Developing and Testing Smartphone Game Applications for Physical Activity Promotion in Adolescents

Kacie C. Allen

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Human Nutrition, Foods, and Exercise

Paul A. Estabrooks

Jamie M. Zoellner

Jennie L. Hill

D. Scott McCrickard

Wen You

April 5, 2013

Blacksburg, Virginia

Keywords: physical activity, adolescents, smartphone games, low socioeconomic status, intervention

Developing and Testing Smartphone Game Applications for Physical Activity Promotion in Adolescents

Kacie Chanelle Allen

ABSTRACT

Though the benefits of physical activity are numerous and well-known, very few adolescents are meeting physical activity recommendations. Moreover, past research shows that physical activity declines with increasing age with this decline beginning in adolescence. One approach to promote physical activity is through mobile technology such as a mobile phone. Since mobile phone ownership is relatively high (77%) and there is no digital divide by race/ethnicity or socioeconomic status, mobile phones may be suitable for physical activity promotion. Few studies have promoted PA using a mobile phone and those studies showed increased physical activity outcomes. However, more research is needed to explore the effectiveness of mobile phone physical activity promotion especially in more health disparate populations.

The purpose of this research was to develop and test smartphone game application for physical activity promotion in adolescents. The first study included various user-centered approaches (e.g. qualitative data, idea sessions) to get feedback on what was desired from the adolescents in terms of game development and design. The second study examined the degree to which mobile health studies reported on internal and external validity indicators. The last study evaluated the smartphone game applications through a mixed-methods approach.

The results of this research showed that physical activity while playing smartphone game applications can yield moderate physical activity intensity. Moreover, adolescents had moderate perceptions of the games and recommended specific changes to the games. Likewise, the data suggest that smartphone physical activity game applications can be enjoyable if they are aesthetically appealing, easy to use, and foster social peer interactions. Overall, this research demonstrated that smartphone games that were developed and designed based on adolescents' preferences and persuasive technology design principles could increase physical activity in adolescents and provides a tool for further exploration.

ACKNOWLEDGMENTS

I would like to thank my Lord and Savior, Jesus Christ. Without Him, I could not have done the things that I have done, especially complete graduate school and defend my dissertation. I am excited for the blessings that you have in store. To my soon-to-be husband, Randall, I am grateful and forever indebted to the sacrifices that you have made for me. Thank you for being there to hear the good and bad experiences that I had while in graduate school. Also thank you for always providing words of encouragement and for emphasizing "stay in the moment and enjoy the journey". To my immediate family (greatest parents, brother, sister, in-laws, nieces and nephews), thank you for your continued love, prayers, support and encouragement throughout my entire life. To my paternal grandparents, Grandma & Grandpa Allen: Even though physically you did not get to be here to see this day, I know that you are here in spirit watching over me. Thank you for instilling a spirit of hard work, dedication, love and compassion. Though you didn't have formal schooling past the 4th grade, you were so wise. I pray that I get at least a little ounce of your wisdom. I will always love you. To my maternal grandparents, Grammy & Papa, and thank you driving to Virginia Tech for my initial visit and for your continued prayers and encouragement. To my aunts, uncles, and cousins thank you for your encouraging words and prayers. Special thanks to Aunt Pennye for always checking in on me.

Thank you to my advisors Drs. Estabrooks and Zoellner for your guidance will all of my projects. I am grateful for your expertise in various fields. Thank you for showing that there are endless possibilities in research and how to critically think and apply knowledge in different areas. I appreciate the invaluable experiences that I have had while working under you. To my committee members, thank you for your input and support throughout my graduate work. Thank you to Dr. Winchester for connecting me with three students (Darryl, Clarence, and Antonio) in the Virginia Tech Human Computer Interaction-Research Experience for Undergraduates and for assisting in conceptualization of app development. Thank you to Judith (Julee) for assisting me in development and implementation. To Dr. Almeida, thank you for always making yourself available if I had a question related to data management/analysis or accelerometry. To my undergraduate mentee and programmers (Adil, Becky, and

Brandon), thanks for all of your hard work in making the project become a reality and with data management.

Thank you to my special high school friends (Sarah, Nikhol, Barbrieka, Angel, Lakeah, and Quan) who may not have understood what I was going through in graduate school, but consistently supported me. Thank you to my college friends (Tiffany, Shelby, Dina, and Jamie) who have continued to push me to excel. To the 7 Deltanents, thank you for being my sisters and being an inspiration to me to persist.

Thanks Serena for mentoring me throughout graduate school and for being an accountability sister. Thanks Samantha for providing humor on our various worksite car rides and for enhancing my experiences at SBM conferences. To Erin, thanks for your willingness to provide clear instruction and to assist others (esp to me in SOPARC). To Ashley, thanks for being a consistent voice of encouragement throughout my graduate school tenure. To Clarice and Blake, from IMA DIVA, to stats and accelerometer assistance, thanks for being such awesome teachers! To my "Club Cubicle Mates" (Ramine, Felicia, & Karissa), thanks for always providing a social and humor relief when work got stressful. You all taught me the importance of balancing work and life. To Circle, thanks for keeping me grounded and inspiring me spiritually, academically, and professionally.

To Mrs. S, my 4th grade teacher (my favorite teacher), I'm so blessed to have been able to keep in touch with you over the years. To Ms. Carroll, a counselor at my high school. Though you were not designated as my counselor, I appreciate you taking me under your wing. It was nice that I could drop by your office to just hang out and talk with you. Thanks for your many words of wisdom. To Dr. Stewart, my undergraduate advisor, though you left HU after my 1st 2 years, the impact you made in my life continues. You were so tough on me but that helped instill taking the initiative and being competitive. I remember you would always ask me about my personal life, grades, and internships that I was applying too. I would think like man it's only December and he's already asking about summer plans. But now I realize that you were teaching me to plan ahead if I want to stay ahead. Thank you for writing my recommendation letter for graduate school.

To Mr. Carl Butler, if it was not for you I would not be at Virginia Tech. Thank you for the wealth of connections that you have. You continue to teach me how important it is to stay connected in the networking relationships that I make. Thank you for being like the East Coast father, I never had. To Dr. Randy Grayson. You were the first person I met at Virginia Tech. Thank you for being like a grandfather to me. You are always willing to share personal and professional experiences with me. Thank you for willingness to fund my time in graduate school and suggesting for me to participate in different councils/organizations (CALS Diversity Council, MANRRS, IMSD, etc.). To IMSD, thank you for being my Virginia Tech family. You provided such a strong support system. I will always remember the forums, ABRCMS, and our social gatherings. Much thanks to Bianca and Shernita for studying with me while we prepared for our preliminary exams.

To the Boys & Girls Club administrators (Laurie Gibbons) and staff (especially, Tiffany Muse, Lauren Wimbish, Richelle Price, Marie Moore, Eric Wise, Thomas Tate, Donald Burnette, and Diana Pless) thank you for collaborating with me and allowing me to conduct two of my studies at three of your southwest Virginia sites. To all of the study participants thank you for your time and willingness to participate.

ATTRIBUTIONS

Manuscript 1:

Ramine Alexander is a graduate student in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted with coding.

Margaret Berry is a graduate student in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted with coding.

Jason Fanning is a graduate student in the Department of Kinesiology and Community Health at University of Illinois at Urbana-Champaign. He assisted with coding and conceptualization of inclusion and exclusion criteria.

Jamie Zoellner is an associate professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted in editing of the manuscript.

Paul A. Estabrooks is a professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. He assisted in editing of the manuscript.

Manuscript 2:

Judith Harlow was a graduate student in the Department of Industrial and Systems Engineering at Virginia Tech during the development of the manuscript. She assisted with coding data, creating the hand-drawn and computer-generated prototypes in the results section, and editing of the manuscript.

Woodrow Winchester, III, is an assistant professor in the Department of Industrial and Systems Engineering at Virginia Tech. He assisted with conceptualization and editing of the manuscript.

D. Scott McCrickard is an associate professor in the Department of Computer Science at Virginia Tech. He assisted with conceptualization and editing of the manuscript.

Jamie Zoellner is an associate professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted in editing of the manuscript.

Jennie L. Hill is an assistant professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted in editing of the manuscript.

Paul A. Estabrooks is a professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. He assisted in the conceptualization, coding, and editing of the manuscript.

Manuscript 3:

Adil Kadir is an undergraduate student in the Department of Computer Science at Virginia Tech. He assisted in programming the games.

Brandon Dockery was an undergraduate student in the Department of Computer Science at Virginia Tech. He assisted in programming the games.

Sarah Elizabeth Johnson is a graduate student in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted in coding qualitative data.

Fabio Almeida is an assistant professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. He assisted in quantitative data analysis.

Jamie Zoellner is an associate professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted by editing the manuscript for content and guiding data analysis.

D. Scott McCrickard is an associate professor in the Department of Computer Science at Virginia Tech. He assisted with editing of the manuscript.

Wen You is an assistant professor in the Department of Agriculture and Applied Economic at Virginia Tech. She assisted by reviewing the manuscript for content.

Jennie Hill is an assistant professor in the Department of Human Nutrition, Foods, and Exercise at Virginia Tech. She assisted by reviewing the manuscript for content.

Paul A. Estabrooks is a professor of in the Department of Human Nutrition, Foods, and Exercise. He assisted in the conceptualization, guiding data analysis, and editing of the manuscript.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Physical activity (PA) has been recognized as a leading health indicator, as it provides numerous benefits towards overall physical and mental health (United States Department of Health and Human Services [USDHHS], 2010). Conversely, physical inactivity increases the risk of dying prematurely, dying of heart disease, developing diabetes, colon cancer, and high blood pressure (USDHHS, 2008). The benefits of PA can be realized early in life and the adolescent population has the added PA benefits of improvements in emotional well-being and self-esteem (Schmalz, 2010), opportunities to learn new social skills (Bailey, 2005), improved personal development (Hansen, Larson, Dworkin, 2003), enhanced academic performance (Nelson & Grodon-Larson, 2006; Shephard, 1997), lower levels of anxiety and depression (Kirkcaldy, Shephard, & Siefen, 2002), increased bone mineral content and bone mineral density (Sundberg et al., 2002), and associations with lower insulin and glucose levels (Ferguson et al., 1999). Thus, in addition to the advantages of risk reduction, adolescents also benefit across the physical, emotional and social aspects of life when they are physically active.

