Mobile Exergaming Heuristics

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Abstract

An alarming number of adolescents experience obesity and related health issues, in part because of a lack of exercise. Increased mobile technology availability can have negative effects on amount of exercise, but they can have positive effects as well. Leveraging mobile technology to encourage and motivate exercise has potential to decrease unhealthy lifestyles, especially among young people. Mobile exergaming is an emerging field that has the potential to motivate users to exercise while also having fun. However, much of the early development work on mobile exergames has been ad-hoc, with little guidance available for designers. This work seeks to identify heuristics catered for mobile exergaming. This thesis presents four mobile exergaming heuristics were identified based on recent literature and on the author's mobile exergame design and development efforts: 1) Motivational game concepts that promote physical activity; 2) Game cues that engage active users; 3) Physically and temporally appropriate game structure to encourage continual, recurring play; 4) Game play movements that are safe for the user and for the device. This thesis describes the development of the mobile exergame heuristics, along with the creation and distribution of an ExergameApp Suite comprised of three mobile exergames: Fish Out of Water, Color Hunt and Space Rayders.

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Chapter 1

Introduction

Over the past ten years, obesity in the United States has become a serious epidemic, especially in children and young adolescents. According to the CDCP, "12.5 million children and adolescents aged 2-19 years are obese" [CDC 2014]. From among the many factors that potentially contribute to obesity, this thesis focuses on increased opportunities and motivation to exercise, specifically through the development of mobile exergames. Healthy living programs and campaigns have been created to provide various motivational tools and methods, like the "Apps for Healthy Kids" competition—part of Michelle Obama's *Let's Move* campaign to address childhood obesity. This competition required for game designers in America "to design engaging online or mobile games and tools to educate people of all ages about the importance of healthy eating and physical activity" [Eamich 2010]. In children under the age of eight years old, 17% use a mobile device [Ritcher 2013]; about 14% of children under eight years old use a computer. In young adolescents, 61% of teens between the ages of 12-17 own a smartphone [Newswire 2013]. This familiarity and availability of mobile technology reflect an opportunity to intervene through technology.

With the rise in mobile device and computer technology usage by children and young adolescents, programs, like Let's Move, are pursuing the avenue of incorporating healthy living and exercise applications into the daily lives of children and young adolescents. Furthermore, the gaming industry has also had an increased interest in developing fitness based games, or exergames. Within the scope of this thesis, *exergames* are video games that use external, non-portable gaming consoles that requires the user's physical activity in order to complete various tasks in a game; examples of popular exergames are Wii Fit Plus and Zumba fitness. One main goal of exergames is to hide the "tiresome side of working out with the fun side of playing to make the exercise process more attractive" [Görgü, Campbell, & O'Hare 2010]. Even though initiatives have been undertaken to promote and motivate exercise and healthy living, more research needs to be done in the field of exergaming, especially pertaining to the emerging field of mobile exergaming.

Mobile exergames are games that use mobile devices, such as smartphones, to engage the user in physical activities, like walking or running, to complete various tasks in a game. Koivisto, Merilampi, and Kiilli presented mobile exergames as "an exergame platform which does not require special game consoles" [Koivisto, Merilampi & Kiili 2011]. Furthermore, according to Mortazavi et al, mobile exergames "use the mobile device for controller input" [Mortazavi et al. 2014]. With the increase of mobile smartphone usage, the field of mobile exergaming is very promising. Mobile devices allow for easy transport and convenience, especially in a fast paced society. With the incorporation of accelerometers, GPS, Bluetooth, and Wifi, the possibilities of future development of mobile exergames seem limitless. Furthermore, the actual game cost for creating and deploying mobile exergames will be cheaper than console games; in addition, updates can be made and quickly distributed to users once the mobile exergame is downloaded.

Currently, sedentary games dominate in mobile gaming venues like the Android Play Store, while mobile exergames are fewer in number and harder to find. Even though there are some mobile exergames available on the Android Play Store, there is not a specific category to identify mobile exergames as there are for "Action Games", "Role Playing Games", and "Educational Games". Mobile exergames are scattered in these and other categories, reducing their accessibility and impact. If mobile exergaming development increased to a point at which a category was warranted in the Android Play store, it could help highlight the number of mobile exergames in the Android Play Store. Furthermore, the scope of the target audience for mobile exergames needs to be taken into consideration; several of the mobile exergames target a general and or adult audience. Because physical activity can vary depending on the target audiences' demographics, such as age, it is important to also categorize mobile exergames by age so that there are mobile exergames available for children as well as adults. In addition, mobile applications that share similarities with mobile exergames include fitness tracking apps. These apps generally just track fitness progress, give exercise routines, and or give health tips, though some seek to directly engage the user in physical activity by using the mobile device as part of the physical movement (e.g., by encouraging people to reach step counts or by discouraging extended sedentary periods).

Because there are no set guidelines to creating successful mobile exergames, more research is needed to see what requirements are necessary to create successful mobile

exergames; creating mobile exergaming heuristics will help in the design and evaluation process. *Heuristics* are "design guidelines which serves as a useful evaluation tool for both product designers and usability professionals" [Desurvire, Caplan,& Toth 2004]. Even though there are some heuristics that currently exist for mobile gaming, in the field of mobile exergaming, there are no set design heuristics for mobile exergames to follow. This has contributed to the lack of impact mobile exergames have had on the Android Market. In order to develop heuristics, the domain area needs to be understood from reading various pieces of literature and through personal development experience. By creating heuristics that are specific to mobile exergames, it will help identify issues that are common amongst mobile exergames that can be overlooked by using general heuristics. This development will allow for future developers to understand mobile exergaming and will help them create more mobile exergames that can be applicable to a specific and or wider audience range, especially for children.

In this thesis, the creation and background of four mobile exergaming heuristics is discussed and explained. Each of these heuristics will be presented in the traditional style as well as in the form of claims. The claims include the description, the upsides, and the downsides of each heuristic. The following are the four heuristics that were created for mobile exergaming: 1) Motivational game concepts that promote physical activity; 2) Game cues that engage active users; 3) Physically and temporally appropriate game structure to encourage continual, recurring play 4) Game play movements that are safe for the user and for the device. Different versions of these heuristics were presented in expert review sessions; these expert reviews helped uncover further insight on the usage of heuristics and their applicability to mobile exergaming.

Chapter 2

Background

2. 1 History of Exergames and Exergaming.

Because of the increased need to promote healthy living and exercise in sedentary lifestyles, many researchers have developed different methods to incorporate fun into exercise. The term "exergaming" has become a new and immature topic of research, especially in the mobile technology field of study. Over the years, exergaming has acquired many definitions and objectives. According to Görgü, Campbell, O'Hare 2010 , "exergaming is the combination of words 'exercise' and 'gaming,' and its objective is to motivate people to participate in exercise regimes" [Görgü, Campbell, O'Hare 2010]. In 1988, Bandai released a game called *Dance Aerobics*, which was targeted towards the female audience [Bogost 2005]. *Dance Aerobics* used the NES, Nintendo Entertainment System, PowerPad as a measurement tool to track the player's progress throughout the game [Bogost 2005]. This style of exergaming was Bandai's first attempt to promote traditional workout methods through a gaming system in the form of aerobic exercise [Bogost 2005]. Using these types of video games are suggested by the authors as factors that can lead to increased healthy behaviors.

Exergaming has also been defined as "the merger of video games with exercise equipment" [Sinclair, Hingston, & Masek 2007]. In order to promote physical activity and fun, many gaming consoles, such as the Wii by Nintendo and Playstation 3 Move by Sony, incorporate motion sensor technology and external devices; players are able to play exergames in the comfort of his or her own home. Since the late 1980s, devices, like the Powergrid Kilowatt, were designed and created to be an "isometric workout videogame controller" [Bogost 2005]. A major issue consumers had with these types of products was that they were very bulky, heavy, and were not easily transportable. Over the years, more research has been conducted on how to incorporate the benefits from exercise equipment into a videogame without the actual exercise equipment being an inconvenience. For example, Life is a Village is an exergame that uses a recumbent bicycle to navigate around a virtual world; the recumbent bicycle is "more stable and

comfortable to sit in, therefore more approachable than a traditional bicycle" [Yim & Graham 2007].

In 1988, the gaming company Nintendo was one of the first to introduce the external device called the PowerPad, which accompanied the Nintendo Entertainment System [Bogost 2005]. The PowerPad was very large, complex and was double sided; one side had a grid with twelve touch-sensitive circles, while the other had "eight circles in a star configuration" [Bogost 2005]. Many of the exergames that were made to incorporate the PowerPad were mostly "single player sports activities, usually track" [Bogost 2005]; however, games, like Dance Aerobics, were created to attract a more diverse audience. Almost two decades later, Nintendo released the game Wii Fit Plus, which used the external device called the Wii Fit Plus board. Unlike the PowerPad, the Wii Fit Plus Board is more technologically equipped, is smaller, and lighter than the PowerPad; this board captures the movements of the user and can be used as a body measurement tool [Wii 2007]. In addition, the exergame Wii Fit Plus provides versatility in the activities users can participate in, like jogging, yoga, strength exercise routines, and even hula hooping.

Because of the recent advances in gaming technology, the requirement for external devices to be used along with gaming consoles has decreased. Games, like Just Dance for Wii and Zumba Fitness for Wii, have become popular because players are able to have fun interacting with the games without having to worry about buying other external devices to accompany specific games; furthermore, players are able to immerse themselves in the game without having to use extensive exercise equipment. One main objective of exergames is to hide the "tiresome side of working out with the fun side of playing to make the exercise process more attractive" [Görgü, Campbell, & O'Hare 2010]. The philosophy seems to be that the less equipment that is needed, the more players can immerse themselves and have fun playing the exergame. Further descriptions of various exergames can be found in Table 1.

Game	Author	Paper	Description
Gener-G (2012)	Remi Bec	Creating Physically Active Games for Young Adolescents	Players pick up trade cards which correspond to family tasks. The winner is the last player in the game with remaining energy and has the opportunity avoiding household chores.
Just Dance 2014 [Wii]	Ubisoft	N/A	The player or player mirror dance moves performed by a computer generated character. There's a feature called Just Sweat, which tracks how many calories the user burns.
Wii Fit Plus (2007) [Wii]	Nintendo	N/a	Uses the Wii Fitness Board, which is used as both a measurement and interaction tool, to interact with different exercise, aerobic, and yoga routines.
Dance Aerobics (1988)[Nintendo Entertainment System]	Ian Bogost	Rhetoric of Exergaming	Uses the PowerPad, which was used as a measurement tool for player's progress. Player has to mimic the moves of the virtual character on screen and make contact with specific sensors on the PowerPad.
Yourself Fitness (2004) [PS2, XBOX, PC]	Ian Bogost	Rhetoric of Exergaming	Allows for users to follow at-home exercise routines and input their own information.
Powergrid Fitness by Kilowatt (1984)	Ian Bogost	Rhetoric of Exergaming	Used an isometric external workout videogame controller to play game.
Life is a Village (2007)	Jeffrey Yim and T.C. Nicholas Graham	Using Games to Increase Exercise Motivation	Is a multiplayer virtual world exercise program that used an exercise bike to control the virtual avatar.

Table 1. Examples of exergames for gaming consoles

2. 2 History of Mobile Exergaming

Mobile exergames are games that use mobile devices to engage the user's body in physical activities to complete various tasks. Researchers have found that the "time children and adolescents spend by playing video games has increased remarkably" over the years [Koivisto, Merilampi, Kiili 2011]. Furthermore, there has been an increase in the amount of children and young adolescents that use mobile devices on a daily basis. A main goal for mobile exergaming is to "present an exergame platform that does not require special game consoles" in order to play [Koivisto, Merilampi, Kiili 2011].

Games are a cornerstone for most mobile platforms, and most of the lessons from this thesis apply to any smartphone platform—though this thesis focuses on the Android platform for several reasons. First, the Android operating system is the biggest part (85% share) of a worldwide smartphone market that grew over 25% to 301 million phones in the year time period ending in June 2014 [PC World 2014]. In addition, the Android Play Store provides an inexpensive license (compared to iOS) that allows developers to upload apps for a small one-time registration fee. This allows developers to have a quick and easy path to publishing their apps, and it often results in lower prices for the apps. These factors support access by a larger group of people, including those from low socioeconomic status groups that might benefit the most from access to these apps.

However, in the Android Play Store (and in other mobile stores), mobile exergaming is not very prominent or popular. Sedentary games, such as Don't Tap the White Tile and Minecraft, are highly rated in the Play Store as of July 2014. Furthermore, many fitness mobile apps are only fitness trackers, allowing users to record their fitness stats and exercise routines. For instance, Fitocracy allows users to create a workout regimen based off a list of routines; it also gives points, as incentives, for users to progress in their exercise routines. Another popular fitness tracker is Virtuagym, which is similar to Fitocracy but allows the user to view three-dimensional demonstrations of the exercises. A selection of fitness trackers can be found in Table 2, along with the Play Store rating and range of number of downloads as of July 2014.

Game	Cost	Rating	Number of downloads
Nexercise	Free	4.6	100,000-500,000
Fitocracy	Free	3.7	100,000-500,000
Virtuagym	Free	4.4	1,000,000-5,000,000
Zumba Fitness	Free	3.7	100,000 - 500,000

Table 2. Select mobile fitness trackers.

