - Multiple Game Board Paths - Trading - Social Alliances - Finishing Condition (everyone on the space or just one) - Altering Game Board
Tokens	<ul style="list-style-type: none"> - Turn Indicator - Player Token - Marker Token - Chance Element 	<ul style="list-style-type: none"> - Turn Indicator - Player Token - Marker Token - Chance Element 	<ul style="list-style-type: none"> - Turn Indicator - Player Token - Marker Token - Chance Element
Display	<ul style="list-style-type: none"> - Board Game - Programmed game spaces - Chance cards - Turn indicator space - Game Stats - Winner 	<ul style="list-style-type: none"> - Board Game - Programmed game spaces - Chance cards - Turn indicator space - Game Stats - Winner 	<ul style="list-style-type: none"> - Board Game - Programmed game spaces - Chance cards - Turn indicator space - Score - Game Stats - Winner

The Smart Token found in TangiPlay is a chance token that was transformed into a skill object through digital augmentation. I propose that a deck of cards can also be augmented, perhaps by turning it into a small handheld LCD screen. The unit may be used for chance just like a deck of cards, or to display private information for specific players. Sensors can be used to indicate the unit

has been 'flipped' like a card and new chance-orientated information displayed. Since the information may be updated, new sets of information could be added to a database to better reflect players' progress. The ability to update information is a key element video games use to immerse players and a digital card may be one way of making board games more immersive.

Turn indicators are found in many popular guessing games such as Cranium and Trivial Pursuit and are often simple hourglass timers. These timers are used to indicate how long a player or players have to complete a task or answer a question. Augmenting a timer may take the rule concept further by being able to also evaluate a player's response through voice recognition. By adding more rule-tracking features to the timer, players can focus more on playing the game and let the computer become the referee. Again, this concept of the computer being an impartial umpire is exploited by video games and further helps users focus on the game and less on rules.

In TangiPlay, the Simple Token acted as both player tokens and marker tokens. For simplicity sake, TangiPlay used different coloured sticky notes on the generic Simple Tokens to indicate differences, but this setup could be much more meaningful. The Simple Tokens placed on the surface may cause the interactive surface to display a unique graphic around it. Furthermore, with a different construction design, the whole token may conduct the colour displayed by the UI. This flexibility means a small number of tokens can represent any kind of token or type of information.

6.1.2 Output Technology

TangiPlay's interactive surface is built from a fifty-inch projection TV. The screen has been modified to support tokens and whiteboard markers, while capturing the projected image from below. The system knows where there are tokens on the board and displays related still graphics. This interaction between the tokens and interactive surface is novel; however, it can do so much more. A projection surface can display video and moving graphics, which means that the interactive surface can support an interactive background image specific to a game. Hotspots would not just flash, but indicate to the system to generate an appropriate response to a player's token. With the advent of 3D TVs, the interactive surface itself can potentially have depth and dimensions. Mixing physical objects on a 3D surface has the capacity to offer a whole new means of interaction. In addition to the video, TangiPlay has built-in speakers, which have not been utilized. Use of audio cues and a sound track mixed with video would further immerse players into a game.

6.1.3 User Interface

The design of TangiPlay's UI functioned similarly to a combination of RCX Code and Adobe Photoshop. One of the goals of this design was to provide users with a toolkit of rules to apply to tokens. However, during initial exploration, I found that it separated the game designing and testing procedures, and required a keyboard and mouse for interaction. TangiPlay's current UI does not include this toolkit nor relies on a keyboard and mouse. During user testing, half of the game designers mentioned that they wanted more rules available or a

pseudo scripting language to enable the system to have more automation. Based on this feedback, a future iteration of TangiPlay's UI would have to find a way of balancing the simplicity of the current version with more programming ability. A system like Adobe Dreamweaver would be a reasonable model to follow as it includes three levels: a finished product, drag and drop editing system, and access to the code. A key element of the system should be a toolkit of common rules as previous envisioned for TangiPlay.

6.1.4 Physical Product

The fifty-inch projection TV for TangiPlay is held on its back within a medium-density fibreboard (MDF) box. Surrounding the surface of the TV is a twelve-centimetre wide border. This means the box is large and heavy, which means that TangiPlay is not very portable. Instead, game testers had to travel to Surrey Simon Fraser University. Furthermore, since the sides of the box go down to the ground, users are unable to sit comfortably at the table, as their legs cannot be tucked underneath. This seemingly trivial issue caused awkward user interaction, such as users having to stand and bend over the table to interact. The physical design of tabletop displays has been studied in "System Guidelines for Co-located, Collaborative Work on a Tabletop Display" (Scott, Grant, & Regan L. Mandryk, 2003). Their first guideline is to support natural interpersonal interaction and this has been understood as "avoiding bulky components under the table ... [and] users should be able to sit anywhere around the table" (Holleman et al., 2006). If applied, this information would allow for a more convenient and natural design for user interaction.