Despite the well-known PA benefits, nationally representative surveys consistently have shown that adolescents have difficulty meeting physical activity (PA) guidelines (i.e., 60 minutes of moderate to vigorous PA on 5 or more days per week) or Healthy People 2020 (HP 2020) objectives (CDC, 2011, 2012). According to the 2011 Youth Risk Behavior Surveillance, approximately half had been physically active at least 60 minutes per day on 5 or more days, 28.7% had been physically active at least 60 minutes on all 7 days, and a little over half (55.6%) had participated in muscle strengthening activities on 3 or more days (CDC, 2012). However, the 2010 National Youth Physical Activity and Nutrition Study showed that only 15.3% of students in grades 9-12 met the aerobic objective, 51% met the muscle-strengthening objective and only 12.2% met both objectives (CDC, 2011). Also problematic is that PA declines with increasing age beginning in adolescence (CDC, 2012; Kimm et al., 2000; Riddoch et al., 2004; Sallis, Prochaska, & Taylor, 2000). Lastly, a possible factor towards not meeting guidelines is that adolescents spend an average of 5-7 hours per day in sedentary activity (Whitt-Glover et al., 2009).

One contributor to physical inactivity is the continued lack of access to physical education (PE) at school which is as a result of budgetary concerns and competing academic demands (American Alliance for Health, Physical Education, Recreation and Dance, 2009). Only 3.8% of elementary schools, 7.9% of middle schools and 3.1% of high schools provide daily physical education or its equivalent for the entire school year (Lee, Burgeson, Fulton, & Spain, 2007). Twenty-two percent of schools do not require students to take any PE at all (Kann, Brener, & Wechsler, 2007). Moreover, PE allots approximately only 8-11% of student's daily PA (Tudor-Locke, Lee, Morgan, Beighle, & Pangrazi, 2006).

Another factor that has been linked with lower PA levels in adolescents, is being in a racial/ethnic minority group (Brodersen, Steptoe, Boniface, & Wardle, 2007; CDC, 2011). A higher percent of Black (19.6%) and Hispanic (15.9%) high school students did not participate in at least 60 minutes of PA on any day of the week compared to their White (11%) counterparts. Similarly, a lower percent of Black (44.4%) and Hispanic (45.4%) high school students participated in PA for 60 minutes/day on 5 or more days than Whites (52.7%; CDC, 2011). Moreover, a smaller percent of Black (26%) and Hispanic (26.5%) high school students have been physically active for at least 60 minutes per day on all 7 days compared to Whites (CDC, 2011).

Additionally, low socioeconomic status (SES) has been identified as a barrier to PA in children (Gordon,-Larsen, McMurrey, & Popkin, 2000; Kristjandottir & Vilhjalmsson, 2001; Lasheras, Aznar, Merino, & Lopez, 2001; La Torre, Masala, Devito, Langiano, Capelli, Ricciardi, & PHASES, 2006; Lindstrom, Bertil, & Ostergren, 2001; McVeigh, Norris, & de Wet, 2004). A past review also indicated that the barrier of low SES extends from adults to include adolescents (Stalsberg & Pedersen, 2009). Access to high quality and safe resources for PA is typically lower for low SES families when compared to families with higher SES (Giles-Corti & Donovan, 2002). Furthermore, neighborhood walkability that is inhibited by higher volumes of traffic and environments for walking may be perceived as less attractive or supportive in low SES neighborhoods (McVeigh et al., 2004). Hence, key barriers to PA for adolescents from lower SES families include low accessibility of facilities such a playgrounds, parks, sidewalks, and unsafe location of facilities for PA (Gordon-Larsen et al., 2000). Lastly, another review

showed that more general barriers included lack of peer and parental support for PA, that adolescent girls had concerns about appearance during and after PA and had competing sedentary behaviors (van der Horst, Paw, Twisk, & van Mechelen, 2007).

Given the challenges to promote PA during school time and the differential prevalence of PA across socioeconomic and demographic groups, the after-school hours have been identified as a promising time of day to promote PA for adolescents (DHHS, 2006). Approximately 8.4 million children in the US attend accredited afterschool childcare (Afterschool Alliance, 2009). Furthermore, data from a nationally representative adolescent sample suggest that participation in the use of a community recreation center (e.g. for afterschool programs) was associated with an increased likelihood of engaging in high level PA (DHHS, 2006). Further, to address health disparities, the Boys and Girls Club of America (BGCA) provides an ideal setting for afterschool PA promotion. The BGCA is a non-profit organization that provides after-school and summer child program and is well known throughout the US. It is very low cost and offers resources and services for adolescents from low SES families. Furthermore, a key outcome for members of the BGCA is a healthy lifestyle, which provides an opportunity to align research and practice goals for PA and to improve the likelihood of integration of study findings into their current afterschool program (Boys & Girls Clubs of America Virginia, 2010b; Estabrooks & Glasgow, 2006). Additionally, adolescent PA may be formed more by peers and social influences than by parental or other adult influences (Story, Lytle, Birnbaum, & Perry, 2002) and an afterschool program at BGCA provides a safe environment to nurture these peer interactions (Boys & Girls Clubs of Southwest Virginia, 2010a).

Identifying BGCA as a setting for PA promotion has the added benefit of providing an opportunity for children to be exposed to a variety of PA equipment—an effective method of increasing PA in children (Council on Sports Medicine and Fitness and Council on School Health, 2006). However, when considering the afterschool program setting, for adolescents, most equipment focused on sports (e.g., basketball) rather than PA (e.g., walking briskly) which may demotivate adolescents who do not feel competent or are aversive to sport competition (DHHS, 2006). This suggests the need for different, and prevalent, equipment that could be used to facilitate PA in adolescents at afterschool programs. One

possibility is the use of mobile phones as a catalyst to PA promotion. While, not traditionally considered PA equipment, the high prevalence of ownership and the growing body of literature that suggests interactive games can promote moderate PA (Biddiss & Irwin, 2010) provide some rationale for doing so.

Adolescent mobile phone ownership is relatively high (77%; Lenhart, 2012) and there are no significant differences in mobile phone ownership by SES or race/ethnicity (Lenhart, 2010). Though mobile phone ownership is lower in adolescents in households earning less than $30,000 annually, a considerable amount of those teens (59%) still own a mobile phone compared to wealthier adolescents (75%; Lenhart, 2012). Furthermore, mobile phone usage has been shown to be higher in adolescents from lower SES backgrounds with fathers with low education and non-nuclear family types compared to adolescents with high SES, highly educated fathers, and nuclear family homes (Lenhart, 2010). There are no differences by race or ethnicity in mobile phone ownership (Lenhart, 2012). Additionally, more Black adolescents (44%) and Hispanic adolescents (35%) use their mobile phones to go online, compared with White adolescents (21%) (Lenhart, 2012). Further, a large percentage of adolescent girls (97%) and adolescent boys (99%) aged 12-17 play video games (Vandewater, 2004), providing additional rationale for the promotion of PA via mobile phones games that could be both effective approach and have the potential to reach more adolescents with varying demographic characteristics.

The use of mobile phones to promote physical activity and other health outcomes (mhealth) have focused primarily on adults (Fanning, Mullen, McAuley, 2012) or have been used for ecological momentary assessment for PA monitoring or for texting PA promotion/reminder messages for rather than for intervention (Dunton, Liao, Intille, Spruijt-Metz, Pentz, 2011; Newton, Wiltshire, Elley, 2009; Shapiro et al., 2012; Toscos, Faber, Connelly, Upoma, 2008; Toscos, Faber, An, Gandhi, 2006). Though effectiveness in PA has been shown in those studies, there is a need to move beyond PA monitoring and to progress to promotion of PA. Few studies to our knowledge have attempted to benefit from multiple features of mhealth technologies (e.g. accelerometer, GPS, camera) in promoting PA for adolescents and rarely have they reported on development that was from a user-centered approach.

This dissertation consists of a series of manuscripts that focus on the development and testing of smartphone games for PA promotion. Manuscript 1 outlines the systematic review of internal and external validity reporting of mobile health interventions for PA promotion. Manuscript 2 describes the process of engaging adolescents and their parents for the design and development of smartphone PA game-based applications (SPAGA) for adolescents. Manuscript 3 elaborates on SPAGA testing in adolescents through a mixed-methods approach.

Manuscript 1 is a systematic literature review that examined the extent to which mhealth PA interventions reported on internal and external validity indicators. Traditional literature reviews of PA interventions primarily have focused on the effectiveness, an internal validity component, of an intervention (Fanning et al., 2012; Koivusilta, Lintonen, Rimpelä, 2007; Lau, Lau, Wong, & Ransdell, 2011). However, in addition to reporting on the effectiveness, Glasgow and colleagues (1999) emphasized that in order to assess the public health impact of an intervention, the reporting on external validity factors and other internal validity factors was vital. External validity examines to see if the observed effects are generalizable across different populations, settings, and time (Shadish, Cook, & Campbell, 2002). The RE-AIM framework developed by Glasgow and colleagues (1999) was used to evaluate the mhealth PA interventions included in our systematic review. It specifies standards related to the reporting of **r**each into the target population and representativeness of the study sample; **e**fficacy/effectiveness of the intervention on the primary outcome, quality of life, and on avoiding unintended negative consequences; **a**doption rates of organizations and staff that would ultimately use the intervention and the characteristics of those organizations and staff; the degree to which the intervention is **i**mplemented as intended; and the **m**aintenance of effects at the individual level and sustainability of the intervention at an organizational level (RE-AIM; Glasgow, Vogt, & Boles, 1999).

Because PA interventions are more effective when they are based in theory or guided by a conceptual framework (Dishman and Buckworth, 1996), this project adopted a user-centered design process (Weissenberger and Thompson, 2009) to guide the development and design of the SPAGA. User-centered design is a collaborative process for software development projects that enables teams to more

effectively meet the ends of users (Weissenberger and Thompson, 2009). In essence, it looks at the tasks being performed from the perspective of the user and integrates that perspective into the design and development. The five phases of UCD are plan, research, design, adapt, and measure (see Figure 1-1). "Planning" determines all activities needed and the necessary resources; "research" is done before designing to better understand the users' goals and tasks, "design" defines the system from the user perspective, in the "adapt" phase, adaptations are made based on need for changes discovered during development, and in the "measure" phase, usability (e.g. effectiveness, efficiency, and satisfaction) is measured.