Although mobile exergames are not as popular as the sedentary games, there are a few mobile exergames in the Play Store with high ratings, which can be found in Table 3. Each of the exergames were chosen because they use the phone as part of the physical activity instead of as a viewing device for exercises; as mentioned previously, other applications on the Play Store catered for exercise motivation were only fitness tracking tools and only used the mobile device for recording and viewing exercises. Zombie, Run! uses the user's GPS location to create virtual zombies that the user has to avoid; this exergame has a high rating of 4.0 and the most download counts. Zumba Dance tracks the motions made by the user dancing, which provides the user feedback on how their dance moves are relevant to the computer instructor's moves; this exergame has a high rating of 4.2 but the number of download counts isn't as high as Zombie, Run!. Deep Squat is an example of a mobile exergame that is exercise-oriented but involves the mobile device in the exercise; as the player implements the deep squats, the mobile device is attached to the player's thigh and monitors the player's angle. Another example of an exercise oriented mobile exergame is Fitness Game Adventure; unlike Deep Squat, Fitness Game Adventure motivates users to exercise by having them do certain tasks in order to complete different obstacles of the game. Players are rewarded with virtual incentives once their obstacles have been overcome.

Game	Cost	Rating	Number of installs
Zumba Dance	$4.99	4.2	1,000-5,000
Zombies, Run!	$3.99	4.3	100,000-500,000
Zombie, Run! (different)	Free	4.0	1,000,000-5,000,000
GoldCatcher	Free	N/A	50-100
Fitness Game Adventure	Free	3.1	100-500
Deep Squat	Free	4.2	1,000-5,000
C:geo	Free	4.5	1,000,000-5,000,000
Tourality	Free	3.2	10,000-50,000
Rundomize	Free	1.5	100-500
Whereyougo	Free	3.9	100,000-500,000
CYA (Claim Your Area)	Free	2.7	5,000-10,000
FitNet	Free	4.0	10 - 50

Table 3. Mobile Exergames from the Play Store

Even though mobile exergames are catered towards exercising, this does not mean that the gameplay has to be a specific exercise routine. Mobile exergames can be related to numerous activities, including outdoor games, like tag. For instance, Swordfight is a multiplayer mobile exergame that allows two users to imitate the motions of an actual swordfight [Zhang et al 2012]. In addition, Chasecat is another multiplayer mobile exergame that involves one player chasing another for a certain period of time, while the other player is maintaining their distance [Zhang et al 2012]. Some game developers have designed stationary mobile exergames, like Neverball [Berkovsky et al 2010]. Neverball allows the user to control a ball by tilting their body around maze; there is no running or exercise routine involved with gameplay. Table 4 depicts selected

mobile exergames that have been researched over the years; however, many of these mobile exergames have not been added to the Play Store or other online stores.

Game	Author	Paper	Description
Neverball (with PlayMate! design)	Shlomo Berkovsky, Mac Coombe, Jill Freyne, Dipak Bhandari, Nilufar Baghaei	Physical Activity Motivating Games: Virtual Rewards for Real Activity	The user controls the ball by tilting their body around a maze puzzle and collecting coins.
Swordfight	Zengbin Zhang, David Chu, Xiaomeng Chen, Thomas Moscibroda	Mobile Motion Gaming: Enabling a New Class of Phone-to-Phone Action Games on Commodity Phones	Allows the two users to imitate the motions of an actual swordfight; each user's amount of energy is measured.
ChaseCat	Zengbin Zhang, David Chu, Xiaomeng Chen, Thomas Moscibroda	Mobile Motion Gaming: Enabling a New Class of Phone-to-Phone Action Games on Commodity Phones	Involves one player maintaining distance away from the other player, while the other player chasing that player.
iFitQuest	Andrew Macvean and Judy Robertson	Understanding Exergame Users' Physical Activity, Motivation and Behavior Over Time	Involves eight exercise mini-games that can be played on the go.
SNAP suite	Anthony Whitehead, Hannah Johnston, Nicole Nixon, Jo Welch	Exergame Effectiveness: What the Numbers Can Tell Us	Uses full body sensors and requires users to be in a specified pose before time runs out.
Bug Attack	Antti Koivisto, Sara Merilampi, Kristian Killi	Mobile Exergames for Preventing Diseases Related to Childhood Obesity	An individual and multiplayer mobile exergame that the user controls their character by jumping.

Speeding	Antti Koivisto, Sara Merilampi, Kristian Killi	Mobile Exergames for Preventing Diseases Related to Childhood Obesity	Is a collaborative multiplayer game where the users drive their drag car by increasing their heart rate
World of Workout	Jamie Payton, Evie Powell, Andrea Nickel, Katelyn Doran, and Tiffany Barnes	GameChanger: A Middleware for Social Exergames	Players are given different challenges involving walking certain distances.
Final Reality	Jamie Payton, Evie Powell, Andrea Nickel, Katelyn Doran, and Tiffany Barnes	GameChanger: A Middleware for Social Exergames	Involves players using different gestures that simulate a battle system over a network using mobile device
Move2Play	Pavol Bielik, Michal Tomlein, Peter Kratky, Stefan Mitrik, Michal Barla, and Maria Bielikova	Move2Play: An Innovative Approach to Encouraging People to Be More Physically Active	The user is able to choose different training plans, which include various types of aerobic and walking activities.
ExerLink platform	Taiwoo Park, Inseok Hwang, Uichin Lee, Sunghoon Ivan Lee, Chungkuk Yoo, Youngki Lee, Hyukjae Jang, Sungwon Peter Choe, Souneil Park and Junehwa Song	ExerLink: Enabling Pervasive Social Exergames with Heterogenous Exercise Devices	Allows the users to engage in various, stationary activities, including hula hoop, jump rope, stationary bike and treadmill.
Neat-O-Games	Yuichi Fujiki, Justin Starren, Konstantinos Kazakos, Colin Puri, Ioannis Pavlidis, James Levine	NEAT-o-Games: Ubiquitous Activity-based Gaming	The user wears an activity sensor, while holding a PDA device, which allows the user to engage in different physical activities.

Table 4. Mobile Exergames from Literature

The Android Play Store features numerous mobile games; even though mobile exergames are not as popular, a few are available as of September 2014 on the Play Store, which can be found in Figure 3. The literature has presented various types of mobile exergames, found in

Figure 4, that are both routine based and based off of outdoor games. These games are important to game designers because they show the various factors that are included in mobile exergames and the various characteristics of mobile exergames. In the next chapter, it introduces the ExergameApp Suite, which is a collection of three mobile exergames originally developed for a previous dissertation for Kacie Allen [Allen 2013]. These mobile exergames are not exercise routine based but based on outdoor activities such as walking and the game "tag." These mobile exergames are unlike traditional exergames because they are not based on a strict exercise routine, and allow for users to engage in physical activity, while having fun.

2. 3 History of Heuristics and Mobile Gaming Heuristics

Heuristics are "a small set of fairly broad usability principles" [Nielson 1994]. Jakob Nielson was one of the first to develop usability heuristics for heuristic evaluations; these heuristics were developed to be broad enough to evaluate a variety of user interfaces. His heuristics are as follows: visibility of status; match between system and the real world; user control and freedom; consistency and standards; error prevention; recognition rather than recall; flexibility and efficiency of use; aesthetic and minimalist design; help users recognize, diagnose, and recover from errors; and help and documentation [Nielsen 1995]. Since 1995, these heuristics have been applied and leveraged to user interface design as a bar for comparison and a cornerstone for creation of usability-related design heuristics that have been developed since then.

In the two decades since Nielsen introduced his heuristic set, many other researchers have created complimentary and supplementary heuristic sets for other domain areas. Somervell developed heuristics for Large Screen Information Exhibits that could be used to explore a unique and emerging subset of large displays [Somervell 2004]. By reviewing previous work, Somervell found that when other researchers modified Nielson's heuristics to be more specific to the research they were conducting, more usability issues related to that user interface were uncovered [Somervell, Wahid & McCrickard 2003]. In comparing his heuristics to two other sets ([Neilsen 1995; Berry 2003], Somervell found that tailored heuristics were more effective on several measures than generic ones [Somervell & McCrickard, 2004]. Furthermore, tailored

heuristics can serve as the central component of usability evaluation tools [Somervell & McCrickard 2005].

Numerous domain-specific heuristics can be found in several fields of study, including IT Security Management, Ambient Displays, and Sensor Networks. Most researchers have found promise from creating domain-specific heuristics; according to Rusu et. al, most heuristic evaluations miss domain specific problems, which makes domain-specific heuristics very helpful [Rusu et al. 2011]. When evaluating domain-specific heuristics in sensor networks, Jang, Weon, and Yoo found that by applying domain-specific heuristics, they were a powerful tool to use to help extract common features among the different node clusters in the sensor networks [Jang, Weon, & Yoo 2014]. In contrast, Mankoff and her colleagues found that their modified heuristics for ambient displays were not as applicable in many situations as Nielsen's heuristics [Mankoff et al. 2003]. One main factor that may have contributed to this result is the wording and specificity of their heuristics; because their heuristics were too general, similar to Nielsen's style, they did not uncover issues that could address the various error conditions found within ambient displays [Mankoff et al. 2003]. In summary, it seems that use of heuristic sets has shown promise for the analytic abilities of specific heuristics over general heuristics, though using multiple sets of heuristics may yield the greatest benefit.

As heuristic sets have emerged, design requirements have also been emerging from various design methodologies. Design requirements differ from heuristics because they are only used as guidelines and not used as part of an evaluation tool. Consolvo and her colleagues developed four key design requirements for exergaming: give users proper credit for activities; provide personal awareness of activity level; support social influence; and consider the practical constraints of users' lifestyles [Consolvo et al. 2006]. These design requirements can only be used as guidelines for developed design requirements but more specific to mobile exergames. These design requirements described what was needed in order to create a successful solution to encourage physical activity, especially when incorporating mobile devices [Bielik et al. 2012]. Similar to the Consolvo design requirements, these design requirements can only be used as guidelines when planning a design.

Due to the recent rise of mobile phone devices, mobile heuristics have begun to emerge over the years. Bertini, Gabrielli, and Kimani focused on creating heuristics specifically for mobile computing [Bertini, Gabrielli, & Kimani 2006]. To create this set of mobile heuristics,

usability researchers were given Nielsen's set of heuristics to determine which were relevant for evaluating mobile interfaces. Then, a set of eight heuristics were developed and assessed by using a mobile device for evaluation [Bertini, Gabrielli, Kimani 2006].

To meet the needs of the frequently advancing mobile device realm, Inostroza et. al developed mobile heuristics for touchscreen based mobile devices [Inostroza et al. 2012]. These heuristics were targeted for evaluation of touchscreen based mobile device interfaces since the hardware and software components, like the screen size, had experienced tremendous growth in recent years. To use Nielsen's or Bertini, Gabrielli and Kimani's set of heuristics, which were developed in 1995 and 2006, did not seem as beneficial as creating a set of heuristics that focused on touchscreen-based mobile heuristics.

According to Desurvire, Caplan, and Toth, "heuristics are design guidelines which serve as a useful evaluation tool for both product designers and usability professionals" [Desurvire, Caplan, & Toth 2004]. For the field of gaming, Desurvire, Caplan and Toth created heuristics to help evaluate the playability of mobile games. These heuristics were divided into four categories: game play, game story, game mechanics, and game usability. The game play category describes "the set of problems and challenges a user must face to win a game" [Desurvire, Caplan, & Toth 2004]. The game story category describes the "plot and character development" [Desurvire, Caplan, & Toth 2004]. The game mechanics describes the programming of the virtual environment and its interactions [Desurvire, Caplan, & Toth 2004]. The game usability describes the interface and the external elements the user needs to interact with the game [Desurvire, Caplan, & Toth 2004]. These heuristics were tested against "traditional user methodologies during the critique of a new game design" [Desurvire, Caplan, & Toth 2004].

Mobile gaming playability heuristics are necessary because of the lack of knowledge on how inspectors are using heuristics and "whether they actually help in identifying playability problems" [Korhonen 2011]. By using prior heuristics, such as Nielson and Desurvire, Caplan and Toth, Korhonen & Koivisto developed a playability evaluation model that focused on three main aspects of mobile gaming: gameplay, mobility and game usability [Korhonen & Koivisto 2006]. Each component of this model is built in a modular structure, which allows for separate evaluation and for more modules to be added to this model if necessary. Unlike Desurvire, Caplan, and Toth's heuristics, Korhonen and Koivisto designed these set of heuristics for mobile gaming playability. The gameplay component consists of the game mechanics and the game

story; the game usability component consists of the usability issues that are common amongst mobile devices [Korhonen & Koivisto 2006]. The game mobility component describes the mobility issues that occur and can affect gameplay; even though these issues could fall under the game usability category, there are mobility issues that occur that need to be taken into account. For instance, smartphone screens are more advanced than phones in the past, such as having touch screens and bigger interfaces; this can lead to more distractions and interferences during gameplay. In addition, because safety is an important concern for users today, mobile exergame designers will need to be considerate of the physical activities that they incorporate into gameplay so that both the users and the smartphone is safe during gameplay.

By looking at prior research pertaining to heuristics, each set of heuristics mentioned earlier are stemmed from Nielsen's heuristics. Used as a foundation, Nielsen's set of heuristics provide a base to develop specific heuristics for various fields, including mobile computing and exergaming. However, there are currently no modern sets of heuristics for mobile exergaming. If one were to use mobile design heuristics or traditional exergaming heuristics to evaluate a mobile exergame, there will be some usability issues that will not be identified or resolved. Furthermore, because the field of mobile exergaming is fairly new, having mobile exergaming heuristics will help in the development and evaluation of future exergames.