6.2 Tangible Electronic Prototyping Issues

With the development of any new field, there are both technical innovations and techniques that shape the final products we currently know. Film is a good example, as from a technical perspective, film has been developed from short, single shot, black and white, soundless clips to three-hour movies with computer graphics and engineered soundscapes, displayed in 3D. In terms of technique, films started off being short clips like a shot of a train pulling into a station (A. Lumière & L. Lumière, 1897); yet now movies include many hundreds of clips edited together based on rules to help viewers understand the director's story. Tangible electronic games are, much like the development of film in the past, still being defined by the projects being produced and shaped by the tools supporting their development. Through the developing TangiDice and TangiPlay, I feel there are couple of areas in tangible electronic games that require refinement: the development of prototyping tools and how player turn-taking is understood.

6.2.1 Authoring Prototyping Tools

TangiPlay is a prototyping environment for game designers to make games. The rules, tokens and interactions within the system are the tools that enable a variety of outcomes. As the designer of TangiPlay, the research done studying board games, interviewing game designers and making TangiDice led me to the finished version of TangiPlay. Quite simply, as the developer of a prototyping tool, my decisions on how it was developed shaped the types of games designers made. This became evident through analyzing TangiDice, as

the outcomes were a permutation of four different rules. In response to this, TangiPlay's development began by providing more rules to enable more outcomes, but initial testing of the concept made it apparent that TangiPlay was becoming a computer wizard and guiding game designers through a predefined development process. At that point TangiPlay was simplified to tokens and basic rules in an effort to cause the game developer to drive the process rather than letting the system dictate the outcome. Even with this effort, the tools and rules still shape the outcomes, as expressed by Participant D whose game design was inspired by using the Smart Tokens as skill based objects: "I created this game thinking within the constraints of the table" (Schreiber, 2009). Nonetheless, the exciting aspect of tangible electronic games is that there are so few examples, which means that the potential of tangible electronic tokens is far from being explored or understood even within prototyping tools.

6.2.2 Goals of Rapid Prototyping

Prototyping is one way of exploring the potential of tangible electronic games, yet what constitutes a prototype varies from kit to kit like Papier-Mâché (Klemmer et al., 2004) and higher-level systems like CookieFlavors (Kimura et al., 2007). A system like Papier-Mâché requires the developer to have more time and programming knowledge to develop a prototype than a system like CookieFlavors. On the other hand, this allows a system to be more flexible and able to create varied projects than could be done with CookieFlavors. Of the current prototyping environments, none are specific for tangible electronic games, nor are they as 'high-level' as TangiPlay. Operating TangiPlay requires

no programming skills or knowledge of electronic tangibles, and the project was designed as such to enable rapid prototyping. The user testing verified the system could be learned in ten minutes before a functioning tangible electronic game could be made, played, edited and then played again, which as a process itself took an average of twenty minutes. The speed of TangiPlay is its key asset as game designers are able to rapidly prototype new games in the emerging field. While the varied outcomes are more limited due to the specific game tokens that are available to game designers, the speed at which games are being designed through TangiPlay is significantly greater than what has been the case with low-level programming and prototyping kits.

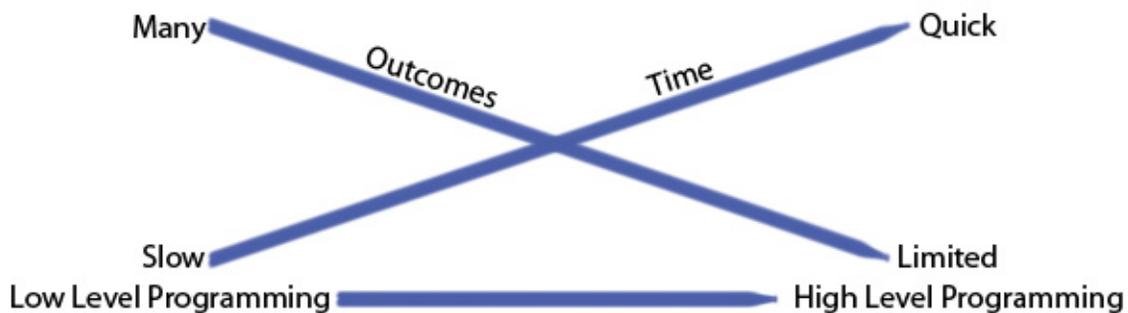


Figure 25: Outcomes compared to Time in relation to programming levels

6.2.3 Turn-Taking

Dice or board games seem to have a simple structure that should be easily duplicated by electronics. TangiDice was based on dice games, as the concept of digitally modifying a die appeared straightforward. The notion was to make an electronic dice that could be rolled like a traditional die, but with a couple of sensors that would know its orientation and acceleration. The issue