Furthermore, persuasive technology is defined as technology that is designed to change the attitudes or behaviors of the "users" through persuasion and social influence, but not coercion (Fogg, 2003) the model used in the development (manuscript 2) and testing (manuscript 3) of the SPAGA was the Fogg Behavior Model (FBM (see Figure 1-2); Fogg, 2009). The FBM is an individual-level model that allows designers and researchers to understand factors underlying behavior change (Fogg, 2009). The FBM emphasizes that behavior results from motivation, ability and triggers. Motivation is described as the driving force that causes someone to do a particular behavior. The three core motivators are pleasure/pain, hope/fear, and social acceptance/rejection. Ability is defined as how simple it is to perform a behavior. The six elements of ability are time, money, physical effort, brain cycles, social deviance, and non-routine. A trigger is something that tells individuals to perform a behavior immediately (Fogg, 2009). The three types of triggers are facilitator (high motivation, low ability), spark (low motivation, high ability) and signal (high motivation, high ability). Examples of how the concepts were operationalized are presented in Table 1-1.

The FBM concepts are well known by designers and researchers in persuasive technology with the FBM landmark article cited over 140 times. Moreover, it has been concluded that best practices in mobile game design follow the design guidelines in FBM (Yamakami, 2012). The FBM has been used to guide the promotion of healthy behaviors (Chen, Goh, & Abdul Razak, 2012) and to improve study habits (Hedin, 2012). One large gap of the FBM is that has been used primarily to design persuasive

technologies in adults. Thus, it is less clear how past researchers and designers have implemented the FBM principles into persuasive technologies for adolescents. In this dissertation, we sought to design SPAGA for adolescents based on the FBM components.

The development and testing of the smartphone games used interdisciplinary perspectives to enhance the field of science and technology and to target one of the national health priorities (i.e., PA promotion). Members of the research team had expertise in various backgrounds including exercise science, behavioral science, healthful eating and PA promotion, industrial and systems engineering, computer science engineering, and agricultural and applied economics. Having these different perspectives and varying expertise backgrounds helped to guide in terms of feasibility and innovativeness of the smartphone game development and testing.

Figure 1-1 User-Centric Design process

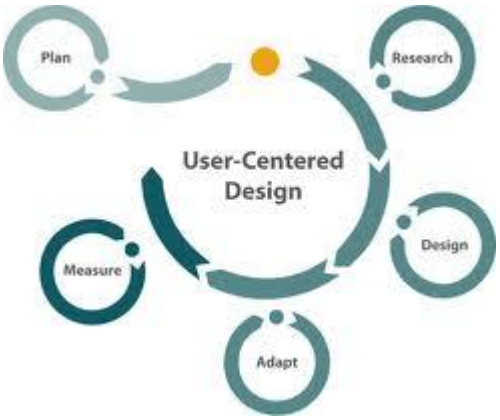


Figure 1-2 The Fogg Behavior Model

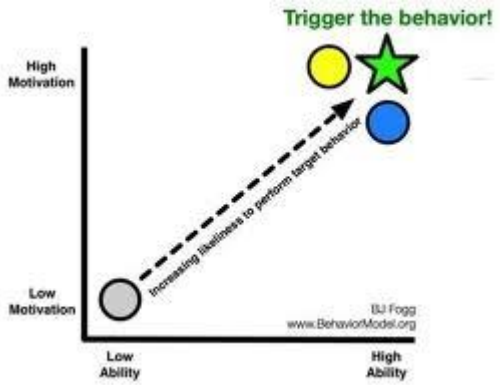


Table 1-1 The Fogg Behavioral Model Components and Examples

Components	Example
Core Motivators	
Pleasure	Participants learn new ways to be physically active by playing smartphone games.
Hope/Fear	Participants anticipate that while playing the SPAGA they will be rewarded points when they execute a task, but lose or not gain points when they insufficiently do a task.
Acceptance/Rejection	Participants will be able to share their experiences after playing the SPAGA on a daily basis and through exit focus groups
Simplicity	
Time, Money, and Physical Effort	The interface was designed with minimal navigation and participants are not required to make any payment for SPAGA usage.
Brain Cycles	The messages from virtual characters within SPAGA and SPAGA directions are straightforward
Social Deviance	The SPAGA and the messages and rewards within SPAGA are designed to promote PA.
Non-routine	Participants will have access to SPAGA on 4 of the 5 days while at the testing sites (afterschool program site), so this will help with making playing SPAGA a routine.
Trigger	
Spark/Facilitator/Signal	Since there are different types of participants, the SPAGA will be used accordingly. The SPAGA was designed as a ‘spark’ by participants being reminded each day that they will have a chance to play, earn points, and move to higher levels. The SPAGA was designed as a ‘facilitator’ by having minimal navigation and designed for all participants to play regardless of skill level or past gaming experience. The SPAGA was designed as a ‘signal’ through game play in 30 minute increments 4 days a week in the Boys & Girls Club.

References

Afterschool Alliance. (2009). *America after 3pm: A household survey on afterschool in America*, Washington DC.

American Alliance for Health, Physical Education, Recreation and Dance. (2009). *FACTS learning for life: Physical education in public schools.* Retrieved from http://www.aahperd.org.

Bailey, R. (2005). Evaluating the relationship between physical education, sport and social inclusion. *Educational Review, 57*, 71-90.

Biddiss, E., & Irwin J. (2010). Active video games to promote physical activity in children and youth: A systematic review. *Archives of Pediatrics & Adolescent Medicine, 164*(7), 664-672.

Boys & Girls Clubs of Southwest Virginia. (2007). *Who we are-Alumni Survey*. Retrieved from http://www.bgcswva.org.

Boys & Girls Clubs of Southwest Virginia. (2010a). *Who we serve and what we do*. Retrieved from http://www.bgcswva.org.

Boys & Girls Clubs of America. (2010b). *Mission*. Retrieved from http://www.bgca.org.

Brodersen, N.H., Steptoe, A., Boniface, D.R., & Wardle J. (2007). Trends in physical activity and sedentary behaviour in adolescence: Ethnic and socioeconomic differences. *British Journal of Sports Medicine, 41*(3), 140-144.

Centers for Disease Control and Prevention. (2011). Physical activity levels of high school students---United States, 2010. *Morbidity and Mortality Weekly Report, 60*(23), 773-777. Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6023a1.htm?s_cid=mm6023a1_w.

Centers for Disease Control and Prevention. (2012). Youth Risk Behavior Surveillance-United States, 2011. *Morbidity and Mortality Weekly Report, 61*(No.SS-4):1-168.

Chen, Y.Y., Goh, K.N., & Abdul Razak, M.F. (2012). Development of a web-based tailored intervention for excessive gaming. Proceedings of the World Congress on Engineering and Computer Science. San Francisco, CA.

Council on Sports Medicine and Fitness and Council on School Health. (2006). Active healthy living: Prevention of childhood obesity through increased physical activity. *Pediatrics*, *117*(5), 1834-1842.

Dishman RK, Buckworth J. (1996). Increasing physical activity: A quantitative synthesis. *Medicine & Science in Sports & Exercise*, *28*(6), 706-719.

Dunton, G., Liao, Y., Intille, S.S., Spruijt-Metz, D., & Pentz, M. (2011). Investigating children's physical activity and sedentary behavior using ecological momentary assessment with mobile phones. *Pediatric Obesity, 19*(6), 1205-1212

Estabrooks, P.A., & Glasgow, R.E. (2006). Translating effective clinic-based physical activity interventions into practice. *American Journal of Preventive Medicine, 31,* 45-56.

Fanning, J.T., Mullen, S.M., & McAuley, E. (2012). Increasing physical activity with mobile devices: A meta-analysis. *Journal of Medical Internet Research, 14*(6), e161.

Ferguson, M.A., Gutin, B., Le, N-A., Karp., W., Litaker., M., Humphries, M.,…Owens, S. (1999). Effects of exercise training and its cessation on components of the insulin resistance syndrome in obese children. *International Journal of Obesity and Related Metabolic Disorders, 23,* 889-895.

Fogg, B.J. (2002). Persuasive computers: Using computers to change what we think and do. Waltham, Massachusetts: Morgan Kaufmann.

Fogg, B.J. (2009). A behavior model for persuasive design. Proceedings from Persuasive ’09*: The 4th International Conference on Persuasive Technology,* ACM, New York, NY, USA, 1-7.

Glasgow, R.E., Vogt, T.M., & Boles, S.M. (1999). Evaluating the public health impact of health promotion interventions: The RE-AIM framework. *American Journal of Public Health, 89*(9), 1322-1327.

Giles-Corti, B., & Donovan, R.J. (2002). Socioeconomic status differences in recreational physical activity levels and real and perceived access to a supportive physical environment. *Preventive Medicine, 6,* 601-611.

Gordon-Larsen, P., McMurrey, R.G., & Popkin, B.M. (2000). Determinants of adolescent physical activity and inactivity patterns. *Pediatrics, 105*(6), 83-88.

Hansen, D.M., Larson, R.W., Dworkin, J.B. (2003). What adolescents learn in organized youth activites: A survey of self-reported developmental experiences. *Journal of Research on Adolescence, 13,* 25-55.

Hedin, B. (2012). Teaching procrastination – A way of helping students to improve their study habits. Proceedings from *The 7th Educational Lunds Tekniska Högskola's Pedagogical Inspiration Conference*, Lund, Sweden.

Kann, L., Brener, N.D., & Wechsler, H. (2006). Overview and summary: School health policies and programs study 2006. *Journal of School Health, 77,* 385-397.

Kimm., S.Y., Glynn, N.W., Fitzgerald, S.L., Aaron, D.J., Similo, S,L,, McMahon, R.P., & Barton, B.A. (2000). Longitudinal changes in physical activity in a biracial cohort during adolescence. *Medicine and Science in Sports and Exercise, 32*(8), 1445-1454.

Kirkcaldy, B.D., Shephard, R.J., & Siefen, R.G. (2002). The relationship between physical activity and self-image and problem behaviour among adolescents. *Social Psychiatry and Psychiatric Epidemiology, 37*(11), 544-550.

Koivusilta, L.K., Lintonen, T.P., & Rimpelä, A.H. (2007). Orientations in adolescent use of information and communication technology: A digital divide by sociodemographic background, educational career, and health. *Scandinavian Journal of Public Health, 35*(1), 95-103.

Kristjandottir, G., & Vilhjalmsson, R. (2001). Sociodemographic differences in patterns of sedentary and physically active behavior in older children and adolescents. *Acta Paediatrica., 90*(4), 429-435.

Lasheras, L., Aznar, S., Merino, B., & Lopez, E.G. (2001). Factors associated with physical activity among Spanish youth through the National Health Survey. *Preventive Medicine, 32*(6), 455-464.