Chapter 3

Developing the ExergameApp Suite

The goal of this chapter is to describe the research that was done to create and distribute mobile exergames that are based on sound design principles elicited from prior work. Based off of Kacie Allen's previous work involving mobile exergames, three of the four mobile exergames were chosen and redesigned to meet the combined design principles acquired from prior research [Allen 2013]. Descriptions of the initial and redesigned versions of each mobile exergame will be given along with screenshots. By the end of this chapter, you will be able to see how the design principles, found and combined from previous research, can be applied to the Exergame Suite and can be a lead to further distribution of mobile exergame research. Videogames that encourage healthy lifestyles and wellness are becoming very important field of research, as discussed in 2.1 (background). As a Norfolk State University undergrad, I was part of a partnership between Norfolk State University and Virginia Tech (NSU-VT), led by Woodrow Winchester, VT, Scott McCrickard, VT, and Felicia Doswell, NSU, which targeted ways in which mobile apps could help address health needs of African American youth. The partnership was part of a larger research effort, partnering with NSU, North Carolina A&T State University, Bennett College, and Hollins University to create pods of researchers that pursued efforts related to technology and underrepresented groups [Dozier et al. 2009]. By stemming from various design theories, the culturally empowered design method was developed, which included four tenets: active end-user involvement; leveraging of readily-available technologies; rapid prototype development; and development by people aware of issues first-hand [Winchester et al. 2010]. During my participation in the NSU-VT partnership, I, along with three of my NSU peers, looked at ways to encourage African American children between the ages of 7-11 to eat healthier by using a mobile app called Health Attack, which is a memory game that incorporated the USDA Food Pyramid and common foods that are usually found in the African-American culture [Hill et al. 2011].

Other work from this partnership looked at various aspects of designing applications for encouraging healthy lifestyles, such as reward incentives and methods that apps can appeal to a sense of coolness amongst youth. One effort looked at how virtual card activities can encourage

culturally situated design [McCrickard et al. 2011]. Another project explored ways that mobile interfaces could support awareness in a smart home environment [Gracanin et al. 2011]. A different project examined how multitouch tables could help engage young people in learning [George et al. 2011]. In addition, another effort investigated the aspects of games that give the idea of being "cool" [McCrickard et al. 2012]. The conclusion from this study found that users perceive a game's "coolness" factor very differently across the demographics that were involved in the expert review [McCrickard et al. 2012].

Similar work by others focused on creating positive reinforcements for children with chronic diseases by using various sticker charts [Luersen et al. 2012]. This study found that sticker charts were an effective method to increase adherence when applied to therapy in children with chronic disease [Luersen et al. 2012]. Another study involved testing and implementing an interactive game, based off the game called Punch Punch, which used images of various fast foods to help users learn about the association between fast food and obesity [Kim et al. 2007].

In an effort to develop mobile exergames in a controlled environment, Winchester and McCrickard partnered with Paul Estabrooks, VT and his Ph.D. student Kacie Allen. Their early work indicated that mobile phones are a promising platform for development, particularly when targeting young people [Allen et al. 2011; Allen et al. 2012]. The following two subsections of this chapter describe these efforts. First is an outline of the development and deployment of four mobile exergames, and then the efforts key to this thesis toward adapting the games for deployment through the Google Play mobile application store.

3.1 Background of Kacie Allen's Exergames

Development of mobile exergames is very beneficial to promoting healthy lifestyles and physical activity. Kacie Allen, a Ph.D. student, led a user study, using four mobile exergames to determine their potential in promoting physical activity [Allen et al. 2012]. The following games were designed, developed, and tested in support of Allen's user study: Fish Out of Water, Space Rayders, Scavenger Hunt, and Whack-a-Mole. Each game was tailored for the Motorola A855 Android smartphone device. Furthermore, each mobile exergame was developed using "various Android versions (SDK, 2.0.1 (eclair) and 2.2 (froyo)", and the development environment tool used to program the Android devices was the Eclipse Indigo using an Android plugin; this was used "to provide extra tools for writing and organizing Android code" [Allen 2013].

As part of her dissertation work, Allen led a controlled study at two Boys and Girls Clubs located in Christiansburg VA and Roanoke VA [Allen 2013]. This study was conducted over a six week period and consisted of twenty-seven participants, ages 10-16. Two groups, with a maximum of seven participants, were formed and alternated between thirty minute sessions, during gameplay testing; these sessions were held for four days out of the week, Monday through Thursday. Before the initial introduction of each game, "members of the research team briefly demonstrated how to play". For the first five weeks, each game was randomly assigned to one week, and during the sixth week, the participants chose the game they wanted to play.

Allen's user study demonstrated that mobile exergames were able to increase the physical activity in young adolescents [Allen et al. 2012]. More participants liked the mobile exergame Space Rayders, due to its competitive nature, but found that Whack-A-Mole was not as fun because it was more of a collaboration game. Furthermore, Allen found that more participants desired to play mobile exergames that allowed for each individual user to earn points based off of individual performance. Even though some participants suggested to add the ability to have avatars included, Allen concluded that using "the role of virtual characters as motivators can decrease and affect participant motivation" [Allen et al. 2012]. Participants also suggested that the graphics and sound effects should be improved [Allen et al. 2012]. Some participants felt as though the audio cues that were given were very robotic and boring, while other participants believed that the graphics were very poor and could also include animation.

The remainder of this section details the apps that emerged as part of this study, each of which I identified as a candidate for release through the Google Play store (after appropriate modifications), as described in the next section.

3.1.1 Scavenger Hunt

Created by Clark et al, Color Scavenger Hunt was part of a suite of three Android mobile exergames. The objective of this game is for the player to locate specific colors and take a picture of an object with the same color. To begin, the player must "choose a color between red, green, and blue (the three primary colors)" [Clark et al. 2012]. When the color is specified, the player is prompted to take a picture of the specified color. To incorporate physical activity into the game, hints are given to help find the specified color in different locations.

Adopted from Color Scavenger Hunt, Scavenger Hunt is a mobile exergame, whose main objective is for the player to locate and take a picture of objects, according to the specified colors. The colors are programmed in a set order and are not chosen by the player. Two additions were incorporated to help add motivation factors for physical activity: a time limit feature and a level system. With these features, players are tasked to locate and capture a picture of an object, with the specified color, in a certain time constraint. After each task is completed, the player is prompted to move to the next task. Each level has a designated number of tasks and time limit. As the player completes and progresses through each level, the number of tasks and time limit increases.

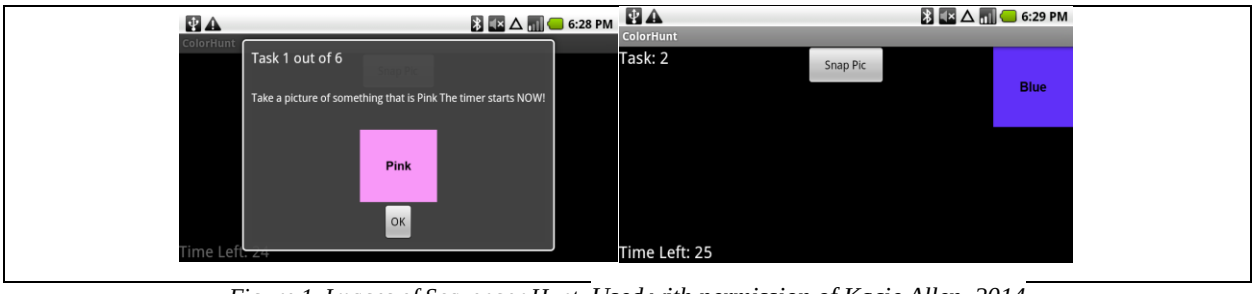

Figure 1. Images of Scavenger Hunt, Used with permission of Kacie Allen, 2014

3.1.2 Fish Out of Water

Fish Out of Water is a mobile exergame that was part of Kacie Allen's user study. By using a user-centered design approach, Allen was able to gather information from parent interviews, previous adolescent focus groups, and idea generation sessions [Allen 2013]. The main objective of Fish Out of Water is to save a fish named "Goldie" that has jumped out of its bowl; in order to save Goldie, the player must chase Goldie to put it back in its bowl. There are a total of fifteen levels that the player must complete before winning the game. To successfully complete each level, the player has to take a certain number of steps in a given time constraint. Also, as time progresses, the player will be faced with several obstacles; these obstacles include having the player follow direction commands, such as turn left and turn right. In addition, the game will inform the player of their progress throughout each level. For instance, if the player has halfway completed the number of steps, the game will display a message notifying the user.

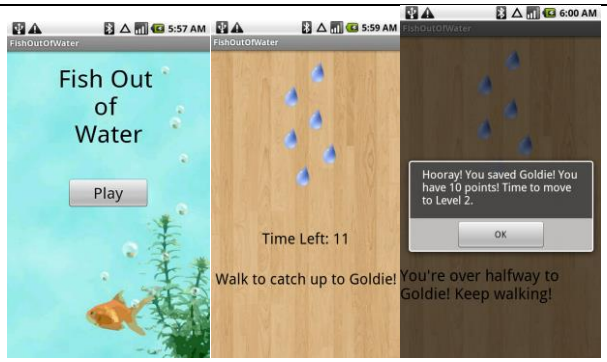

Figure 2. Original images from Fish Out of Water, Used with permission of Kacie Allen, 2014

3.1.3 Space Rayders

Space Rayders is a multiplayer tag game. As part of Allen's user study, this game was part of a mobile exergaming suite designed and developed to test mobile exergame's ability to be used as a motivational tool to encourage physical activity [Allen 2013]. For Allen's study, this mobile exergame required a game administrator, who was in charge of pre-setting each player's mobile device for every initial gameplay. In order to begin gameplay, the game administrator had to open the context menu, for each phone, and select a unique color for each mobile device; the color could not be the same as any other player throughout the current game session. When the player's color is chosen, the game administrator also had to select the other players' colors on

each mobile device; if this task was not completed, the game will not be able to recognize the other players' mobile devices. Once every color is saved, each player's color information is sent to each mobile device's Bluetooth adapter.

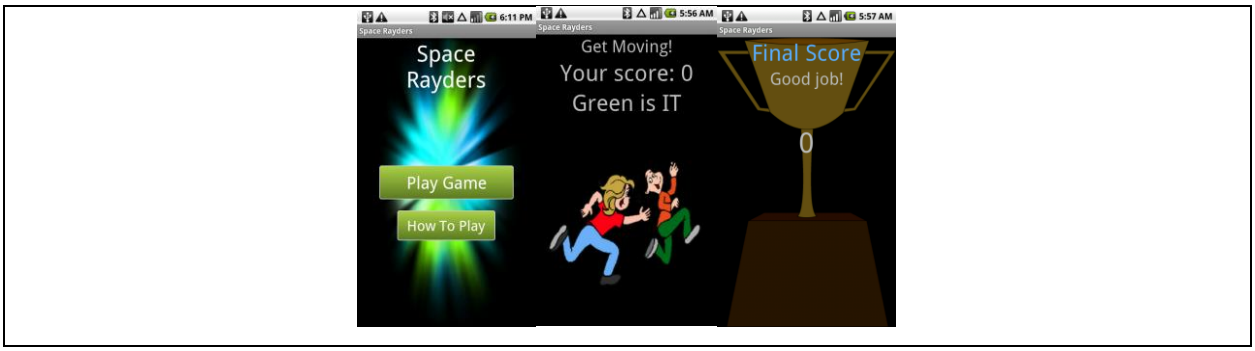

Figure 3. Original images of Space Rayders, Used with permission of Kacie Allen, 2014

After initial setup, all of the players must click "Start Game" at the same time; the person who is "it" is determined by the timestamp. Each player playing has the same amount of time being "it". When a player is "it", the objective is to stand as close to as many players as possible; the stronger the Bluetooth signal, the more points the player earns. When the player are not "it," the players have to "maintain their distance away from the "it" person [Allen 2013]; players can lose points if the "it" person is too close to them.

3.1.4 Whack-A-Mole

Whack-a-Mole is a mobile exergame similar to a large field-sized version of the popular arcade game used in Allen's user study, implemented by undergraduate students Adil Kadir and Brandon Dockery. Like Space Rayders, Whack-a-Mole is a multiplayer mobile exergame. However, this mobile exergame was designed to be played outside using the GPS receivers in the Android smartphone. In order for gameplay to begin, each Android device needed to have its GPS receiver turned on. Next, the game administrator sets mole hills around the outdoor premises; during gameplay, each mobile device shows the location of the active mole hills. The main objective of Whack-a-Mole is for players to find "pre-set virtual mole hills" [Allen 2013]. Once the mole hills are found, each player, with the collaboration of other players, moved their

mobile devices vigorously to imitate “whacking a mole” [Allen 2013]. Players gained points based of their contribution in whacking the mole. As each level progresses, the time decreases, while the number of moles increases, thus making the game increasingly challenging.

3.2 Adapting the ExergameApp Suite for Deployment

Throughout the Android Play Store, the presence of mobile exergames is minimal, as described in the background section of this thesis. Sedentary games dominate the Android Play Store, which makes it even more difficult for mobile exergames to emerge in searches and gain in popularity. As a key step in this thesis work, I explore how to tailor mobile exergames in ways for them to be successful. I considered the four mobile exergames from Kacie Allen’s user study that would be best suited to be redesigned, uploaded, and distributed through the Android Play Store. These mobile exergames were chosen based off of simplicity, feasibility, and uniqueness. Redesign was necessary as the games were designed for controlled settings, with administrator assistance necessary and significant data logging in place. In addition, it seemed necessary to redesign the games toward broader appeal.