arose when the computer was receiving raw data; it could not decipher the difference between a roll and shaking of a die. Furthermore, what constitutes a roll? Is a roll when the die leaves a player's hand? These questions were never relevant before because the number at the end of the roll was the only important piece of information. Tangible electronic games initiate questions like this, and finding their answers will allow for the production of more projects. With TangiPlay, a roll was determined to begin once the die hit the table, as it was technically the only way I could determine that a die was being rolled. Computers are good at crunching numbers, but when physical gestures are included, there often is no simple answer. Rolling dice or completing a turn on an electronic board game is not simple for a computer to understand. In order for tangible electronic games to progress, this is one issue that needs to be understood.

7: CONCLUSION

“Many people of all ages play games, such as board games, PC games or console games. They like game play for a variety of reasons: as a pastime, as a personal challenge, to build skills, to interact with others, or simply for fun.”

(Mazalek & van den Hoven, 2007, p. 2). Tangible electronic games are a growing trend within the game field because they combine many of the benefits from both board and video games. This thesis began by introducing tangible electronic games and laying out the ‘tangible dilemma’. Through a methodical literature review of related fields, interviews with game designers and an analyzed proof of concept project, TangiPlay was constructed. TangiPlay was created to be a conceptualizing environment with a ready toolkit of tangibles and an interactive surface for the formation of tangible games, and then assessed for future development.

“I could have a lot of fun with this!” (Schreiber, 2009) said, Participant G at the end of the user testing session. TangiPlay was able to generate a wide variety of enjoyable tangible electronic board games. It was encouraging to see professional game designers able to use this tool to create a game, especially after only ten minutes of being introduced to it. Tangible electronic games were developed, tested, evaluated, refined and played through, all within approximately twenty minutes. From the feedback I received, both the process of making and playing the games was engaging and entertaining. Despite its

technical flaws, the concept of a prototyping environment has proven to be successful. TangiPlay is a ready toolkit of modifiable tangibles and an interactive surface capable of supporting the development of tangible electronic games.

7.1 Contributions

TangiPlay was created to be a functioning prototyping environment in order to further understand the tangible electronic game field, the prototyping process and where the field may be headed. Knowledge was gained from the beginning when making TangiDice, the proof of concept, to the final step of analysing the user testing sessions from TangiPlay.

During the development of TangiDice, the turn-taking issue became apparent. When people play dice or board games, they are able to know when a player's turn has begun and finished. While rolling a die seems simple, a computer still needs to be told exactly what constitutes a turn or a die roll. For TangiDice and TangiPlay, a die roll was considered to have begun once the die first made contact on the surface. This action produced a bang that triggered the system to begin tracking the data. When more automation is built into a prototyping system, the computer will need to know which players are performing specific actions in order to enforce rules and facilitate scoring.

During user testing sessions, game designers were able to build an electronic tangible game through interacting with a completely tangible interface. The UI was designed to be intuitive, yet users needed some clarification on how to use certain tokens. In the end, six unique games were made on an interactive

surface with electronic tangible tokens and no keyboard or mouse was used at any point. This confirms that a tangible interface can support a prototyping system.

During the development of the six electronic games, users interacted with the Smart Token, a digitally augmented die. In addition to the traditional chance element of the die, sensors were installed to track rotations and acceleration. The sensor information allowed a chance object to measure skill, such as how many times a die is rolled or the average acceleration. Even with my specific efforts to alter the appearance of the die, half of the users either didn't know how to utilise the new information or ignored its potential and only used the Smart Token as a regular die.

The other half exploited the Smart Token as a skill object. Some games used the token to generate two separate skill based outcomes, while others used the token for both skill and chance at the same time. Either way, the Smart Tokens enabled new games to be made that were not possible without the augmentation. The Smart Tokens have set the stage for other augmented tokens, such as cards, timers and markers.