La Torre, G., Masala, D., De Vito, E., Langiano, E., Capelli, G., Ricciardi, W., & PHASES (Physical Activity and Socio-Economic Status) collaborative group. (2006). Extra-curricular physical activity and socioeconomic status in Italian adolescents. *BMC Public Health, 6,* 22.

Lau, P.W.C., Lau, E.Y., Wong, D.P., & Ransdell, L. (2011). A systematic review of information and communication technology-based interventions for promoting physical activity behavior characteristics in children and adolescents. *Journal of Medical Internet Research, 13*(3), e48.

Lee, S.M., Burgeson, C.R., Fulton, J.E., & Spain, C.G. (2007). Physical education and physical activity: Results from the school health policies and programs study. *Journal of School Health, 77*(8), 435-463.

Lenhart, A., Ling, R., Campbell, S., & Purcell, K. (2010). Teens and mobile phones. *Pew Internet & American Life Project*. Retrieved from http://pewinternet.org/Reports/2010/Teens-and-Mobile-Phones.aspx.

Lenhart, A. (2012). Teens, smartphones, & texting. *Pew Internet & American Life Project*. Retrieved from http://pewinternet.org/Reports/2012/Teens-and-smartphones.aspx.

Lindstrom, M., Bertil, S., & Ostergren P. (2001). Socioeconomic differences in leisure-time physical activity: The role of social participation and social capital in shaping health related behaviour. *Social Science & Medicine*, *52,* 441-452.

McKenzie, T.L., Sallis, J.F., & Nader, P.R. (1991). SOFIT: System for observing fitness instruction time. *Journal of Teaching in Physical Education. 11*, 195-205.

McVeigh, J.A., Norris, S.A.. & de Wet, T. (2004). The relationship between socio-economic status and physical activity patterns in South African children. *Acta Paediatrica, 93*(7), 982-988.

Nelson, M.C., Gordon-Larson, P. (2006). Physical activity and sedentary behavior patterns are associated with selected adolescent health risk behaviors. *Pediatrics, 117*, 1281-1290.

Newton KH, Wiltshire EJ, Elley CR. (2009). Pedometers and text messaging to increase physical activity randomized controlled trial of adolescents with type 1diabetes. *Diabetes Care, 32*(5), 813-815.

Riddoch, C.J., Andersen, L.B., Wedderkopp, N., Harro, M., Klassen-Heggebo, L., Sardinha, L.B.,… Ekelund, U. (2004). Physical activity levels and patterns of 9-and 15-yr-old European children. *Pedatric Exercise Science, 36*(1), 86-92.

Sallis, J., Prochaska, J., & Taylor, W. (2000). A review of correlates of physical activity of children and adolescents. *Medicine and Science in Sports and Exercise, 32*, 963-975.

Schmalz, D.L. (2010). 'I feel fat': Weight-realted stigma, body esteem, and BMI as predictors of perceived competence in physical activity. *The European Journal of Obesity, 3*(1),15-21.

Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton-Mifflin.

Shapiro, J.R., Koro, T., Doran, N., Thompson, S., Sallis, J.F., Calfas, K., & Patrick, K. (2012). Text4Diet: A randomized controlled study using text messaging for weight loss behaviors. *Preventive Medicine, 55*(5), 412-417.

Shephard, R.J. (1997). Curricular physical activity and academic performance. *Pediatric Exercise Science, 9*(2),113-126.

Stalsberg, R.P., & Pedersen, A.V. (2009). Effects of socioeconomic status on the physical activity in adolescents: A systematic review of the evidence. *Scandinavian Journal of Medicine & Science in Sports, 20,* 368-383.

Story, M., Lytle, L.A., Birnbaum, A.S., & Perry, C.L. (2002). Peer-led, school-based nutrition education for young adolescents: Feasibility and process evaluation of the TEENS. . *Journal of School Health, 72*(3), 121-127.

Sundberg M, Gardsell P, Johnell O, Karlsson MK, Ornstein E, Sandstedt B, & Sernbo I. (2002). Physical activity increases bone size in prepubertal boys and bone mass in prepubertal girls: a combined cross-sectional and 3-year longitudinal study. *Calcified Tissue International, 71*(5),406-415.

Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., & Raitakari, O. (2005). Physical activity from childhood to adulthood: A 21-year tracking study. *American Journal of Preventive Medicine, 28,* 267-273. 39.

Toscos, T., Faber, A.M., An, S., & Gandhi, M.P. (2006). *Click Clique: Persuasive technology to motivate teenage girls to exercise.* Proceedings from CHI '06: *The Conference for Human-Computer Interaction.* Montréal, Québec, Canada.

Toscos, T., Faber, A., Connelly, K., Upoma, A.M. (2008). *Encouraging physical activity in teens Can technology help reduce barriers to physical activity in adolescent girls?* Paper presented at the Second International Conference on Pervasive Computing Technologies for Healthcare, 2008, Tampere, Finland.

Tudor-Locke, C., Lee, S.M., Morgan, C.F., Beighle, A., & Pangrazi, R.P. Children's pedometer-determined physical activity during the segmented school day. *Medicine and Science in Sports and Exercise, 38,* 1732-1738.

United States Department of Health and Human Services Administration for Children and Families Child Care Bureau. (2006). *Promoting Physical Activity and Healthy Nutrition in Afterschool Settings: Strategies for Program Leaders and Policy Makers,* 1-32. Retrieved from http://www.researchconnections.org/childcare/resources/13558/pdf.

United States Department of Health and Human Services. (2008). *Physical activity guidelines advisory committee report.* Health and Human Services, Editor. Washington DC.

United States Department of Health and Human Services. (2010). *Healthy people 20W: Understanding and improving health.* Retrieved from http://www.healthypeople.gov/lhi/lhiwhat.htm.

United States Department of Education. (2011). *21st Century Community Learning Centers*. Retrieved from http://www.ed.gov.

van der Horst, K., Paw, M.J.C.A., Twisk, J.W.R., & van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine & Science in Sports & Exercise, 39*(8), 1241-1250.

Vandewater, E.A., Shim, M., Caplovitz, A.G. (2004). Linking obesity and activity level with children's television and video game use. *Journal of Adolescence, 27*(1), 71-85.

Weissenberger, U., & Thompson, C.F. (2009). User-centered design: Getting it right the first time. SAP AG.

Whitt-Glover, M.C., Taylor, W.C., Floyd, M.F., Yore, M.M., Yancey, A.K., & Matthews, C.E. (2009). Disparities in physical activity and sedentary behaviors among US children and adolescents:

Prevalence, correlates, and intervention implications. *Journal of Public Health Policy, 30*(Suppl 1), S309-S334.

Yamakami, T. (2012). Mobile social game design from the perspective of persuasive technology. Proceedings from NBiS '12: *The 15th International Conference on Network-Based Information Systems,* Melbourne, Australia.

CHAPTER 2: MANUSCRIPT 1

Assessing the internal and external validity of mobile health physical activity promotion interventions: A systematic literature review using the RE-AIM Framework

Authors: Kacie Allen BS[1], Margaret Berrey BS[1], Ramine Alexander BS[1], Jason Fanning BS[2], Jamie Zoellner PhD[1], Paul A. Estabrooks PhD[1]

Affiliations: [1]Virginia Tech, Human Nutrition, Foods, and Exercise, Blacksburg, VA; [2]University of Illinois at Urbana-Champaign, Department of Kinesiology and Community Health, Urbana-Champaign, IL

Abstract

Mobile health (mhealth) interventions are effective in promoting physical activity (PA); however the degree to which external validity indicators are reported is unclear. The purpose of this systematic review was to use the RE-AIM (reach, effectiveness, adoption, implementation, and maintenance) framework to examine the extent to which mhealth interventions for promoting PA are generalizable across settings and populations; and provide recommendations for investigators planning to conduct this type of research. Twenty articles reflecting 15 trials published between 2000 and 2012 were identified through a systematic review process (i.e., queries of three online databases, reference lists of eligible articles) and met inclusion criteria (i.e., implementation of mobile technologies, target physical activity, and provide original data). Two researchers coded each article, using a validated RE-AIM data extraction tool (reach, efficacy/effectiveness, adoption, implementation, maintenance). Two members of the study team independently abstracted information from each article (inter-rater reliability >90%) and group meetings were used to gain consensus on discrepancies. The majority of studies were randomized controlled trials (n=14). The average reporting across RE-AIM indicators varied by dimension (reach=54.7%; effectiveness/efficacy=77.8%; adoption=11.1%; implementation=24.4%; maintenance=0%). While most studies described changes in the primary outcome (effectiveness), few addressed the representativeness of participants (reach) or settings (adoption) and few reported on issues related to maintenance and degree of implementation fidelity. This review suggests that more efforts need to focus on research designs that highlight and report on both internal and external validity indicators. Specific recommendations are provided to encourage future mhealth interventionists and investigators to report on representativeness, settings, delivery agents for planned interventions, the extent to which protocol is delivered as intended, and maintenance of effects at the individual or organizational level.

Keywords: Physical activity, Mobile technology, Review, Systematic

Introduction

The numerous health benefits of physical activity (PA) are well known, but still it is estimated that roughly 31% of the world's adult population (28% men, 34% women) is classified as insufficiently active (WHO, 2008). Likewise, it is a concern in the US where only 6-11% of children (Trojano et al., 2008) and 8.2% of adults are meeting the national PA guidelines based upon objective physical activity assessments (Tucker, Welk, & Beyler, 2011). Given these low PA rates, there is a need for increased attention to the development of effective and scalable PA promotion interventions that can reach a large number of people at a low cost (Davies, Spence, Vandelanotte, Caperchione, & Mummery, 2012).

One such approach is the use of mobile technology, since ownership is on the rise in adults and children (Smith, 2010; Lenhart, 2010). In 2011, 70% of the world's population were mobile phone subscribers (The World Bank, 2011), by 2012, it was estimated that there were 7 billion mobile-connected devices across the globe and the number of mobile devices outnumbered the human population (Cisco Systems, Inc., 2012). In the US, mobile technology ownership statistics are high as well. According to a 2012 nationally representative survey, more than 88% of American adults own mobile phones which is an 11% increase from 2011 (Smith, 2012). Fifty-three percent of American mobile phone owners own a smartphone (Smith, 2012). Furthermore, roughly 75% of 12-17 year olds own mobile phones which is a drastic surge (i.e., up 30%) from 2004 (Lenhart, 2010).