Redesigning mobile exergames for the Android Play Store presented numerous challenges. Because each game, except for Fish Out of Water, required a game administrator, major modifications were necessary so that players could still enjoy the same core concepts of gameplay but without assistance. When considering which games were going to be redesigned, simplicity of the core gaming concepts was taken into account. The three exergames chosen had core game concepts that were simple, could be easily set up, and would actively engage the user in any type of environment. Whack-a-Mole, which was the fourth game from Allen’s user study, wasn’t chosen for this mobile exergame suite for several reasons. Of the four mobile exergames from Allen’s user study, Whack-a-Mole received the most negative feedback. Many of the participants did not like the collaboration aspect of the game; players could only gain points by working with other players [Allen 2013]. Allen concluded that the participants “wanted to earn individual points based on individual performance” [Allen 2013]. Furthermore, she concluded that “more competitive games should be created to better suit adolescent desires” [Allen 2013]. In reference to the core game play, it would have to be recreated in its entirety. It can still remain a multiplayer mobile exergame; however, it would need to incorporate an independent player

progression concept. Furthermore, the game needs to be able to be played both indoors and outdoors.

Each game brings a unique approach to motivate players to engage in physical activity. These games do not follow the traditional style of mobile exergaming, where a set exercise or aerobics routine is incorporated into gameplay. Rather, they engage the user in physical activity by having the user complete certain tasks that are not part of an exercise or aerobics routine. Mobile exergames should have the ability to be used as a motivational tool to promote users to exercise. Redesigning these games for the Android Play Store can lead to a path of understanding of how mobile exergames can be used as a motivational tool to promote exercise and healthy living.

In the earlier stages of this thesis, the focus was directed towards distribution and promotion of Android mobile exergames. As mentioned in the previous section, three mobile exergames were redesigned for the Android Play Store. Before this could begin, brainstorming and gathering information on prior mobile exergame literature were key factors to redesigning. By looking at Allen's four mobile exergames, I, along with undergraduate assistant Adil Kadir, discussed each game's goals, playability, and previous instructions on how to play. Some of the characteristics that we were looking at changing were the duration of time spent playing the game, the difficulty of each game, the target audience, and adding incentives, such as a high score feature. Based off of different literature, several researchers have come to similar conclusions on how mobile exergames should be designed. The following are a few common key requirements found in different literature for designing mobile exergames: having a storyline; duration of gameplay; having rewards or incentives; and having attractive graphics and sound effects.

Based off of the previous literatures' design requirements, I analyzed each of Allen's four mobile exergames to determine how each of them could be redesigned for the Android Play Store. Because each game required an administrator, the literature helped bring insight to the characteristics needed for mobile exergames to play for personal use. One main characteristic to include was a high score feature; by adding a high score feature to each game, this could help attract more users and add a competitive factor. The three mobile exergames chosen were as follows: Color Hunt (formerly Scavenger Hunt), Space Rayders, and Fish Out of Water. Each game was reworked as a standalone game that could be downloaded and used without

administrative help. In addition, the feedback from Allen's user study was taken into consideration. The common issues that each game faced were poor graphics and audio cues. In addition, these mobile exergames each had their own issues. The remainder of this section details the changes that were made to each game and the steps taken in distributing the exergames through the Google Play store. The remainder of this section describes how the games were adapted for distribution.

3.2.1 Color Hunt

Color Hunt is based off of the mobile exergames, Color Scavenger Hunt and Scavenger Hunt, discussed earlier in this document. After reviewing the game's basic gameplay and instruction, we brainstormed different ideas to make Scavenger Hunt more attractive for the Android Market. Even though this game had an administrator facilitating gameplay, this game is able to be played without any additional assistance. Therefore, the characteristics we discussed on adding focused on a storyline, task completion rewards, and adding animations. With targeting young adolescents, we discussed developing a storyline based off of a garden of fruits and vegetables. As the player completes each task, they would receive a fruit or vegetable as a reward in an animation; the fruits and vegetables would go to a garden, which would fill each time a fruit or vegetable is rewarded. If the player fills the entire garden, they would be rewarded with an animation showing the player that they have completed all the tasks for the game. We decided to not add a storyline to Scavenger Hunt to keep the simplicity of the game. However, we added three levels of difficulty by decreasing the amount of time as each level gets harder. Furthermore, an instruction would be developed to help the user understand how to play the game.

Color Hunt was going to keep the name "Scavenger Hunt." However, because the name was not available in the Android Play Store, the name "Color Hunt" was chosen. The main objective is the same as Scavenger Hunt and Color Scavenger Hunt: to locate and capture pictures of objects matching the specified colors. Like Scavenger Hunt, players have a certain amount of time to complete each task. However, instead of having the same colors repeat in the same order, each time the player initializes the level mode, the colors will be in a random order. Color Hunt is derived into three level modes: Easy, Medium, and Hard; each level mode has a

total of six tasks for the player to complete. If the player selects the Easy level, the player will have thirty seconds to complete each task. If the player selects the Medium level, the player will have twenty seconds to complete each task. If the player selects Hard, the player will have ten seconds to complete each task. Another modification that was made to Color Hunt was the addition of colors. With Color Scavenger Hunt and Scavenger Hunt, they only had three colors that the players needed to find, while Color Hunt has six colors the players can find. In order for players to gain points, the players are scored based on how close the object's color is to the specified color.

Figure 4. Image of Color Hunt after name change, Used with permission of Kacie Allen, 2014

During development of Color Hunt, the main modifications made were as follows: the graphics were updated and a level mode feature was added to the gameplay. The level mode feature was added, so that players could be challenged to engage more in physical activity. In this version, players have the option to choose between three different modes: Easy, Medium, and Hard; each mode presented an increased level of difficulty by decreasing the amount of time available to find objects that matched the specified colors. Also, a help screen was added, so that players could understand the game's concept and what they need to do.

Figure 5. Images of Color Hunt with updated graphics, Used with permission of Kacie Allen, 2014

3.2.2 Space Rayders

Based on its high appeal in the user study, Space Rayders seemed to be a very promising game to be re-designed for the app store. The main objective of Space Rayders remains the same as Allen's version: to stand as close to as many players as possible, within the given time period, when you are "it" and to stay as far possible from the player that is "it when you are 'not it'." Space Rayders did not include a storyline; however, because of the complexity of gameplay, a storyline would only add additional complications that may have had an impact on gameplay. The key characteristic that needed to be focused on for this game was related towards instruction for gameplay. If a player cannot understand how to play a game, then they would be unlikely to continue gameplay. Therefore, an instruction screen needed to be developed so users could understand the gameplay.

Unlike Allen's version, this version of Space Rayders does not require the assistance of a game administrator. Players are able to set up gameplay on their own device. Similar to Allen's version only five players can play at a time. The mobile exergame must be downloaded and opened before anyone can play; furthermore, each player must give permission to have their Bluetooth adapter activated. Each player must designate their color, select each participating color, and click "Save." After the players have set up their devices, each player must select "Start Game" at the same time, in order for each player to participate in the same game session together. The game play session remained the same as Allen's. A player is selected to be "it" based off of the players' timestamps when selecting "Start Game." Once "it," the player has to

stand as close to the other players as possible to gain points. The other players must stay away from the player that is "it" so that they will not lose points.

Figure 6. Images of Space Rayders with updated graphics, Used with permission of Kacie Allen, 2014

A few modifications needed to be made before it could be uploaded in the Play Store. For Allen's user study, logging information was taken, while the participants played Space Rayders. However, because of several concerns, the logging information code was removed from the game. Also, a Bluetooth permission alert box was added to the game, so that the exergame didn't automatically turn on the Bluetooth device without the player's permission. Furthermore, a direction screen was added, so that the users are able to understand the initial setup for each mobile device.

3.2.3 Fish Out of Water

According to Allen's user study, Fish Out of Water was one of the mobile exergames that the participants would recommend to others [Allen 2013]. This seemed to be a very promising choice to redesign and implement for the Android Play Store. Because Fish Out of Water was designed for individual player usage and was well received during Allen's user study, there were no major modifications to the gameplay. The characteristics we decided to focus on were related to the graphics, sound effects and incentives. Fish Out of Water had a storyline entwined in the gameplay; however, an instruction screen would need to be included to help explain the objective and instruction for gameplay.

When the mobile exergame is downloaded and opened, players are taken to the home screen with a button that says "Play." Once the "Play" button is clicked, it will direct the player

to another screen that directs the player to play the current level available, beginning with "Level 1" for initial gameplay. The main objective remained the same as Allen's user study: to catch "Goldie" and avoid the obstacles by following the directions cued by the game.

Figure 7. Images of Fish Out of Water with updated graphics, Used with permission of Kacie Allen, 2014

Fish Out of Water, one of the major limitations was from poor graphical and audio cues. Although participants suggested adding other aspects, such as customizable avatars or animations, the graphics and audio cues were the priority to redesign for this paper. Furthermore, as the redesign phase progressed, another addition to the game was added: a help menu. During Allen's study, players were shown how to play the game; if a player downloaded this version of the mobile exergame, they wouldn't have a game administrator to tell them how the game is supposed to be played. Therefore, a Help menu was created, as shown below, that described the main objective of the game and the requirements on how to play.

3.3 Distribution and Usage

For the promotion aspect of these games, we looked at various social media methods, such as Facebook and Twitter, to promote these mobile exergames. Over the last decade, social media has become a popular method for advertisement. Other methods that were discussed included emailing listservs from local college departments, distributing flyers, and visiting local after school programs. Another way to focus on promotion and distribution was to track the number of downloads of each mobile exergame. This would help gauge the games' active download users and the total number of downloads overall. Facebook also allows a page's popularity to be tracked as well; this would allow for users to leave their comments and reviews about each game.

From uploading each of the mobile exergames from the ExergameApp Suite, it was found that Fish Out of Water was the most popular of the three games with a total of 270 downloads. Space Rayders had 21 downloads, while Color Hunt had 29 downloads. Even though promotion and distribution was a focus in the earlier stages of this thesis, what developed from this research was the beginning of the design guidelines. The literature information gathered from the brainstorming session helped me have a better understanding as to what mobile exergames specifically needed and what other characteristics are missing from others research.

3.4 Discussion

This section describes the development and distribution of the ExergameApp Suite, which consisted of three mobile exergames, Fish Out of Water, Space Rayders, and Color Hunt. The goal of this section was to show how having sound design principles can help increase distribution in the Android Market. Based on the results from the Android Market data, I believe I was able to show how incorporating sound design principles can lead to increased distribution, although having marketing strategies is also a key factor to increase promotion.

My ExergameApp Suite and Allen's original mobile exergames share several characteristics; however, with the ExergameApp Suite, these games were redesigned to be played without any assistance from an administrator and to be played in various settings, including homes and schools. The core concepts of each of the mobile exergames, in the ExergameApp, Suite were kept the same because of the positive reviews they received in Allen's user study. Allen and I do share a common objective for this game: to encourage and motivate exercise but not replace traditional exercise regimens. By approaching mobile exergames from this direction, it will help future designers design mobile exergames for motivational purposes instead of replacing traditional exercises.

From looking at the data gathered from the Android Play Store, Fish Out of Water had the highest download count, a total of 296 downloads, out of all of the mobile exergames in the ExergameApp Suite. I believe this occurred due to the simplicity of gameplay of Fish Out of Water. Users were able to easily get involved with gameplay, which may have been due to the directions being displayed on the screen along with audio directions. With Color Hunt, the total download count was significantly lower than Fish Out of Water, with a total of 30 downloads. Even though Color Hunt's gameplay seemed challenging, some users may have found the gameplay to be boring. Space Rayders had the lowest total download count, with a total of 21

downloads. Because Space Rayders is a multiplayer game, users may have had difficulty finding other Android users to play this mobile exergame with. Furthermore, even though Space Rayders included an instruction screen, some users may have overlooked the directions button and went straight into gameplay. Throughout the redesign process, different lessons began to emerge on how mobile exergames should be designed to cater towards the users' needs. These lessons turned into design requirements, which then turned into heuristics. In the field of mobile exergaming, there are no set heuristics for mobile exergaming; in the next chapter, I will be discussing my mobile exergaming heuristics and how they were developed from the development of the ExergameApp Suite and expert reviews.

Chapter 4

Toward Mobile Exergaming Heuristics

For mobile exergaming to evolve into a core technology design field, it is important to identify and capture good practices for their creation and evaluation. This chapter seeks to capture these practices through the identification of design heuristics. Through development of the mobile exergames, I learned several good practices for mobile exergame design. The main purpose for creating exergames is to motivate players to become engaged in physical activity, while allowing the player to enjoy themselves and have fun. Allen's design initiative and user study introduced unique ways to incorporate the exergaming field with mobile technology. By creating mobile exergames that did not match the traditional exercise routine genre, she was able to incorporate physical activity and fun. However, even though her games had positive feedback from her participants, they did not focus on standalone usability and hence did not support full engagement from user downloads.

From the Android Play Store, players are able to download and play each exergame for their personal use; because Allen's games were not designed for this purpose, being that they were used in a controlled setting, each game lacked key elements that made it difficult for users to understand how to play the game without administrator assistance. During the redesign phase, these usability issues led to the identification of design guidelines that can be used to set the standard of how mobile exergames should be developed. These usability issues can be avoided or lessened in the future if there exists a tool to help with the design and evaluation of mobile exergames.

To address this need, this thesis captures these design guidelines in a heuristic set. Specific domain heuristics allow for usability researchers to evaluate key issues that are common in some user interfaces and not in others. Heuristics are "design guidelines which serve as a useful evaluation tool for both product designers and usability professionals" [Desurvire, Caplan, & Toth 2004]. Traditionally, Nielsen's heuristic set is used to help to design and evaluate user interfaces [Nielsen 1994]; however, researchers have found that by having domain specific heuristics, more usability issues pertaining to that particular domain were discovered [Somervell & McCrickard 2004]. Unlike traditional design requirements, having domain specific heuristics

allows for usability issues to be discovered throughout the development of the project. Because mobile exergame development is an emerging discipline that is on the rise, there are currently not yet any specific heuristic sets for mobile exergames. Even though others have presented their own heuristic sets, many of them are outdated and cannot discover issues for today's mobile technology.