All six games were made after a ten-minute introduction to TangiPlay, and then in an average of twenty minutes, game designers were able to develop a new game. The ten-minute introduction is important, as it shows how user-friendly an electronic prototyping system can be. All users had zero experience prototyping tangible electronics; after only a short explanation, they were able to use the tangible interface to create a game. As for the development of the actual

game, twenty minutes included coming up with an idea, making it, playing it, editing it and then doing a final run-through. TangiPlay is able to support game designers playing and editing a game at the same time, but most importantly, designers were able to speedily produce entertaining and engaging games. Due to 'high-level' programming in TangiPlay, game variety is limited; nonetheless, it was acceptable as it permitted the rapid speed designers could prototype a game. On the whole, TangiPlay is a tangible prototyping environment that has helped further understand tangible electronic games.

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APPENDICES

APPENDIX 1: USER TESTING SCRIPTS

Phone Interview Script

Introduction:

- Hello, my name is Jason Boileau and I am a Masters of Arts Candidate at Simon Fraser University.
- I am working on a project called CAT Games (Creativity Assist Tools for Games). The goal of CAT Games is to create new tools for game production, specifically focused on quickening the creative process, and expanding and enriching content environments and platforms.
- The specific aspect I am working on is a Gesture and Tangible Prototyping Tool. The concept is to enable designers to quickly conceptualize and create physical, tangible and virtual game prototypes based on physical gestures and manipulation of “smart” objects.
- To learn more about this field, I am conducting phone interviews to find out about game prototyping practices. It would be great if you could spend some time answering some questions. This interview should take about 15-20 minutes. If it's all right with you, I would like to record our session for some of my future papers and eventually, my thesis.

Questions:

1. Lets begin finding out how you **interpret** tangible games?
 - a. Have you ever worked with tangible games or game controllers before, and if so, please briefly describe the final project.
2. Our project's goal is to aid in the creation process for game developers, so we would like an understanding of your **prototyping and design experience**. Are there specific tools, programs or strategies you use?
3. How does your **creativity** fit into this development process?
4. Through our experience, the prototyping process yields a variety of **solutions** for one project; however, the majority of the time only one solution is carried forward.
 - a. How does your **selection process** work and what do you do with the unselected solutions?
5. What kind of **prototyping tools** would aid your development process?
 - a. Are there specific elements or features you would like to see? For example, paper prototyping for interface, or foam prototyping for shape of a physical object.
6. Our prototyping tool is currently being debugged and readied for user testing. Would you or your company be interested in **helping us** test our project, or in learning more about our research findings?

Conclusion:

- Thank you very much for participating in this phone interview. If you have any questions or comments I would be more than happy to answer them now or later by email at jboileau@sfu.ca.

TangiPlay User Testing Script

Introduction:

- Hello, my name is **Jason Boileau** and I am a **Masters of Arts** candidate at Simon Fraser University.
- I am working on a project called **TangiPlay – Prototyping Tangible Games**. TangiPlay consists of an **interactive surface** and both “**simple**” and “**smart**” **tokens**. The concept is to enable game designers to quickly **conceptualize** and **create tangible game prototypes**.
- This session should take about **20 minutes**. If it’s alright with you, I would like to **record** our session for future papers and my thesis.

Overview:

- The table is a **digital display surface**, which can be written on with whiteboard markers.
- There are three **types of tokens**: simple, programming and smart.
 - o The overall system knows the **simple tokens** location and unique ID.
 - o The **programming tokens** function similarly to the simple tokens, but are designed to carry out specific programming tasks.
 - o With the two **smart tokens**, the system knows which side is facing upwards, how many times it rolls and the average acceleration during the throw.
- All of the tokens **interact** with the display surface and each other. The square programming tokens turn on/off and toggle how the information of the smart token is displayed. The simple token displays how close they are to the proximity token and/or if they are on a hotspot made by the stamp tool.

Demonstration: (make a game with the participant)

- Snakes and ladder board game
 - o Stamp tool
 - o Writing on table
 - o Playing the game

Audience Participation:

- Ask participant to **explore** the table and tangibles
- **Goal** of the session
 - o Does TangiPlay **work**?
 - o **Patterns** of usage
 - o **Suggestions**
- **Make** a game
- **Play** game

Questions:

- Are you satisfied with the **finished product**?
- How would you summarize the conceptualization **process**?
- How did making a game with TangiPlay compare to your **previous experience** with _____ prototyping:
 - o Paper
 - o Board game
 - o Video game
 - o Tangible input
- Do you have any **questions** about the project?

Conclusion:

- **Thank you** very much for participating in this testing session. If you have any questions in the future and you can reach me at jboileau@sfu.ca.