This growth in mobile technology ownership has led to the development of a number of PA promotion interventions (Fjeldsoe, Marshall, & Miller, 2009; Heron, & Smyth, 2010; Krishna, Boren, & Balas, 2009; Lau, Lau, Wong, & Ransdell; Militello, Kelly, & MeInyk, 2012). For example, mobile health (mhealth) interventions that deliver information and behavioral strategies through short message service (SMS) via mobile phones have been developed to increase PA (Fjeldsoe, Marshall, & Miller, 2009; Heron, & Smyth, 2010; Krishna, Boren, & Balas, 2009; Lau, Lau, Wong, & Ransdell; Militello, Kelly, & MeInyk, 2012). In addition, ecological momentary interventions (EMI) through palmtop computers and mobile phones (Heron, & Smyth, 2010) can enhance interventions and aid in improving health outcomes. A recent meta-analysis on the use of mobile devices for PA promotion summarized the

literature in this area and concluded that interventions delivered through this modality are effective for increasing PA (Fanning, Mullen, & McAuley, 2012).

Despite the popularity of commercially available health-related applications, there is little evidence that the mobile phone-based interventions with demonstrated efficacy have been translated beyond the research setting and been broadly adopted (Dolan, 2010). One potential reason for the lack of translation of these interventions into more wide spread use is that the scientific approach typically emphasizes high internal validity at the expense of external validity (Estabrooks & Gyurcsik, 2003a) Current reviews of mhealth interventions have based the quality evaluation of studies through the lens of internal validity, and as such conclusions are largely limited to factors related to intervention efficacy/effectiveness (Fjeldsoe, Marshall, & Miller, 2009; Heron, & Smyth, 2010; Krishna, Boren, & Balas, 2009; Lau, Lau, Wong, & Ransdell; Militello, Kelly, & MeInyk, 2012; Fischer, Stewart, Mehta, Wax, & Lapinsky, 2003). Unfortunately, the extent to which these evidence-based mhealth interventions report on or achieve external validity to different settings and populations is unclear.

Glasgow and colleagues (Glasgow, Vogt, Boles, 1999) developed a useful RE-AIM framework for evaluating the degree to which behavioral interventions, including those targeting physical activity, report on internal and external validity factors (Glasgow, Klesges, Dzewaltowski, Bull, & Estabrooks, 2004). The framework specifies standards related to the reporting of **r**each into the target population and representativeness of the study sample; **e**fficacy/effectiveness of the intervention on the primary outcome, quality of life, and avoidance of unintended or negative consequences; **a**doption rates of organizations and staff that would ultimately use the intervention and the characteristics of those organizations and staff; the degree to which the intervention is **i**mplemented as intended; and the **m**aintenance of effects at the individual level and sustainability of the intervention at an organizational level (RE-AIM; (Glasgow, Vogt, Boles, 1999)). The RE-AIM framework has demonstrated utility in summarizing reports of internal and external validity factors across numerous bodies of literature (e.g., weight loss maintenance, health literacy, tobacco use, PA interventions for older adults and for breast cancer survivors) (Akers, Estabrooks, & Davy, 2010; Allen, Zoellner, Motley, & Estabrooks, 2011; Antikainen & Ellis, 2011; Bull,

Gillette, Glasgow, & Estabrooks, 2003; Dzewaltowski, Estabrooks, Klesges, Bull, & Glasgow, 2004; Estabrooks, Dzewaltowski, Glasgow, & Klesges, 2003; Glasgow, Bull, Gillette, Klesges, & Dzewaltowski, 2002; Kessler et al., 2012; Klesges, Dzewaltowski, Glasgow, 2008; McMahon, & Fleury, 2012; White, McAuley, Estabrooks, & Courneya, 2009). Collectively, these previous reviews have provided recommendations and future directions to enhance the likelihood for future intervention translation from research to practice settings. Despite the popularity and efficacy of mhealth-based PA interventions (Fanning et al., 2012), no known systematic review has examined the reporting of both internal and external validity factors. Therefore, the primary purpose of this systematic review is to determine the degree to which studies testing mhealth interventions to promote PA report across the RE-AIM dimensions. Recommendations to improve the likelihood of broad dissemination of effective mhealth interventions are also provided.

Methods

Selection of Studies for Review

This review focused on mhealth interventions that targeted PA promotion. The search strategies and methods for selection of mhealth intervention studies for this systematic review were identical to a recently published meta-analysis publication that focused solely on intervention effectiveness at the individual level, and have been described in detail (Fanning et al., 2012). In short, the literature search was conducted between August 2011 and July 2012 and included articles published between 2000 and 2012 which met the inclusion criteria indicated in Table 2-1. Review articles, observational (e.g., cross-sectional, descriptive), commentaries, methodological articles, and articles not explicitly related to PA were excluded. Implementation of mobile technologies included data collection or conveyance of intervention information via SMS, or native mobile device software or hardware. The search strategies to identify eligible articles included queries using three online databases (PsycINFO, PubMed, and Scopus) and a hand search of reference lists for of articles that met inclusion criteria. In addition to comprehensively evaluate the reporting of RE-AIM criteria on a single trial, data was extracted from companion articles (e.g., qualitative/quantitative methods measuring implementation) of studies that met

inclusion criteria. The initial search yielded 1497 non-duplicated articles that possibly met inclusion criteria (see Table 3-1). From there, titles which did not meet inclusion criteria were eliminated (n=1426). Abstracts (n=71) and subsequently full-text articles (n=24) were assessed against the inclusion criteria. In total, 20 articles representing 15 trials were included in this systematic review.

[Insert Table 2-1]

Assessment of Reporting Quality Across RE-AIM Dimensions

Quality of articles was determined using a previously developed 21 item validated data extraction tool that included both internal and external validity indicators based on the RE-AIM framework (Akers et al., 2010; Allen et al., 2011; Dzewaltowski et al., 2004; Estabrooks et al., 2003; Glasgow et al., 2002). Table 2-2 included details on each of the indicators assessed across the RE-AIM framework, included 5 reach components, 4 efficacy/effectiveness components, 6 adoption components, 3 implementation components and 3 maintenance components.

Coding Protocol and Scoring

All studies were coded independently by two members of the research team with the exception of the first three studies which were coded by five members of the research team to promote familiarity with the data extraction tool. For each of the 21 items, coders indicated whether or not the indicator was reported (i.e., yes or no), and subsequently extracted specific data. After independently coding, the Kappa statistic (Cohen, 1960) was calculated to evaluate inter-rater reliability. The average Kappa statistic for consistency of coding was 0.90, indicating strong inter-rater reliability. For the differences that did arise, researchers met to discuss articles, resolve uncertainty, and gain consensus in the coding by revisiting the specific article.

To calculate the proportion reporting for each item, the number of coded "yes" was added across the 15 studies and then divided by 15. Then the resulting number became the proportion reporting for that particular item. An overall quality score for each article was calculated based on the number of reported indicators (possible score 0-21). Quality score categories have been published in a past RE-AIM review

(Allen et al., 2011), with articles scoring 15-21, 8-14, and less than 8, were considered high, moderate, and low quality reporting, respectively.

Results

Study Characteristics

All trials were published after 2006 and 13 were conducted in Western countries. Six studies were conducted in the United States (Burke et al., 2009, 2011; Conroy et al., 2011; Consolvo et al., 2008; Fukuoka, Vittinghoff, Jong, & Haskell, 2010; Fukuoka, Kamitani, Dracup, & Jong, 2011; Fukuoka, Lindgren, & Jong, 2012; King et al., 2008; Nguyen, Gill, Wolpin, Steele, & Benditt, 2009; Shapiro et al., 2008), three trials were conducted in the United Kingdom (Hurling et al., 2007; Prestwich, Perugini, Hurling, 2010; Sirriyeh, Lawton, & Ward, 2010), three trials were conducted in Australia (Fjeldsoe, Miller, & Marshall, 2010; Kirwan, Duncan, Vandelanotte, & Mummery 2012; Lubans et al., 2010, 2012) and one each was conducted in Hong Kong (Cheung, Chow, & Parfitt, 2008), New Zealand (Newton, Wiltshire, & Elley, 2009) and Taiwan (Liu et al., 2008). The majority of studies were randomized controlled trials (Burke et al., 2009, 2011; Cheung et al., 2008; Conroy et al., 2011; Consolvo et al., 2008; Fjeldsoe et al., 2010; Lubans et al., 2010, 2012; King et al., 2008; Kirwan et al., 2012; Liu et al., 2008; Newton et al., 2009; Nguyen et al., 2009; Hurling et al., 2008; Prestwich et al., 2010; Shapiro et al., 2008; Sirriyeh et al., 2010) and one was a quasi-experimental without control group (Fukuoka et al., 2010, 2011, 2012). Most studies were individual-based (Cheung et al., 2008; Consolvo et al., 2008; Fjeldsoe et al., 2010; Fukuoka, Vittinghoff, Jong, & Haskell, 2010; Fukuoka, Kamitani, Dracup, & Jong, 2011; Fukuoka, Lindgren, & Jong, 2012; King et al., 2008; Liu et al, 2008; Newton et al., 2009; Nguyen, Gill, Wolpin, Steele, & Benditt, 2009; Hurling et al., 2007; Kirwan et al., 2012; Prestwich et al., 2010; Sirriyeh et al., 2010), two were group-based (Burke et al., 2009, 2011; Conroy et al., 2011; Lubans et al., 2010; 2012) and one was individual and group-based (Shapiro et al., 2008) Length of studies ranged from 2 weeks to 2 years, with an average of 19 weeks. The most commonly reported intervention length was 12 weeks.

Five studies measured PA only through self-report (Burke et al., 2009, 2011; Conroy et al., 2011; Fjeldsoe et al., 2010; King et al., 2008; Kirwan et al., 2012; Shapiro et al., 2008), four used objective measures (Consolvo et al., 2008; Liu et al., 2008; Shapiro et al., 2008; Sirriyeh et al., 2010), and three used both self-report and objective measures (Fukuoka et al., 2010, 2011, 2012; Hurling et al., 2007; Newton et al, 2009). Of the seven studies that objectively measured PA half of the studies used a pedometer (Cheung et al., 2008; Fukuoka et al., 2010, 2011, 2012; Newton et al., 2009; Shapiro et al., 2008). Each of the following objective PA measures were collected once: both biaxial and triaxial accelerometers (Lubans et al., 2010; 2012), uniaxial accelerometers (Hurling et al., 2007), biaxial accelerometers (Nguyen et al., 2009), the walking distance of the incremental shuttle walking test (Liu et al., 2008), and a mobile sensing platform (Consolvo et al., 2008).