By using a similar approach as Somervell, creating heuristics will allow for future usability designers to evaluate mobile exergames and identify the common issues that they may face [Somervell 2004]. Furthermore, mobile exergame heuristics will help advance the field of HCI to be aware of the need to identify issues with incorporating physical activities into mobile gaming. As described in this chapter, these heuristics emerged from a review of the design and use of exergames in Kacie Allen's dissertation and other literature, as well as exergames that appear online.

4.1 Domain-specific heuristics for Mobile Exergaming

As discussed in Chapter 1, there have been several researchers that have used domain-specific heuristics; some were successful in applying them, while others found that there was either no difference or that Nielsen's heuristics were all that were needed. Jang and his colleagues both found the usefulness and significance of using domain-specific heuristics versus using Nielsen's heuristics to identify problems in their systems [Jang, Weon, & Yoo 2014; Jaferian et al. 2011]. They found that by using domain-specific heuristics, it served as a powerful tool to use to extract features from the distributed sensor network. Jaferian and his colleagues found that their new heuristics for IT Security Management identified more severe problems than Nielsen's heuristics, but they also found that using both heuristic sets will be able to identify the most problems within the IT Security Management [Jaferian et al. 2011]. However, researchers, like Mankoff and her colleagues found that Nielsen's heuristics were better at discovering certain issues than the modified heuristics that were created for ambient displays [Mankoff et al. 2003]. One factor that may have contributed to Nielsen's heuristics being more applicable than the modified heuristics in those situations is the generalization of the modified heuristics. Domain-specific heuristics need to have a balance between being specific while maintaining generality [Rusu et al. 2011].

This section introduces my four heuristics for mobile exergaming. These heuristics can be categorized as domain-specific heuristics, which are focused on mobile exergaming. Because mobile exergaming is a newer field of study, there are currently no defined heuristics for mobile exergaming. Developing these heuristics required reading various pieces of literature and listing lessons learned from development of the ExergameApp Suite. These are the brief version in the style of Nielsen's heuristics, which are widely accepted because of each heuristic's breadth and applicability to a wide range of usability issues; also, this style will allow for novice and expert designers to understand how to identify the usability issues.

Motivational game concepts that promote physical activity.
Description: Game immerses players into the game concepts through an engaging storyline, meaningful goals, and challenging physical activities.

Game cues that engage active users.
Description: Game should engage physically active players using multiple senses, including visual, haptic, and sounds, toward keeping the user interested in the game activities.

Physically and temporally appropriate game structure to encourage continual, recurring play.
Description: Games should engage the target audience at an appropriate level of physical exertion and within an acceptable length of game (or round) completion.

Game play movements that are safe for the user and for the device.
Description: Required actions that are necessary to succeed in the game should not endanger the users, either by encouraging harmful physical activity or by distracting a user who is moving.

Figure 8. Nielsen-style mobile exergaming heuristics

These heuristics were developed to have a balance between being sufficiently general to cover a wide range of issues but to also be sufficiently specific to target specific areas where issues can be identified. The key to having successful mobile exergame heuristics is to have a set of heuristics that can be applied to multiple usability scenarios during and after the design phase. Even though these heuristics are specific to mobile exergaming, they need to be used in combination with other heuristic sets; e.g. Nielsen's heuristics for usability, or Korhonen and Koivisto's for mobile playability. This will help to identify multiple issues that can be found in all types of usability and mobile gaming.

In the next section, the four mobile exergaming heuristics will be presented in the style of claims. Leveraging claims will allow the design guidelines to be presented in a balanced fashion. Furthermore, having claims allows for other researchers to agree, disagree, or make situation-specific changes if they feel as though the heuristics need more description based on the

anticipated context of use. Because claims are not accepted as absolute truths, they provide a platform for addressing any concerns that others may have with the heuristics.

4.2 Mobile Exergaming Heuristics as Claims

In the previous section, a brief version of the mobile exergame heuristics were presented with a short description describing each heuristic. This section describes heuristics in the format of *claims*, falsifiable hypotheses that are meant to spark discussion and study regarding applicability for new situations [McCrickard 2012]. According to McCrickard, "claims capture knowledge in a way that can be shared, debated, strengthened, rebutted, connected, and reused" [McCrickard 2012]. Having claims-based heuristics will allow for further explanation on how these heuristics can be applied; both the upsides and the downsides are discussed, which will allow for future developers to further understand each heuristic. Claims have been used for many years in rhetoric as an argument tool [Toulmin 1958]. Claims were introduced to the field of human-computer interaction as a way to explore theoretical contributions in a practical way [Carroll & Kellogg 1989]. By capturing design knowledge as claims, human-computer interaction designers and evaluators have shown how they can be used with scenarios in formal usability engineering processes [Sutcliffe 2010], [Carroll & Sutcliffe 2001], captured and indexed in a library [Payne et al. 2003; Fabian et al. 2004], used with (or instead of) design patterns [Abraham & Atwood 2009], compared using formal relationship models [Wahid et al. 2004], leveraged in storyboarding [Somervell, Wahid & McCrickard, 2003], incorporated into design tools [Wahid et al. 2011], used as part of design and evaluation [Wahid et al. 2010] and used to inspire creative design [McCrickard, Wahid, Branham, & Harrison 2011]. Claims, and methods for indexing and searching for claims and similar knowledge, have been a focus of many workshops and similar meetings (e.g., [Cadiz et al. 2003; McCrickard et al. 2010; McCrickard & Lewis 2013]).

Using claims-based heuristics will allow for future developers of mobile exergames to take into consideration each heuristic rather than accepting that these heuristics are absolute truths; it allows for further possible expansion of this heuristic set in the future. During the design process, claims-based heuristics can be used to explore potential uses (and pitfalls) for new exergames. During the evaluation process, claims-based heuristics can be used as part of analytic evaluation methods like cognitive walkthroughs and expert reviews. By presenting

heuristics in this format, the upsides and downsides for each heuristic can be debated, which can lead to an increase or decrease in the feature set, and ultimately in the number and breadth of heuristics.

The remainder of this section outlines the heuristics that were created. Each heuristic includes a title (in bold), a description (labeled), upsides (marked with a +), downsides (marked with a -), and rationale from existing apps or the literature for each upside and downside (included in square braces []).

<table>
<tr><td colspan="2">Motivational game concepts that promote physical activity.</td></tr>
<tr><td colspan="2">Description: Exergames must be able to immerse the player with the game concept, such as a storyline, by using physical activities as the engaging factor. Designers need to create mobile exergames that match the fitness level of the target audience. This is necessary because different levels of physical activity may need different motivational tools and techniques. This can include the attractiveness of an exergame, difficulty of fitness, and virtual rewards.</td></tr>
<tr><td>Upsides:
+Physically engaging the user will lead the user to doing more physical activity.
+Users will not be intimidated to do physical activity, due to the motivational factors of the exergame.
+When the exercise level of the game matches the fitness level of the user, they will be more likely to enjoy, complete, and return to the exergame.
+ Encourages physical activity at times that it may be waning and when game play may be impacted
a. In Fish Out of Water, the game notifies the user when the user is or is not catching up to Goldie.</td><td>Downsides
-External factors may distract the player, such as loud noises or crowds, and will discontinue the player from returning to the exergame experience.
-If players are too engaged with the game, they will ignore obstacles in actual reality.
-If the exercise level is too difficult for the user, they will not be able to fully enjoy the game enough to complete it and or return to it.</td></tr>
</table>

<table>
<tr><td colspan="2">Game cues that engage active users.</td></tr>
<tr><td colspan="2">Description: Mobile exergames should include a variety of physically engaging game cues, such as vibrations, sound effects, and other haptic cues, to keep the user alerted to any important phases, events or stages in game. By physically notifying the user, this will allow for the user to be focus their attention on the mobile exergame. For instance, if the mobile exergame doesn’t require the user to focus on the screen, the haptic or audio features will signal for the user’s attention to be brought back to the game.</td></tr>
<tr><td>Upsides:
+ Informs the user of important stages, alerts, and or events happening in the game, providing a reward that encourages further game play and more activity.
+ Notifies users of important health-related impacts of the game</td><td>Downsides:
- Game cues can be distracting and lessen user engagement.
a. During the expert review of Fish Out of Water, several reviewers commented on the audio cues being very noisy, annoying and discouraged gameplay. Furthermore, one reviewer even stated that the losing audio sound also discouraged continued game play.
- Too many alerts and sounds makes the user feel overwhelmed and not want to play the game.
- If game cues are not used appropriately, it can cause users to miss important aspects in the game.</td></tr>
</table>

<table>
<tr><th colspan="2">Physically and temporally appropriate game structure to encourage continual, recurring play.</th></tr>
<tr><td colspan="2">Description: Mobile exergames need to have a tailored game structure, where the physical gameplay is tailored to the target audience’s fitness level. Furthermore, the gameplay movements need to be appropriate for the target audience to implement during short gameplay sessions.</td></tr>
<tr><td>Upsides:
+ Short game lengths will encourage users to do continuous, recurring game play.
+ Appropriate physical movements for the tailored audience will encourage users to complete the game.
a. In an expert review, one reviewer played the exergame Fish Out Of Water by running into a wall numerous times because the game told them to do so; even though the game wasn’t intended for this movement to occur, the game was still completed by using this movement.</td><td>Downsides:
- Short game lengths could be less of a challenge to the target audience; Users may want to be challenged more.
-The activity must be captivating enough to have the player return to it on a regular basis (frequency)
-These last two factors mandate that we must ensure that whatever is built is actually fun</td></tr>
</table>

<table>
<tr><th colspan="2">Game play movements that are safe for the user and for the device</th></tr>
<tr><td colspan="2">Description: The movements required to play a mobile exergame should not only be safe enough for the user but to also be safe enough for the user's device to not be damaged or require extensive additional equipment for game play (i.e., large headset or large monitoring device). The mobile exergame should use full body movements that do not involve the phone leaving the user's grip; furthermore, the physical activity movement requirements should be suitable for mobile exergame gameplay.</td></tr>
<tr><td>Upsides:
+ Establishing safe movements for the mobile exergame allows for the user, mobile device, and surrounding areas to be safe and undamaged.</td><td>Downsides:
- Depending on the user, every movement may not be safe for the user to implement.
a. if a user suffers from a physical health condition, what may be considered “safe” for a user without a physical health condition may be harmful for a user with a physical health condition, especially if there are no alerts or warning prior to activity.</td></tr>
</table>

This section presented the four mobile exergaming heuristics in the format of claims. Having claims-based heuristics involves including a detailed description, upsides of the heuristics and downsides of the heuristics. Each heuristic was supported using findings from the literature and lessons learned from development of the ExergameApp Suite. Because claims are not absolute truths, they are able to be updated, removed or more heuristics can be added. It is important to consider others’ opinion because one reader may find that an upside is actually a downside or that a heuristic should be removed or reworded. Claims offers other readers the opportunity to share their opinions with supported evidence. In the next section, it will discuss the process of creating the four mobile exergaming heuristics that were discussed in the previous two sections. In addition, the next section also includes the expert reviews that were done on the heuristics and the mobile exergame Fish Out of Water.

4.3 Stages of Heuristics

Throughout the redesign process, key common themes began to emerge when considering different design modifications. Appendix A shows the guidelines that began to emerge upon the initial redesign development. At this time, the purpose for this set of guidelines was to determine the common elements between the literature and development research. Several researchers have been developing various design requirements for mobile exergaming. However, many of these design requirements need to be applicable to today's mobile technology, which has advanced dramatically over the last decade. One main issue that mobile exergaming is facing is not having a solid foundation to build mobile exergames from; in other words, there are no set guidelines or evaluation tools that can be applied specifically for mobile exergaming.

After the guidelines were formed, in Appendix A, further research and development transitioned the guidelines into heuristics, which can be found in Appendices B and C. Based off of Korhonen and Koivisto's set of heuristics for mobile playability, the guidelines that were previously developed were able to be expanded upon, especially emphasizing the mobility factor. However, once these heuristics were reviewed, a question of whether these heuristics have already been developed arose, which led to editing and removing several of the heuristics. The purpose of having mobile exergaming heuristics is to allow developers to use these heuristics and identify specific issues that may occur for mobile exergames and not general mobile games.

Putting the heuristics into claims-based heuristics became very important because they presented a framework that will allow for future developers to use along with other mobile game guidelines. As described in the previous section, having claims-based heuristics allows for other developers to agree or disagree with the heuristics and provide any modifications they feel are necessary to improving the heuristic set. These heuristics are presented in both the Nielsen style and claims style because it offers two ways to use the heuristics. The Nielsen style heuristics allows for developers to use the heuristics during their evaluation process, while the claims style allows for other developers to review the heuristics and provide their opinion on them.

After several revisions were made to translate the guidelines to heuristics, a couple of expert reviews were conducted to see if the defined heuristics catered towards mobile exergaming. One expert review was conducted during a graduate in-class activity and used the heuristics found in Appendix E. There were a total of six expert reviewers; these expert reviewers were split into three groups, with two reviewers per group. The groups were asked to

evaluate Fish Out of Water and to use the heuristics as an evaluation tool. Each group played Fish Out of Water for thirty minutes, evaluated the game for fifteen minutes, using the heuristics, and then, discussed evaluations of the game and heuristics for twenty minutes.

During the discussion portion of the expert review, each group expressed several concerns with the heuristics. One group expressed that the heuristics were composed of too many components. Furthermore, they felt as though each of the heuristics packed the requirement and outcome of requirement into one heuristic, which is not the best way to present a heuristic.

Another group expressed that heuristics 3-5 needed to be reshaped into more specific mobile exergame heuristics. In addition, multiple groups felt as though heuristic 4 was problematic; they felt as though this heuristic did not make sense and needed to be separated into two different heuristics. A general consensus of the expert review was that these set of heuristics were not specific to mobile exergames. These heuristics could be applied to almost any regular mobile game and seem similar to other mobile gaming heuristics.

Based on this feedback from this expert review, the defined heuristics were revamped to specifically reflect mobile exergaming. Each heuristic, except for Heuristic #5, was edited along with the description, upsides, and downsides. Once these heuristics were edited, a follow-up expert review was conducted. During the follow-up expert review, four expert reviewers were asked to look over the edited heuristics and determine whether each heuristic was tailored towards mobile exergaming. Each expert reviewer was given each heuristic, along with the description, upsides, and downsides. One expert reviewer expressed that Heuristic #2 should be modified to not only be for stages in the exergame but also safety alerts, directions, and tips. In addition, the expert reviewer suggested that Heuristic #3 needed to take into consideration fatigue. All in all, the expert reviewers that were interviewed felt as though the heuristics found in section A of this chapter were tailored towards mobile exergames.

4.4 Expert Reviews of Mobile Exergames

This section discusses the expert reviews that were given once the heuristics were in their final stages of being finalized. Each expert review was given to three groups of expert reviewers that were knowledgeable in the area of mobile exergaming from reading various research papers on the subject; furthermore, each expert review was presented to a computer science undergraduate and graduate class. The experts were presented with a presentation on mobile exergaming and were asked to read from a selection of various reading material to from prominent researchers in the field of mobile exergaming. These expert reviews were conducted as a formative exercise to gather information on the usefulness of the developed mobile exergame heuristics.

4.4.1 Theory Experts

As expert reviewers were evaluating the mobile exergame heuristics, found in Appendix E, they also were reviewing the mobile exergame Fish Out of Water. Each group analyzed Fish Out of Water using the heuristics found in Appendix E; one group had an updated version of Fish Out of Water, which included new graphics and a help menu, while the other groups had the older version of Fish Out of Water. Overall, the expert reviewers had negative feedback for both versions of Fish Out of Water. One group, who had the new version of the game, felt as though the goal of the game was hard to understand and the story was very unclear. Another group didn't believe that this game was suitable for all environments and found the storyline hard to follow. One group, who had reached level 8, had said that they had reached this level by running into a wall numerous times, which would not be safe if an adolescent had played this game. All of the groups, including both groups with the Help menu, said that they did not know how to play the game at all. A positive remark that was received was that the voice cues were beneficial to one group. However, the same group that gave this positive remark also commented that they will not be playing this game again. Even though this mobile exergame had negative feedback, this will help to enlighten further research on improving this mobile exergame.

4.4.2 Design Experts

During a computer science undergraduate class session, another expert review was conducted as part of an in-class activity, which was focused on heuristic evaluation for mobile exergaming. This class had a total of nineteen students and was split into five groups of three to four people per group.

The heuristic set used for this evaluation comprised of selected heuristics from Nielsen's heuristic set and a version of the mobile exergaming heuristics, found in Appendix E. Three heuristics were chosen from Nielsen's heuristic set because of their relevancy to mobile exergaming and the assignment. A list of the heuristics and their descriptions can be found in Appendix F. Each group was responsible for choosing a mobile exergame for the heuristic evaluation. The following list of mobile exergames was given to each group: Zombie, Run!, Fish Out of Water, C:Geo, and Geodashing. Also, each group had the option to choose a GPS or accelerometer based game for their mobile platform. Once each group chose their mobile exergame to evaluate, they were given an hour and a half to complete the assignment.

In order to conduct the heuristic evaluation, each group had to use a priority rating scale, from 0 to 3, that would help identify the severity of various usability issues. The priority rating scale was designed from lowest (0) to highest (3), with minor problems as 0 and severe problems as 3. Groups were recommended to evaluate their mobile exergame multiple times, in order to have a full understanding of identifying any problems with the mobile exergames. Along with assigning a priority rating, each group was also asked to give positive and or negative feedback for each heuristics; this feedback would bring clarification to the reasoning behind the assigned priority rating. Once the feedback was collected, reviewing the heuristic evaluations led to promising results.

Heuristic	Group 1	Group 2	Group 3	Group 4	Group 5	Average
#1 (Nielsen #4)	0	0	2	1	0	0.6
#2 (Nielsen #6)	0	0	1	0	0	0.2
#3 (Nielsen #8)	1	0	1	2	0	0.8
#4 (Monk #1)	2	1	3	2	1	1.8
#5 (Monk #2)	0	0	1	2	1	0.8
#6 (Monk #3)	0	0	2	2	2	1.2
#7 (Monk #4)	3	2	2	3	3	2.6

Table 5: In-class assignment group priority ratings and averages for three Nielsen heuristics and four Monk heuristics.[1]

When reviewing the heuristic evaluations, it was shown that each group found that the mobile exergaming heuristics yielded more problems than the Nielsen heuristics. The mobile exergaming heuristic that averaged higher priority ratings between each group was Heuristic #7; this heuristic discussed the safety of the movements for the mobile device and users. The average priority rating for Heuristic #7 was 2.6. Having safe movements for both the user and the device is very important priority to address when developing and evaluating mobile exergames. One group identified that when they were playing Fish out of Water, it did not track the user's environment which resulted in the game directing the user to go in a direction that they could not follow. Another group identified that with Zombie, Run!, the set course that the game directs the user to follow may create a route that is in a busy or dangerous area. As mentioned before, safety is a high concern when trying to incorporate GPS and other sensors into mobile exergaming.

In addition to Heuristic #7, another heuristic that identified a high number of problems was Heuristic #4; this heuristic described how the game should immerse the user by engaging the user with a storyline, goals, and challenging physical activity. The average priority rating between each group for Heuristic #4 was 1.8. For mobile exergames, it is important for mobile

[1] *Note that the problems identified through my heuristics received the highest priority ratings.*

exergames to promote physical activity that is beneficial to the user. One group found that their mobile exergame required a significant amount of exercise but lacked motivational aspects to continue gameplay. Another group found that with their mobile exergame, physical activity was promoted but lacked a storyline or plot; in addition, it was recommended that the user be able to set a walking or running goal in the game. In order to promote physical activity, it is important to incorporate various motivational factors in a mobile exergame. The various comments made by each group showed that having a mobile exergame that incorporates level difficulty, a storyline or plot and an objective were important factors in creating a mobile exergame.

Compared to the averages from Heuristic #7 and Heuristic #4, Heuristic #6 averaged a lower priority rating of 1.2 between the groups; this heuristic described the game structure and encouraging continual, recurring play. One group found that their mobile exergame had a setting destination, which gave them a new and fresh experience each time they played the game. Another group found that their game did not remember the last location that the user inputted and was geared towards a multiplayer platform versus a solo platform. It is imperative for a game's structure to have a strong foundation and to incorporate motivational factors that will be able to motivate users to continue and return to gameplay.

Another mobile exergaming heuristic that was used was Heuristic #5, which described game cues engaging the user. This heuristic averaged a priority rating of .8, which is the lowest average for the mobile exergaming heuristics. One factor that may have contributed to this average is because game cues are usually incorporated in many mobile games, the expert reviewers may not have seen a significant issue with their chosen mobile exergame. For instance, one group commented that their mobile exergame included visual, haptic and sound feedback for every direction that they were given in order to engage in gameplay. However, another group found that their mobile exergame lacked sound, which affected their ability to engage in the game. When developing mobile exergame heuristics, it is important to determine if the heuristic is common in the general field of study; this will limit the overlap that may occur when trying to identify problems.

When reviewing the results of Nielsen's heuristics, they showed that the expert reviewers did not find many issues using those heuristics versus using the mobile exergame heuristics. This may be because the mobile exergame heuristics were able to pinpoint common issues found within mobile exergames. Nielsen's heuristics should be used as a foundation for developing

heuristic evaluations. Having domain-specific heuristics, which are based off of Nielsen's heuristics, allows for a more narrowed heuristic evaluation. Although not all of Nielsen's heuristics were used, the relevancy of each heuristic played a key factor in the selection process.

Beginning from guidelines to mobile exergaming heuristics, this section showed the methodology that was taken in order to create the four mobile exergame heuristics. Each step that was taken took into account the findings from various pieces of literature and through the development of the ExergameApp Suite. The expert reviews provided feedback on various aspects of the mobile exergame heuristics, like specificity and generality, which were reviewed and incorporated into the final set of heuristics. Furthermore, the expert reviews showed that by having domain-specific heuristics, the reviewers were able to identify key problems found specifically in mobile exergames, while Nielsen's heuristics, which are very broad and general, were ill-suited to help reviewers identify them.

4.5 Discussion

Mobile exergame heuristics are a vital part of propelling the field of mobile exergaming. These heuristics, when used in conjunction with Korhonen's heuristics, will allow for future designers to detect specific usability issues pertaining to mobile exergaming, such as the amount of time for gameplay. Each draft of my mobile exergaming heuristics stemmed from the guidelines I began to discover during the earlier stages of this thesis. At first, there were nine to ten heuristics, but after reviewing several pieces of literature, mobile gaming heuristics and exergaming heuristics, it was found that several of my heuristics were already in other heuristic sets. Over time, the common heuristics were narrowed down so that the heuristics specifically addressed mobile exergaming features. This is very important because there are no other set of heuristics that mobile exergames can be evaluated with; even though there are several sets of heuristics for mobile gaming and exergaming, these would not detect issues that happen when mobile gaming and exergaming are combined, such as making designers aware of the safety of gameplay movement for both the user and the device.

When the heuristic set, found in Appendix E, was introduced to the expert reviewers, many of them felt as though these heuristics were too specific to address issues with mobile exergames. One group of expert reviewers had commented on how Heuristics 3-5 needed to be more general because it was difficult to evaluate Fish Out of Water. An expert reviewer felt as though part of the heuristic matched but another part did not, which led to them to conclude that Fish Out of Water failed that specific heuristic. From this, it was found that specific domain heuristics should be specific to the domain but to not detail a unique situation; they should be maintain a sense of broadness so they can be applied to other situations that are related.

Based off of the results from the in-class assignment expert review, it showed that the mobile exergaming heuristics were able to identify more problems than the selected Nielsen heuristics. The highest priority rating average heuristic was Heuristic #7, which was based on safety movement concerns for both the user and the device. Even though the heuristic evaluation lasted for an hour and a half, the results were very promising for future developers to utilize in their research. Although the heuristic set used was based off of a previous heuristic set, found in Appendix E, this expert review was able to show that having specific heuristics for mobile exergaming yielded identification of more problems than by using Nielsen's heuristics.

After evaluating the responses from each of the expert reviews, the heuristic set, Appendix E, was updated to reflect the concerns of specificity. As a follow-up, this heuristic set, found at the beginning of this chapter, was evaluated by two expert reviewers, who believed this set was specific to mobile exergames but could be applied to various mobile exergame related issues. It is important that domain-specific heuristics be able to identify a broad amount problems but still yield to a specific concept.

Chapter 5

Conclusion and Future Work

Throughout this thesis, a set of four mobile exergame heuristics was presented; this heuristic set was presented in various formats, including a brief version and an expanded version in the form of claims-based heuristics. Mobile exergaming heuristics are necessary because of the specific elements that composes a mobile exergame, mainly the physical activity element. Incorporating physical activity into a mobile game brings several challenges, including motivational techniques for the target audience, handling distractions for outside factors, and safety for the players and mobile devices used. In order to address these challenges, mobile exergame heuristics can be used to identify issues pertaining to each of these challenges; using general mobile game heuristics or exergame heuristics will not be beneficial because each of these heuristic sets will only overlook issues that are only specific in mobile exergaming.

The following were the four mobile exergaming heuristics that were developed through several drafts of the initial guidelines created at the beginning stages of this thesis:

1) **Motivational game concepts that promote physical activity**

2) **Game cues that engage active users**

3) **Physically and temporally appropriate game structure to encourage continual, recurring play**

4) **Game play movements that are safe for the user and for the device**

Each of these heuristics describes specific issues that mobile exergames may face that can be overlooked if using other sets of heuristics for exergaming or mobile gaming. By centering the core concept of each heuristic on physical activity, these heuristics will be able to capture issues with mobility and game playability, such as players playing their mobile exergame in various environments, like their homes or schools. These heuristics will also be able to help designers incorporate different methods and tools for physical notification cues into their mobile exergame design. In addition to enhancing mobile exergame design with the incorporation of physical notification cues, these heuristics will also help address the issues with the required player's movements during the mobile exergame. Further research can be dedicated towards reviewing appropriate movements players can implement while playing their mobile exergame. By having

a set list, it will benefit mobile exergame designers so that both the player and the mobile device can be kept safe.