In addition to PA, the majority of studies (n=11) reported on other outcomes. Eight studies reported on body mass index (Burke et al., 2009, 2011; Cheung et al., 2008; Conroy et al., 2011; Consolvo et al, 2008; Fukuoka et al., 2010, 2011, 2012; Hurling et al., 2007; Liu et al., 2008; Prestwich et al., 2010); one on BMI-z (Newton et al., 2009); five studies reported on physiological outcomes (Burke et al., 2009, 2011; Conroy et al., 2011; Hurling et al,. 2007; Liu et al., 2008; Newton et al., 2009; Nguyen et al., 2009); five studies on psychological outcomes (Cheung et al., 2008; Fukuoka et al., 2010, 2011, 2012; Hurling et al,. 2007; Lubans et al., 2010; 2012; Nguyen et al., 2009); three studies on weight (Burke et al., 2009, 2011; Conroy et al., 2011; Hurling et al,. 2007; Prestwich et al. 2010); two each on sedentary activity/screen time (Lubans et al., 2010; 2012; Shapiro et al., 2008), diet (Burke et al., 2009, 2011; Conroy et al., 2011; Lubans et al., 2010; 2012), percent body fat (Cheung et al., 2008; Hurling et al., 2007); and one on each of the following outcomes: sugar sweetened beverages intake (Shapiro et al., 2008), upper body muscular endurance and core abdominal isometric muscular endurance (Lubans et al., 2010; 2012), and waist to hip ratio (Prestwich et al. 2010); and waist circumference (Burke et al., 2009, 2011; Conroy et al., 2011).

The types of mobile devices used were similar across studies. Nearly all studies (n=13) used mobile phones while two used personal digital assistants (Burke et al., 2009, 2011; Conroy et al., 2011;

Hurling et al., 2007). Most frequently, mobile technology was implemented as a way to monitor outcomes via self-report (Burke et al., 2009, 2011; Conroy et al., 2011; Hurling et al., 2007; Nguyen et al., 2009; Shapiro et al., 2008) or data from an external pedometer/accelerometer was manually entered on the mobile phone (Hurling et al., 2007; King et al., 2008). Additionally, mobile technology was used to provide prompts Fukuoka et al., 2010, 2011, 2012; Newton et al., 2009; Prestwich et al., 2010), to encourage behavior change (Fjeldsoe et al., 2010; Sirriyeh et al., 2010), and provide health promotion information sent through short message service (SMS) (Lubans et al., 2010; 2012). Furthermore, in two studies mobile technology was used as an interactive mobile application (Consolvo et al., 2008; Kirwan et al., 2012), in one study to deliver an exercise program (Liu et al., 2008) and in another study as a mobile PA diary (Fukuoka et al., 2010, 2011, 2012). Table 2-3 shows the overall quality of RE-AIM reporting across the 21 item validated extraction tool which is displayed as the proportion reporting

[Insert Table 2-3]

Reach

Reach was the second most reported dimension at 54.7%. Approximately half of all studies reported on four of the five items (method to used identify target population, inclusion and exclusion criteria and participation rate). The least reported component was representativeness, with only four studies reporting (Burke et al., 2009, 2011; Conroy et al., 2011; Fjeldsoe et al., 2010; Fukuoka et al., 2010, 2011, 2012; Liu et al., 2008). None of the studies reported on characteristics of dropouts. All trials reported on sample size which ranged from 17 to 210 participants with a median of 78. The majority of studies described recruitment strategies (n=11), which happened through various ways. Eleven studies focused on child participants (Burke et al., 2009, 2011; Cheung et al., 2008; Conroy et al., 2011; Consolvo et al., 2008; Fjeldsoe et al., 2010; Fukuoka et al., 2010, 2011, 2012; Hurling et al., 2007; King et al., 2008; Kirwan et al., 2012; Liu et al., 2008; Nguyen et al., 2009; Prestwich et al., 2010), while four focused on adult participants (Lubans et al., 2010, 2012; Newton et al., 2009; Sirriyeh et al., 2010). Approaches for recruiting children participants included sending recruitment letters home with children (Shapiro et al., 2008), giving a presentation at school assemblies (Sirriyeh et al., 2010), teacher referrals

(Lubans et al., 2010, 2012), and using university listservs (Shapiro et al., 2008). The majority of studies that enrolled adult participants were recruited mainly through local or mass media. Local mass media strategies included distributing flyers (Burke et al., 2009, 2011; Conroy et al., 2011), using voicemail announcement systems (Burke et al., 2009, 2011; Conroy et al., 2011), using mailing lists (Burke et al., 2009, 2011; Conroy et al., 2011), posting ads on city buses (Burke et al., 2009, 2011; Conroy et al., 2011), placing newspaper announcements (Fukuoka et al., 2010, 2011, 2012), emailing (Prestwich et al., 2010; Kirwan et al., 2012), and using local mass media outlets (King et al., 2008; Shapiro et al., 2008). Other studies recruitment methods comprised of obtaining names and contact information from pulmonary rehabilitation coordinators (Nguyen et al., 2009) one by contacting individuals on a weight research registry via letter or email (Burke et al., 2009, 2011; Conroy et al., 2011), targeting previous trial participants (Burke et al., 2009, 2011; Conroy et al., 2011), and using a market research recruitment agency (Consolvo et al, 2008; Hurling et al., 2007).

Efficacy/Effectiveness

Efficacy/Effectiveness was the most reported dimension at 77.8%. All studies reported on measures or results for at least one follow-up. Approximately three quarters of the studies reported on percent attrition (Burke et al., 2009, 2011; Conroy et al., 2011; Fjeldsoe et al., 2010; Fukuoka et al., 2010, 2011, 2012; King et al., 2008; Liu et al., 2008; Lubans et al., 2010, 2012; Newton et al., 2009; Nguyen et al., 2009; Prestwich et al., 2010; Shapiro et al., 2008; Sirriyeh et al., 2010). Percent attrition ranged from 0-53 percent. Four studies reported on intent-to-treat analysis (Cheung et al. 2008; Lubans et al., 2010, 2012; Nguyen et al., 2009; Sirriyeh et al., 2010) six stated present at follow-up analyses were used (King et al., 2008; Kirwan et al., 2012; Liu et al., 2008; Prestwich et al., 2010; Shapiro et al., 2008; Sirriyeh et al., 2010), and one used present at follow-up and intention-to-treat analyses (Burke et al., 2009, 2011; Conroy et al., 2011). Of the two studies that reported a high attrition rate (i.e., 25% or higher) (Fjeldsoe et al., 2010; Shapiro et al., 2008), only one (Fjeldsoe et al., 2010) that indicated using intent-to-treat analysis.

The majority of studies (n=12) reported whether the trial was an efficacy or effectiveness trial. Of these studies, eight were efficacy trials (Fjeldsoe et al., 2010; Fukuoka et al., 2010, 2011, 2012; King et al., 2008; Kirwan et al., 2012; Liu et al., 2008; Nguyen et al., 2009; Shapiro et al., 2008; Sirriyeh et al., 2010) and four were effectiveness trials (Cheung et al., 2008; Consolvo et al., 2008; Kirwan et al., 2012; Lubans et al., 2010, 2012). A little over 30 percent of studies reported quality of life or potential negative outcomes (Burke et al., 2009, 2011; Cheung et al., 2008; Conroy et al., 2011; Hurling et al., 2007; Newton et al., 2009; Nguyen et al., 2009). In terms of PA outcomes for the 14 controlled trials, six studies found that the intervention group had significant differences compared to the control group, four studies had mixed results, and four had non-significant differences between groups. In the only quasi-experimental, single group study included in this study, the post-assessments of PA were significantly higher than pre-assessments (Fukuoka et al., 2010, 2011, 2012). Only one study assessed cost effectiveness, which indicated that costs per participant associated with a mobile phone-based exercise program with coaching ($655), was similar in cost to the same program without coaching ($580) (Nguyen et al., 2009). Moreover there were no significant differences in PA outcomes (i.e., six minute walk distance) between these two groups (i.e., mobile-coached versus mobile self-monitored) in the study (Nguyen et al., 2009).

Adoption

The average proportion reporting on Adoption items was 11%. Level of expertise of delivery agent was the most reported Adoption component (n=5). The staff level of expertise descriptions included a nutritionist (Burke et al., 2009, 2011; Conroy et al., 2011), a master's level prepared exercise physiologist (Burke et al., 2009, 2011; Conroy et al., 2011), a research assistant (Fjeldsoe et al., 2010), a behavioral counselor (Fjeldsoe et al., 2010), a nurse (Nguyen et al., 2009), and a psychologist (Shapiro et al,. 2008). No studies reported on method to identify staff who delivered the intervention, description of staff who delivered the intervention, inclusion/exclusion criteria of delivery agent, or adoption rate of delivery agent.

Setting-level reporting was similar to staff-level reporting. Only five studies specified the intervention location: a school (Cheung et al., 2008; Lubans et al., 2010, 2012), a research center physiologist (Burke et al., 2009, 2011; Conroy et al., 2011; Hurling et al., 2007), and an outpatient setting from four regional adolescent diabetes services (Newton et al., 2009). Lastly, only two studies described the intervention location (Cheung et al., 2008; Lubans et al., 2010, 2012), two studies noted inclusion/exclusion criteria of setting (Cheung et al., 2008; Lubans et al., 2010, 2012), and one indicated adoption rate of setting (Lubans et al., 2010, 2012).

Implementation

The average proportion reporting on Implementation indicators was 24%. Intervention duration and frequency were the most frequently reported items ((n=6); Burke et al., 2009, 2011; Conroy et al., 2011; King et al., 2008; Kirwan et al., 2012; Lubans et al., 2010, 2012; Nguyen et al., 2009; Shapiro et al., 2008). Few studies reported on measures of cost of implementation ((n=3); Liu et al., 2008; Lubans et al., 2010, 2012; Nguyen et al., 2009) or the degree to which the intervention protocol was carried out as intended ((n=2); Hurling et al., 2007; Lubans et al., 2010, 2012). More than half (n=8) of the studies had a theoretical basis (Burke et al., 2009, 2011; Cheung et al., 2008; Conroy et al., 2011; Consolvo et al., 2008; Fjeldsoe et al., 2010; Hurling et al., 2007; King et al., 2008; Lubans et al., 2010, 2012; Prestwich et al., 2010) with the social cognitive theory being used most frequently ((n=3); Fjeldsoe et al., 2010; King et al., 2008; Lubans et al., 2010, 2012). Almost all studies (n=13) stated the degree to which participants received intervention components, including methods such as self-monitoring of outcomes through mobile technology (e.g., mobile phone or PDA), class attendance, application usage, or the completion of intervention (Burke et al., 2009, 2011; Conroy et al., 2011; Consolvo et al., 2008; Fjeldsoe et al., 2010; Fukuoka et al., 2010, 2011, 2012; Hurling et al., 2007; King et al., 2008; Kirwan et al., 2012; Lubans et al., 2010, 2012; Liu et al., 2008; Newton et al., 2009; Prestwich et al., 2010; Shapiro et al., 2008; Sirriyeh et al., 2010).