From the Exergame App Suite, each of the mobile exergames have several features that can be included into future game designs. One feature that can be added is a global high scoring feature, which will allow players to not only view their scores but to also view scores from other players in real-time. Having a high score feature can bring a sense of competitiveness to each of the mobile exergames. Another feature that can be included is a player interaction manager, which "allows game developers to easily include instant messaging, social networking or use of immersive in-game messages as game elements" [Payton et al. 2011]. Including social interactions in a mobile exergame can lead to players being motivated to complete various tasks by other players in the game; this encouragement will serve as an incentive for some players to continue completing difficult tasks in the mobile exergame. When considering including social interactions, one factor to consider for mobile exergames is where the social interactions would be included in the game design; from the literature, some players found that including social interactions during breaks or pauses was motivational for further gameplay [Mueller, Gibbs, & Vetere 2009]. This is very important to consider in mobile exergames because there is a risk of causing distractions if social interactions are included during gameplay. To help limit the distractions from social interactions, one feature that could be included is adding an "immersive social experience" into each of the games [Park et al. 2013]. For example, Fish Out of Water could include a feature where there are multiple players trying to catch Goldie, and each of these players would be able to verbally communicate with each other. Each of the games in the ExergameApp Suite has potential to include social interactions; this will help bring motivation from players to complete tasks and continue to play each of the games until every level or session is completed.

There are opportunities for distribution that can further the use of exergames. For example, in continuation of this thesis, the TOURS scholars program—featuring undergraduate students Sonika Singh and Sea On Lee—has continued research and promotion involving the ExergameApp Suite. This project focused on the distribution and promotion aspect of mobile exergaming by creating promotional tools to distribute the mobile exergames and updating the ExergameApp Suite games based off of the various reviews that are received from users. For marketing, the researchers used various methods of communication and promotion, including in-

person and social media. Due to their popularity, LinkedIn and Facebook were selected as the best options for promoting the mobile exergames. Promotion also included creating paper flyers with QR codes, which direct users to the ExergameApp Suite promotion page. The promotion Facebook page also included updated screenshots and videos that describes each game and shows gameplay. These flyers were distributed to several locations in the Blacksburg area, including music and social events frequented by children and their parents. Targeting this local audience can help foster local interest in the ExergameApp Suite.

Because mobile technology is not limited to smartphones, the possibilities of the expansion of the field of mobile exergaming are endless. Mobile devices, like tablets or fitness watches, can be used in multiple areas, including physical therapy and athletic training. Furthermore, mobile devices are being incorporated with several pieces of health measuring equipment, like heart rate monitors and accelerometers. This will offer different opportunities for users to track their health conditions and progress, especially when they are on the go.

During promotion, users will also be asked to share their reviews of Color Hunt and Fish Out of Water. Space Rayders was not chosen to be included in this promotion because of the multiplayer aspect and scoring feature of this mobile exergame; there is a slight difficulty trying to promote a multiplayer mobile exergame to an audience that may only be able to play single player mobile exergames when at home. Throughout the duration of this project, there will be several updates to Color Hunt and Fish Out of Water, which will partly be based off of user feedback from the reviews. The incorporation of a high score feature and different virtual incentives will allow for further research to the various factors that need to be included in mobile exergame designs. With using the promotion and distribution tools, the following are the statistics that will be monitored over the duration of this project: number of downloads, frequency of gameplay, duration of time played, and activity level of each game. This thesis will allow for future projects, such as the current project being conducted by the TOURS scholars program, to develop in several aspects of the mobile exergaming research field, from heuristics to design development. In addition, with the increase in mobile device capabilities, such as incorporating health equipment, it will present more opportunities, especially in the field of medicine and physical therapy, for users to incorporate mobile exergames into their health routines. With further research, mobile exergames can be used as a primary source of motivation for young adolescents to exercise and live healthier lifestyles.

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Appendices

Appendix A. Guidelines

This appendix shows the first draft of guidelines that was developed through literature and re-designing Kacie Allen's exergames. These guidelines are the beginning of the mobile exergaming heuristics.

Guidelines (Draft 1)
1. Scope an appropriate storyline to motivate the target audience.
2. Make sure the game is simple enough for the audience to understand.
3. Appropriately tailor game length for the target audience.
4. Establish a target audience.
5. Have incentives to keep the target audience engaged.
6. Make sure the game has attractiveness; poor graphics can lead to disinterest.
7. Use social media and physical promotion flyers to promote the game to your target audience.
8. Establish cues in game to go along with attractiveness and incentives.
9. With target audience, decipher if they want single player or multiplayer games.

Appendix B. Guidelines to successful mobile exergames

This appendix describes the second draft of guidelines that were developed after expanding and reviewing the first draft of heuristics found in Appendix A. These heuristics were the beginning stages of creating claims-based heuristics.

GUIDELINES TO SUCCESSFUL MOBILE EXERGAMES (Draft 2)
1. Scope an appropriate storyline to motivate the target audience When an appropriate storyline is established, it will motivate and keep the target audience engaged in the game. User engagement: Does a complex storyline work for games that last less than 20 minutes? Does a simple storyline engage the user enough to play the game? Should the storyline include a default player or specific characters to choose from? Is this too complex to add to mobile exergames? 2. Make sure the overall game can be easily understood by the audience. Having a game that the user can easily understand will produce a higher rate of user engagement than a game that either too complex or not enough background and detail to explain the objective of the game. 1. Directions on how to play 1. Main objective 2. How to earn points 1. Layout design of the games 1. Are things simple to find? 2. Are there elements that need to be added to clarify different actions? (do buttons need to be added, do elements on the phone need to be disabled to not interrupt gameplay) 2. Language 1. Is the language appropriate for the target audience? 2. Will the people outside of the target audience be able to understand the objective of the game? 3. Does the language level affect the user engagement? 3. Appropriately tailor game length for the target audience Once your target audience is established, it is important to make sure the length for each level is less than ten minutes. In order to motivate users, mobile exergames should be considered "casual games". 1. Casual Game 1. Casual games: have simple rules, are easy to learn and play and require very little video game expertise; typically played in short bursts and can easily be stopped and restarted [Let's Play! Mobile Health Games for Adults] 4. Establish a target audience Having a target audience is important for mobile exergames because of the various needs and requirements for different types of users. (ie age, fitness of users, demographics of users, etc) 1. Determine appropriate interaction mode: single player or multiplayer 2. Level of fitness 3. Demographic (gender, age, lifestyle) 4. Benefits 1. Helps determine appropriate activities for the exergames 1. Intensity 2. complexity 2. Helps determine the appropriate language, colors, and layout of the exergame

5. Have incentives to keep the target audience engaged

Incentives are important to give users a motive to continuously play the mobile exergame after initial game play.

1. Determine what type of incentive will be appropriate

1. i.e vibrations, alert cues, sound effects, points, high score feature

2. Will the incentive be relevant to the storyline?

6. Make sure the game exhibits attractiveness; poor graphics can lead to disinterest

The attractiveness of a game determines if a user finds the game appealing enough to play. When the attractiveness of an exergame is poor, the level of interest decreases.

1. Do the graphics correlate with the storyline and theme of the game?
2. Are the graphics made to appeal to the target audience?
3. Are the graphics made by someone knowledgeable in graphic design techniques? Is this even a factor in determining the level of attractiveness?
4. What is considered good attractiveness

7. Make sure that the movement required for gameplay is safe for users to implement

The movement required to play a mobile exergame should be safe enough for the user's phone to not be damaged or require additional equipment for game play.

1. What are physical activity movement requirements are not suitable for mobile exergame gameplay?
2. How many parties are involved?

1. Does the movement of one mobile device affect another?

3. What are the pros and or cons of using one type of motion versus another?

8.Establish game cues in game to go along with attractiveness and incentives.

Game cues will allow the user to become more engaged in the game because it will inform the user of important stages, alerts, and or events happening in the game.

Appendix C. Heuristics for Mobile Exergaming

This appendix is a draft of mobile exergaming heuristics that has been edited and reviewed. The draft of heuristics is focused on framing the heuristics towards being applied only for mobile exergaming.

Heuristics for Mobile Exergaming (Draft 3)

1. Title: Game concepts should be easily understood with minimal directions.

Description: The concept of the game should be quickly and easily understood by the player and require minimal directions for players to follow.

Upsides:

+ The simplicity of a mobile exergame allows the user to become directly engaged with the game and not focus on non-essential aspects.

Downsides:

· By having a simple game, certain details, that may seem minor, may be left out and it will be hard for the user to understand what is going on.

1. In the version 1.0 of the Fish Out of Water, Space Rayders, and Color Hunt games, they did not include direction screens. These had to be added because in the previous version of these games, an instructor would direct the users on how to use it verbally.
2. There needs to be a balance with the details of the game.

2. Title: Mobile game cues should alert players of important events in the game.

Description: Mobile games should include a combination of various game cues, such as vibrations, alerts, and sound effects, that will keep the user alerted to any important changes, events or stages in game. Game cues will allow the user to become more engaged in the game because it will inform the user of important stages, alerts, and or events happening in the game.

Upsides:

+ By having different game cues incorporated into the game, it can be used to notify the user of important messages that are urgent. For example, the game, Wii Fit Plus, incorporates different alerts into the game before the physical activity occurs , so that the user can be warned that if they have a certain condition, they should be careful.

+ Cues can also be used to notify the user when important events are happening in game. For instance, in Fish Out of Water, the game notifies the user when the user is not catching up to Goldie, or if the user is almost caught up to Goldie.

Downsides:

- Game cues can be distracting and lessen user engagement.

a. Too many alerts, sounds, and visual cues makes the user feel overwhelmed and not want to play the game.

- If game cues are not used appropriately, it can cause users to miss important aspects in the game.

3. Title: Mobile games require a tailored game length.

Description: Mobile games require a tailored game length, between 1-5 minutes per level, keeping in mind the established target audience. The game length of each level should be less than five minutes to keep the user engaged in the game. Once your target audience is established, it is important to make sure the length for each level is less than five minutes. In order to motivate users, mobile exergames should be considered "casual games". Game users should not have to be physically fit to play game.

Upsides:

Downsides:

4. Title: .Mobile games should include tailored graphics, sounds, layout, haptics and incentives.

Description: Mobile games should include tailored graphics, sounds, layout, haptics and incentives to encourage frequent gameplay interaction.

· The attractiveness of a game determines if a user finds the game appealing enough to play. When the attractiveness of an exergame is poor, the level of interest decreases.

1. Do the graphics correlate with the storyline and theme of the game?
2. Are the graphics made to appeal to the target audience?
3. Are the graphics made by someone knowledgeable in graphic design techniques? Is this even a factor in determining the level of attractiveness?
4. What is considered good attractiveness?

· With fish Out of Water, the main complaint was that the graphics were very poor. Users were still engaged but didn't like the graphics.

· Incentives are important to give users a motive to continuously play the mobile exergame after initial game play.

1. Determine what type of incentive will be appropriate

· i.e vibrations, alert cues, sound effects, points, high score feature

2. Will the incentive be relevant to the storyline?

· Incentives need to have a purpose

Upsides:

+ Tailoring a mobile exergame to a specific target audience allows for particular users to connect and relate to the game , which allows for the user engagement level to increase.

+ Graphics can highlight state of the game and possible next step, which is important for mobile exergames.

Examples:

· Fish Out of Water: The game play screen shows you which direction to walk in.
· Space Rayders: Tells you when you are it and not it.

Downsides:

- Graphics and sounds can be too flashy, distracting the user from physical activity
- May miss haptic feedback if user is moving aggressively
- May miss phone calls and other haptic interruptions due to overlap in feedback style
- When a mobile exergame is tailored towards a specific audience, it can deter other users outside of the target audience to not be as engaged. For example, if a mobile exergame is tailored for young children ages 6-11, the amount of physical activity required, storyline, etc may not be suitable for audiences above or below this age range.
- Designers would have to design game that is tailored for the target audience but anyone can follow

a. designers need to keep mind that they may have users outside of this target audience that will play this game

5. Title: Required gameplay movement should be safe for users and device.

Description: Make sure that the movement required for gameplay is safe for users to implement

The movement required to play a mobile exergame should be safe enough for the user's phone to not be damaged or require additional equipment for game play.

1. Game should use full body movements but should not involve the phone leaving the user's grip.

1. What are physical activity movement requirements are not suitable for mobile exergame gameplay?
2. What are the pros and or cons of using one type of motion versus another?

2. With games involving mobile-to-mobile contact, there should be a maximum of ten users involved.

1. How many parties are involved?

1. Does the movement of one mobile device affect another?

· Mobile Motion Gaming: Enabling a New Class of Phone-to-Phone Action Games on Commodity Phones

Upsides:

+ Establishing safe movements for the mobile exergame allows for the user , mobile device, and surrounding areas to be safe and undamaged.

Downsides:

- Depending on the user, every movement may not be safe for the user to implement. For example, if a user suffers from a physical health condition, what may be considered “safe” for a user without a physical health condition may be harmful for a user with a physical health condition, especially if there are no alerts or warning prior to activity.

Appendix D. Heuristics for Mobile Exergaming

This appendix is a fourth draft of the mobile exergaming heuristics. Each heuristic in this draft has been reworded to reflect mobile exergaming problems.

Heuristics for Mobile Exergaming (Draft 4)
1. Make sure the overall game can be easily understood by the audience and keeps the user engaged. Having a game that the user can easily understand will produce a higher rate of user engagement than a game that is either too complex or not enough background and detail to explain the objective of the game. § Game should be designed so that there are minimal to no directions required for game play. 1. If directions are needed, users should be able to understand 2. Layout design of the game should be simple for the user to follow. 1. Are things simple to find? 2. Are there elements that need to be added to clarify different actions? (do buttons need to be added, do elements on the phone need to be disabled to not interrupt gameplay) 3. Language of the game should be appropriate for the target audience to follow. 1. Will the people outside of the target audience be able to understand the objective of the game? 2. Does the language level affect the user engagement? 4. Storylines should be tailored for the target audience. 1. When an appropriate storyline is established, it will motivate and keep the target audience engaged in the game. 5. Game should include a combination of various game cues, such as vibrations, alerts, and sound effects, that will keep the user alerted to any important changes, events or stages in game. - Game cues will allow the user to become more engaged in the game because it will inform the user of important stages, alerts, and or events happening in the game. + By having different game cues incorporated into the game, it can be used to notify the user of important messages that are urgent. For example, the game, Wii Fit Plus, incorporates different alerts into the game before the physical activity occurs , so that the user can be warned that if they have a certain condition, they should be careful. + Cues can also be used to notify the user when important events are happening in game. For instance, in Fish Out of Water, the game notifies the user when the user is not catching up to Goldie, or if the user is almost caught up to Goldie. - Game cues can be distracting and lessen user engagement. a. Too many alerts, sounds, and visual cues makes the user feel overwhelmed and not want to play the game. Pros: + The simplicity of a mobile exergame allows the user to become directly engaged with the game and not focus on non-essential aspects. Cons: -By having a simple game, certain details, that may seem minor, may be left out and it will be hard for the user to understand what is going on. 1. In the version 1.0 of the Fish Out of Water, Space Rayders, and Color Hunt games, they did not include direction screens. These had to be added because in the previous version of these games, an instructor would direct the users on how to use it verbally. 2. There needs to be a balance with how detailed the game is 6. Establish a target audience and tailor appropriate game length, incentives and attractiveness. Having a target audience is important for mobile exergames because of the various needs and requirements for different types of users. (ie age, fitness of users, demographics of users, etc) -Benefits

1. Helps determine appropriate activities for the exergames

1. Intensity

2. complexity

2. Helps determine the appropriate language, colors, and layout of the exergame

1. The interaction mode of the game should be tailored to follow the storyline.

1. Space Rayders is multiplayer because is follows the game of "tag"

2. The game length of each level should be less than five minutes to keep the user engaged in the game.

1. Once your target audience is established, it is important to make sure the length for each level is less than ten minutes. In order to motivate users, mobile exergames should be considered "casual games".

1. Casual Game

1. Casual games: have simple rules, are easy to learn and play and require very little video game expertise; typically played in short bursts and can easily be stopped and restarted [Let's Play! Mobile Health Games for Adults]

3.Game users should not have to be physically fit to play game.

4. Game subjects should be relatable to target audience.

3. Demographic (gender, age, lifestyle)

7. The incentives in the game should include a high score feature and track the user's progress throughout the game.

· Incentives are important to give users a motive to continuously play the mobile exergame after initial game play.

1. Determine what type of incentive will be appropriate

1. i.e vibrations, alert cues, sound effects, points, high score feature

2. Will the incentive be relevant to the storyline?

+Including a high score feature allows the user to experience competition within the game, whether it's between the user or other users, which will lead to higher levels of engagement, including playing the game more than once.

+Tracking the user's progress let's the user be aware of how far they have gotten in the game. If, for example, the user has played the game for a long time, the progress tracker should reflect it; if it doesn't, then the user will have decreased levels of user engagement.

-In order to create a competition atmosphere,

8.Game should have attractive graphics, sound and general layout to increase user engagement.

1. The attractiveness of a game determines if a user finds the game appealing enough to play. When the attractiveness of an exergame is poor, the level of interest decreases.

1.. Do the graphics correlate with the storyline and theme of the game?

2. Are the graphics made to appeal to the target audience?

3. Are the graphics made by someone knowledgeable in graphic design techniques? Is this even a factor in determining the level of attractiveness?

4. What is considered good attractiveness?

2.With fish Out of Water, the main complaint was that the graphics were very poor. Users were still engaged but didn't like the graphics.

Pros:

+ Tailoring a mobile exergame to a specific target audience allows for the user to connect and relate to the game , which allows for the user engagement level to increase.

Cons:

- When a mobile exergame is tailored towards a specific audience, it can deter other users outside of the target audience to not be as engaged. For example, if a mobile exergame is tailored for young children ages 6-11, the amount of physical activity required, storyline, etc may not be suitable for audiences above or below this age range.

-Designers would have to design game that is tailored for the target audience but anyone can follow

a. designers need to keep mind that they may have users outside of this target audience that will play this game.

9. Make sure that the movement required for gameplay is safe for users to implement

The movement required to play a mobile exergame should be safe enough for the user's phone to not be damaged or require additional equipment for game play.

1. Game should use full body movements but should not involve the phone leaving the user's grip.

1. What are physical activity movement requirements are not suitable for mobile exergame gameplay?
2. What are the pros and or cons of using one type of motion versus another?

2. With games involving mobile-to-mobile contact, there should be a maximum of ten users involved.

1. How many parties are involved?

1. Does the movement of one mobile device affect another?

· Mobile Motion Gaming: Enabling a New Class of Phone-to-Phone Action Games on Commodity Phones

Pros:

+Establishing safe movements for the mobile exergame allows for the user , mobile device, and surrounding areas to be safe and undamaged.

Cons:

-Depending on the user, every movement may not be safe for the user to implement. For example, if a user suffers from a physical health condition, what may be considered “safe” for a user without a physical health condition may be harmful for a user with a physical health condition, especially if there are no alerts or warning prior to activity.

Appendix E. Mobile Exergaming heuristics

This appendix describes the second to last draft of heuristics. The number of heuristics decreased, which also led to other heuristics being reworded.

Mobile Exergaming Heuristics (Draft 5)
Easy-to-understand game concepts promote game appeal Description: Game objectives and scoring should be quickly and easily understood by players as they move around with the game device. Upsides: + Simplicity allows the user to engage with the physical activity and not on non-essential aspects. Downsides: - Simplicity can result in certain details that may seem minor being obscured or non-obvious or missing, making it hard for the user to understand what is going on. - A minimal storyline may not be motivating for users. Mobile game cues draw attention to important events in the game Description: Mobile exergames should include a variety of engaging game cues, such as vibrations, visual alerts, and sound effects, to keep the user alerted to any important changes, events or stages in game. Upsides: + Informs the user of important stages, alerts, and or events happening in the game, providing a reward that encourages further game play and more activity. + Notifies users of important health-related impacts of the game + Encourages physical activity at times that it may be waning and when game play may be impacted Downsides: - Game cues can be distracting and lessen user engagement. - Too many alerts, sounds, and visual cues makes the user feel overwhelmed and not want to play the game. - If game cues are not used appropriately, it can cause users to miss important aspects in the game. Short play time for mobile exergames encourages continued play. Description: Mobile games require a tailored game length, keeping in mind the established target audience characteristics like age, capabilities, and fitness levels. Engaging storylines with appropriate interaction cues encourage exergaming. Description: Mobile games should meld engaging storylines with appropriately tailored graphics, sounds, layout, haptics and incentives to encourage frequent gameplay interaction. Graphics should correlate with the storyline and theme of the game in ways that appeal to the target audience. Other haptics and sounds can augment the experience and encourage continued play. Upsides: + The attractiveness of a game determines if a user finds the game appealing enough to play. When the attractiveness of an exergame is poor, the level of interest decreases. + Tailoring a mobile exergame to a specific target audience allows for particular users to connect and relate to the game , which allows for the user engagement level to increase. + Graphics can highlight state of the game and possible next step, which is important for mobile exergames. Downsides: - Graphics and sounds can be too flashy, distracting the user from physical activity - May miss haptic feedback if user is moving aggressively - May miss phone calls and other haptic interruptions due to overlap in feedback style - When a mobile exergame is tailored towards a specific audience, it can deter other users outside of the target audience to not be as engaged.

- Designers would have to design game that is tailored for the target audience but anyone can follow

Required gameplay movement should be safe for users and device

Description: Make sure that the movement required for gameplay is safe for users to implement

The movement required to play a mobile exergame should be safe enough for the user's device to not be damaged or require additional equipment for game play. Game should use full body movements but should not involve the phone leaving the user's grip, keeping in mind the physical activity movement requirements suitable for mobile exergame gameplay.

Upsides:

+ Establishing safe movements for the mobile exergame allows for the user , mobile device, and surrounding areas to be safe and undamaged.

Downsides:

- Depending on the user, every movement may not be safe for the user to implement.

-With games involving mobile-to-mobile contact, there should be a maximum of ten users involved.

Appendix F. In-class activity

This appendix includes the in-class activity instructions and heuristic set. A combination of Nielsen's heuristics and a version of the mobile exergaming heuristics found in Appendix E was used.

Mobile exergame analytic evaluation worksheet

Each of the heuristics listed below should be used in evaluating mobile exergames. Consider both positive and negative game elements with respect to each heuristic, and assign a priority rating to each problem on a 0 (minor) to 3 (show-stopper) scale. In keeping with good heuristic evaluation techniques, make sure to make multiple passes through the heuristics list to identify a broad set of problems.

1. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

2. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

3. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

4. Motivational game concepts that promote physical activity

Game immerses players into the game concepts through an engaging storyline, meaningful goals, and challenging physical activities.

5. Game cues that engage active users

Game should engage physically active players using multiple senses, including visual, haptic, and sounds, toward keeping the user interested in the game activities.

6. Physically and temporally appropriate game structure to encourage continual, recurring play

Games should engage the target audience at an appropriate level of physical exertion and within an acceptable length of game (or round) completion.

7. Game play movements that are safe for the user and for the device

Required actions that are necessary to succeed in the game should not endanger the users, either by encouraging harmful physical activity or by distracting a user who is moving.

Appendix G. Notes

This appendix describes the notes that were taken for one of the expert reviews. This gives an overview of the expert review.

NOTES FROM 3/19 CLASS

overview of heuristics generally, then Nielsen's Heuristics, then Korhonen's Heuristics

extensive discussion about the nature of heuristics
Korhonen's aren't validated at all, not by any measure of the work
Nielsen tried, but it's implausible that NONE of the heuristics changed meaningfully due to extensive use and testing

heuristic evaluation of Fish Out Of Water
lots of comments about where FOOW violates heuristics (each pair took notes)
lots of thoughts that these mobile exergaming heuristics aren't really specific to mobile exergames; instead they are specific to many games and/or many mobile devices
→ relate to exergames more, like safety and cue redundancy (with minimal visual cues)

Appendix H. Expert Review Responses

This appendix describes the expert review responses that were given from each group during one of the expert reviews. Each group gave a list of the problems they found with Fish Out of Water and how each group found the usefulness of the heuristics.

Expert Review responses:

Group 1 [New version]

- The goal of the game is hard to understand.
- The events were hard to understand
- Game play time was short, but it didn't encourage frequent gameplay
- The storyline was unclear
- Leveling up system seemed independent of the story

Group 2

- Wasn't easy to understand concept of game
- The illustrations were hard to follow
- Some heuristics are partially satisfied

Group 3 [New version]

- Tried it once but won't play again
- Hard to follow storyline of game
- Not suitable for all environments
- Voice cues increase safety of games
- If you add a calorie counter (incentives)
- Clarity of the font of the instructions
- Give hints or tips before, during and after gameplay
- Refer to other heuristics for playability of mobile gaming
- Many of these heuristics are previously covered
- 3-5 can be reshaped into more specific exergame heuristics
- 4 is what was learned?

recap what exergames are

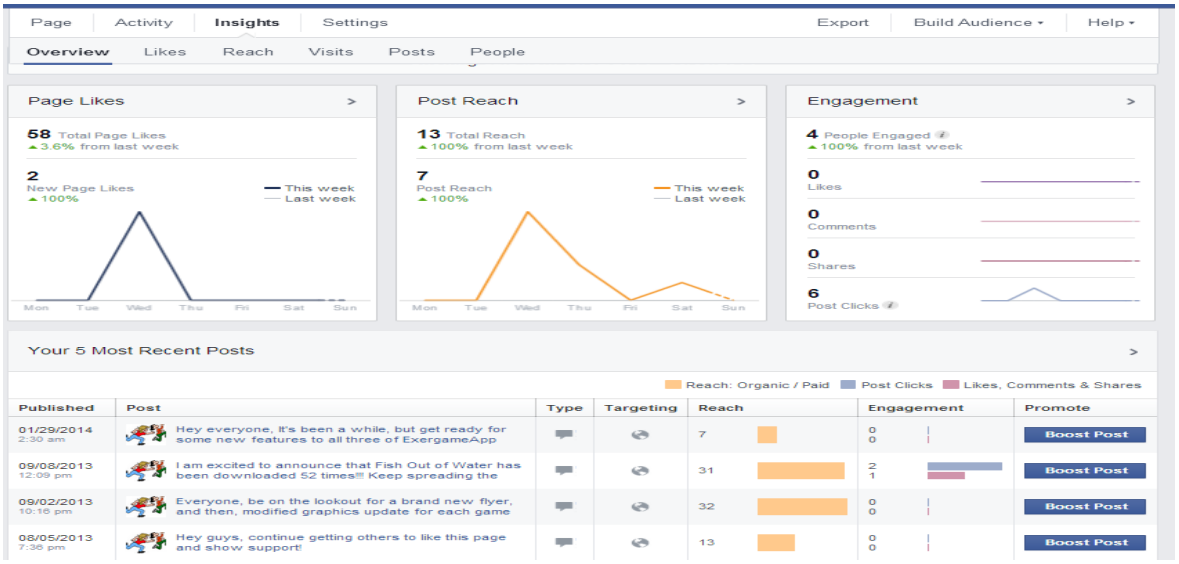
recap lessons about their creation and distribution

recap lessons about when/how they are used

A. Describe what other methods could be used

Appendix I. ExergameApp Suite page data

This appendix is an image of the data that can be found through the administrative view of the ExergameApp Suite page. This image shows how often the page is visited, the amount of people that have seen the post and how often the page is discussed.



Appendix J. ExergameApp Suite page

This appendix shows the ExergameApp Suite page. This page was used as a form of communication with other users about the progression of the ExergameApp Suite. The images used on this page were used with permission of Kacie Allen.

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