Maintenance

The reporting on indicators of maintenance was lowest among the other RE-AIM dimensions, with no items reported on average. Indicators of program-level maintenance (i.e., the extent to which the program is maintained upon completion of the trial) were not reported in any trial.

Quality of Reporting

The average quality of reporting score was a 6.9 out of a possible 21 item reporting coding sheet and scores ranged from 3-13. None of the studies were categorized as high reporting quality, six studies were moderate (range 8-11; (Burke et al., 2009, 2011; Conroy et al., 2011; Fjeldsoe et al., 2010; Liu et al., 2008; Lubans et al., 2010, 2012; Nguyen et al., 2009; Shapiro et al., 2008), and nine studies were of low reporting quality (Cheung et al., 2008; Consolvo et al., 2008; Fukuoka et al., 2010, 2011, 2012; Hurling et al., 2007; King et al., 2008; Kirwan et al., 2012; Newton et al., 2009; Prestwich et al., 2010; Sirriyeh et al., 2010).

Discussion

The present systematic review evaluated mhealth interventions promoting PA in adults and/or children from an internal and external validity view. Although 15 trials were included the majority did not report on external validity indicators and internal validity indicators (e.g., implementation). To our knowledge this is the first systematic review of mhealth interventions for PA promotion which examined external validity indicators operationalized using RE-AIM framework.

Reach

Several of our findings were consistent with past literature. Many studies reported on internal validity individual-level indicators. Method to identify the target population and inclusion and exclusion criteria were frequently reported on. This finding is consistent with past research ((> 60%); Akers et al., 2010; Allen et al., 2011; Klesges et al., 2008; White et al., 2009). On the other hand, the proportion reporting on participation rate was lower than was has typically been reported in past reviews ((>59%); Dzewaltowski et al., 2004; Estabrooks et al., 2003; Glasgow et al., 2002; Klesges et al., 2008). Defining a valid denominator that comprises of the total number of individuals who were approached and eligible is important. Once the denominator is defined, researchers should divide that by the number in the study

sample. Calculating a participation rate helps researchers get a sense of the effectiveness of recruitment activities. It was unclear the extent of which the study samples were representative of the target population because this was hardly reported on. Moreover, characteristics of non-participants who were approached and eligible or characteristics of the target population were seldom reported. This finding is consistent with past RE-AIM reviews (Akers et al., 2010; Allen et al., 2011; Glasgow et al., 2002; Klesges et al., 2008; McMahon et al., 2012; White et al., 2009). Additionally, due to the absence in reporting, inferences cannot me made in regards to what types of individuals (e.g., demographics, behavioral outcomes) are more likely to participate in mhealth PA interventions. The few studies that did report on characteristics of non-participants indicated that non-participants were less educated (Burke et al., 2009, 2011; Conroy et al., 2011; Fjeldsoe et al., 2010) and had greater difficulty in operating technology (Fukuoka et al., 2010, 2011, 2012; Liu et al., 2008). Only one study found that besides differences in education level, there were no other statistically significant differences in demographic characteristics between participants and non-participants (Fjeldsoe et al, 2010). However, there was no information from any of the studies to compare groups by PA level or mhealth technology experience. If mobile technology is going to be used in future studies to promote PA, investigators must be mindful that mhealth interventions should be useful to people regardless of technology experience and education level. Moreover, investigators must be careful not to increase health disparities with implementation of new mhealth technologies. Above all, conclusions cannot be drawn as to whether the study samples were representative of the target population.

Effectiveness

Similar to other reviews, measures and results for at least one follow up time point ((>100%); Akers et al., 2010; Allen et al., 2011; Antikainen et al., 2011; Dzewaltowski et al., 200; Estabrooks et al., 2003b; McMahon et al., 2012; White et al., 2009) and percent attrition ((>70%); Akers et al., 2010; Allen et al., 2011; Antikainen et al., 2011; Estabrooks et al., 2003b; White et al., 2009) were regularly reported on. The intervention with the highest attrition (58%) consisted of three weekly in-person sessions (Shapiro et al., 2008). So, future researchers know a lot about the efficacy/effectiveness of a mhealth PA

intervention outcomes and the expected percent attrition. On the other hand, just 33% reported using intent to treat analyses rather than present at follow-up. This proportion resembles past reviews (Allen et al., 2011; Antikainen et al., 2011; Estabrooks et al., 2003b). Thus, intervention effects may have been overestimated because studies primarily analyzed participants who were present at follow-up. Moreover the reporting of quality of life or negative outcomes was infrequently reported. This proportion is comparable to past reviews (Akers et al., 2010; Allen et al., 2011; Klesges et al., 2008; McMahon et al., 2012). It important to not only know, if a given mhealth PA promotion intervention is successful in PA promotion, but also if it affects quality of life. To enhance program evaluation and participant engagement, understanding potential negative outcomes of an intervention and quality of life should be assessed (Akers et al., 2010; Glasgow et al., 2002).

Adoption

Overall, when compared to individual-level measures, setting-level measures were reported least. The reporting of description of intervention location was much lower compared with past reviews (Akers et al., 2010; Allen et al., 2011; Klesges et al., 2008; McMahon et al., 2012; White et al., 2009). Moreover, dissimilar from other reviews, reporting on description of delivery staff was considerably lower (Akers et al., 2010; Klesges et al., 2008; McMahon et al., 2012; White et al., 2009). The settings that were reported on included schools and clinics. In terms of description of settings, one study provided the range of number of teachers at the school and the other provided school income level. However, there is hardly any information known about the characteristics of the intervention location and delivery staff. Due to the absence of information, the resources needed to conduct mhealth interventions in diverse locations are unknown. Moreover, since there is no information on the characteristics of the delivery staff, it is unclear what characteristics are required for successful implementation. Consistent with earlier reviews, method to identify staff who delivered intervention was seldom reported (Akers et al., 2010; Allen et al., 2011; Glasgow et al., 2002; Klesges et al., 2008; McMahon et al., 2012; White et al., 2009). When compared to other reviews (Akers et al., 2010; Klesges et al., 2008; McMahon et al., 2012) level of expertise of delivery agent was less reported. The limited information provided on the intervention staff shows that the

interventions were delivered by research staff or highly skilled individuals (e.g., psychologists, nurse, behavior counselor, and dietician). Thus, it is unclear how interventions would be implemented when conducted by "non-research" staff (e.g., staff at community centers). Inclusion/exclusion criteria of delivery agent or setting and adoption rate of delivery agent or setting were hardly recorded which is similar to previous reviews (Akers et al., 2010; Allen et al., 2011; Glasgow et al., 2002; Klesges et al., 2008; White et al., 2009). Due to this lack of information, it is unclear why certain delivery agents or settings were selected. Indicating the staff or setting for mhealth interventions, may be less relevant if the intervention is completely implemented by the mobile technology. However, in most of the studies in this review this was not the case. Reporting on the participation rate of settings and representativeness of the participating settings is important so that researchers know who is actually adopting and thus the potential impact and extent of generalizability can be estimated (Estabrooks et al., 2003). In summary, none of the included studies reported on all of the dimensions of adoption.

Implementation

Reporting Implementation (fidelity) is vital for researchers to better understand the essential elements of a program or intervention. Unlike prior reviews, intervention duration and frequency were reported in a fairly high proportion of studies (Akers et al., 2010; Allen et al., 2011; McMahon et al., 2012; White et al., 2009). This data is informative, so that future researchers can determine how long and often to have a mhealth PA promotion intervention. Past RE-AIM reviews have had mixed results in the proportion of reporting on the extent to which the intervention protocol was delivered as intended. In the current review, the proportion reporting on this item was low which is consistent with some reviews (Akers et al., 2010; Allen et al., 2011; Klesges et al., 2008; McMahon et al., 2012). For example, one of the shorter studies consisted of daily and weekly 2-3 minute surveys on a PDA (King et al., 2008), while a longer study comprised of; one to two 10 minute telephone calls over six months and one to two minutes were spent on text messages per week (Nguyen et al., 2009). Very few of studies reported on extent delivered as intended which is consistent with past RE-AIM reviews (Akers et al., 2010; Allen et al., 2011; Antikainen et al., 2011; Bull et al., 2003; McMahon et al., 2012). Without knowledge of

detailed implementation components and the extent to which the trial was delivered as it was designed, solving short term implementation problems and replicating findings becomes difficult. Investigators need to be able to evaluate the effectiveness of an intervention based on the actual process (Antikainen et al., 2011). Lastly, consistent with most prior reviews, the measures of implementation costs were seldom indicated (Akers et al., 2010; Allen et al., 2011; Bull et al., 2003; Glasgow et al., 2002; McMahon et al., 2012; White et al., 2009). To better understand implementation of mhealth PA promotion interventions, future investigators, need to know the actual costs related to implementation so that they can determine feasibility, how much money to request from funding sources and time allotted for implementation.

Maintenance

Consistently, maintenance has been the least reported dimension of RE-AIM. Reporting of outcomes longer than or equal to 6 months was rarely stated in past reviews (Akers et al., 2010; Allen et al., 2011; Glasgow et al., 2002). Furthermore, as in prior reviews, indicators of program level maintenance and measures of maintenance costs have been regularly unrecorded (Akers et al., 2010; Allen et al., 2011; Glasgow et al., 2002; Klesges et al., 2008; White et al., 2009). Reporting on individual and setting-level indicators of maintenance needs to be a priority to researchers because it helps future researchers understand the impact of an intervention. Mhealth interventions may be more prone to maintenance related issues because of advancements in newer technology, potential higher frequency of technical problems or decreased participant engagement over time. However, since none of the studies reported on maintenance, there is a lack of clarity present.

Recommendations

Table 2-4 presents recommendations for the reporting of internal and external validity indicators. Specific recommendations are provided for investigators implementing m
health PA interventions. Of note, there are specific recommended guidelines for PA, but no study reported on the degree to which intervention participants met these criteria upon program completion. These suggestions are not comprehensive but can be used as a guide and built upon when reporting data.

Strengths

This review investigated reporting of commonly described internal validity indicators and occasionally mentioned external validity elements. We used multiple trained coders and had high inter-rater reliability. Additionally, we developed a companion sheet (including definitions and descriptions of variables) that complemented the validated data extraction sheet. Lastly, we clearly defined our purpose, inclusion and exclusion criteria, conducted a stringent search strategy and examined the quality of quantitative and qualitative data reporting.

Limitations

This review does have some limitations. First, we focused on PA promotion interventions that implemented mobile technologies but excluded observational studies. Excluding these studies may have hindered relevant information for included trials. Second, because this technology is relatively novel, the goal of the studies included within this review may have been to establish internal validity (e.g., effectiveness of study outcomes), and therefore we must be cautious of being overly critical of these studies relative to their compliance with RE-AIM principles. Lastly, we looked for the presence of an item on the coding sheet which does not indicate the quality of the actual item. For example, an article that reported a single sentence description versus an article that described a paragraph description still was ranked equally.

Conclusion

Our review suggests that while many mhealth PA promotions interventions have done a fairly good job on reporting on measures of effectiveness, other internal validity indicators (e.g., fidelity) and external validity indicators are rarely reported on. It is difficult to determine the relevance of study outcome results of mhealth PA promotion interventions without important fidelity and generalizability details. To better understand intervention efficacy, how these effects are maintained in the long term, and who it is actually reaching, researchers should pay equitable attention to external and internal validity and report on these items, which may help to promote advancements in mhealth PA studies. Thus, as more mobile technology is developed and utilized for health promotion, theoretical and evidence-based approaches must continue to be used.

Table 2-1 Inclusion Criteria

Data type	Inclusion criteria
Participants Language Study design Control condition Intervention Measurement Primary outcome Type of data	• Any age • English • Experimental and quasi-experimental • Any comparator including active control, inactive control, or pre- and post-measure • Implementation of mobile technologies • Assesses physical activity directly among participants • Physical activity • Original

Table 2-2 RE-AIM Internal and External Validity Indicators

RE-AIM dimension/indicator	Description	Importance
Reach: individual level	The number, proportion, and representativeness of participants	
Method to identify target population	Describe the process by which the target population was identified for participation in the intervention.	Helps investigators develop an approach to determining who may be suitable for the intervention. Examples include using an electronic medical record query or mass media approaches (Estabrooks & Gyurcsik, 2003)
Inclusion criteria	Explicit statement of characteristics of the target population that were used to determine if a potential participant is eligible to participate.	Inclusion criteria should be as inclusive as possible to improve the external validity of findings (National Institutes of Health [NIH], 2012).
Exclusion criteria	Explicit statement of characteristics that would prevent a potential participant from being eligible to participate.	Exclusion criteria should be considered carefully to prevent potential harm to prospective participants, but should also avoid excluding individuals based on criteria that could be related to SES (e.g., ability to travel to intervention site), comorbidities, or other factors that could influence an externally valid depiction of intervention effects (NIH, 2012).
Participation rate	Sample size divided by the target population denominator	Provides information on the acceptability of the study and interventions from the perspective of the target population (Glasgow et al., 1999).
Representativeness	Explicit statement of characteristics of the study participants in comparison to the target population.	Identifies disparities in participation and informs the degree to which the study results are generalizable to the target population (Glasgow et al., 1999).
Efficacy/effectiveness: individual level	The measure of the primary outcome, quality of life, and on avoiding unintended negative consequences	
Measures/results for at least one follow-up	The study variable(s) are measured at a time point after baseline.	To evaluate whether the intervention outcomes were statistically significant or changed (positively/negatively) (Glasgow et al., 1999).
Intent to treat analysis utilized	Analyzing participants in trials in the groups to which they were randomized, regardless of whether they received or adhered to the allocated	Reduces bias from omitting individuals who were lost to follow-up and improves generalizability (The Cochrane Collaboration, 2002)

	intervention	
Quality-of-life or potential negative outcomes	Quality-of-life (QOL): Includes a measure of quality of life with some latitude for coding articles that refer to well-being or satisfaction with life. Negative outcomes; To evaluate unanticipated consequences and results that may be a product of the intervention and may have caused unintended harm.	Provide a metric to compare across interventions with different behavioral targets and provides a better sense of the impact that the intervention on the participants' perceptions of health (Glasgow et al., 1999). Allows for the weight of the harms and benefits of an intervention (Glasgow et al., 1999).
Percent attrition	The proportion that was lost to follow-up or dropped out of the intervention.	High attrition lowers statistical power and treatment-correlated attrition of participants from conditions threatens internal validity (Shadish, Cook, & Campbell, 2002)
Adoption: organizational level (setting and staff)	The number, proportion, and characteristics of adopting organizations and staff	
Description of intervention location	The explicit statement of characteristics of the location of the intervention.	Provides an understanding of resources needed for future researchers (Glasgow et al., 1999).
Description of staff who delivered intervention	The explicit statement of characteristics of the staff who delivered the intervention	Provides information on the characteristics may be needed to deliver an intervention and assist with retention of participants (Klesges, Dzewaltowski & Glasgow, 2008).
Method to identify staff who delivered intervention (target delivery agent)	Describe the process by which the staff was identified for participation in the study.	Helps investigators develop an approach to identify and engage staff that may be suitable for intervention delivery (Klesges et al., 2008).
Level of expertise of delivery agent	Training or educational background in of those delivering the intervention	Allows for the assessment of generalizability of those delivering an intervention to typical practice settings delivery (Klesges et al., 2008).
Inclusion/exclusion criteria of delivery agent or setting	The explicit statement of characteristics of the setting/agent that were used to determine if a potential setting /agent is eligible to participate.	Inclusion criteria should be as inclusive as possible to improve the external validity of findings. Exclusion criteria should not systematically remove potential settings or staff that typical in the practice domain (Estabrooks & Gyurcsik, 2003).
Adoption rate of delivery agent or setting	The number of participating delivery settings or agents divided by the number of eligible and approached delivery	Provides information on the acceptability of the study and interventions from the perspective of the setting and staff that will ultimately be responsible for intervention delivery (Glasgow et al., 1999).

	settings or agents	
Implementation: organizational level	The degree to which the intervention is delivered as intended	
Intervention duration and frequency	Duration: length the intervention over days, weeks, and months as well as the length of each intervention contact Frequency: number of contacts with participants	Useful for replication and comparison of resources needed to resources available in a practice setting (Glasgow et al., 1999).
Extent protocol delivered as intended (%)	Description of fidelity to the intervention protocol.	This provides insight into the feasibility of delivering all components of an intervention at the pre-determined date and time (Glasgow et al., 1999).
Measures of cost of implementation	The ongoing cost (e.g. money, time) of delivery across all levels of the intervention	This is helpful for future researchers to be able to determine if conducting a specific intervention is economically feasible delivery (Klesges et al., 2008).
Maintenance: individual and organization level	The measure of behavior at the individual level and sustainability of the intervention at an organizational level	
Assessed outcomes ≥ 6 months post intervention	Description of follow-up outcome measures of individuals available at some duration after intervention termination	Provides information on the maintenance of intervention outcomes over time (Glasgow et al., 1999).
Indicators of program level maintenance	Description of program continuation after completion of the research study.	Provides information on whether the intervention can be integrated into an existing system/organization (Glasgow et al., 1999).
Measures of cost of maintenance	The ongoing cost of maintaining delivery across all levels of the intervention	Sustainability costs provides information for practice settings to determine the resources needed for long term intervention delivery (Allen et al., 2011).

Table 2-3 Proportion of mobile health interventions reporting RE-AIM dimensions and components

RE-AIM Dimensions and Components	Proportion Reporting*
Reach	
Method to identify target population	60.0
Inclusion criteria	80.0
Exclusion criteria	60.0
Participation rate	46.7
Representativeness	26.7
Average across Reach Components	*54.7*
Efficacy/effectiveness	
Measures/results for at least one follow-up	100.0
Intent to treat analysis utilized	33.3
Quality-of-life or potential negative outcomes	33.3
Percent attrition	73.3
Average across Efficacy/Effectiveness Components	*77.8*
Adoption	
Description of intervention location	13.0
Description of staff who delivered intervention	
Method to identify staff who delivered intervention (target delivery agent)	0.0
Level of expertise of delivery agent	33.3
Inclusion/exclusion criteria of delivery agent or setting	13.3
Adoption rate of delivery agent or setting	6.7
Average across Adoption Components	*11.1*
Implementation	
Intervention duration and frequency	40.0
Extent protocol delivered as intended (%)	13.3
Measures of cost of implementation	20.0
Average across Implementation Components	*24.4*
Maintenance	
Assessed outcomes ≥ 6 months post intervention	0.0
Indicators of program level maintenance	0.0
Measures of cost of maintenance	0.0
Average across Maintenance Components	*0.0*
*Based on denominator of 15 intervention trials, reported across 20 articles	

Table 2-4 Recommendations

RE-AIM component	Recommendations for reporting on future mhealth PA studies
Reach	Report on characteristics (e.g. demographics, behavioral outcomes) of non-participants and compare them to participants to understand the representativeness of the study sample
	Indicate exclusion criteria so that it is clear as to why certain individuals were not eligible for participation.
	Report on inclusion criteria so that investigators can understand why specific individuals were selected.
	Describe recruitment methods so that future researchers will know the best ways to recruit for mhealth PA interventions.
	Calculate the participation rate: # eligible approached and agreed to participate/total # eligible and approached
Effectiveness	Use intention to treat methods
	Assess potential negative outcomes of the intervention and quality of life before and after the intervention
Adoption	Explicitly state inclusion/exclusion criteria of setting (if applicable)
	Explicitly state inclusion/exclusion criteria of participating staff
	Calculate participation rate of settings/staff
	Describe the characteristics of the participating setting and staff (if applicable)
Implementation	Report on content of intervention messages
	Report on intervention duration and frequency of in-person and virtual sessions (e.g. SMS, applications)
	Provide information intervention costs (e.g. price of mobile technology, mobile phone data plan, time it takes to implement each session)
	Indicate percent delivered as intended (e.g. text messages sent/unsent/received/not received; any application functioning problems or other technology problems)
Maintenance	Track adherence to intervention and usage of mobile device. (e.g. text message or application)
	Assess any modifications made to intervention and individual behavior 6 months after the intervention is completed

	In the design of the intervention, work closely with technical staff and potential participants so that the product may be functional and persuasive.

References

Akers, J.D., Estabrooks, P.A., & Davy, B.M. (2010). Translational research: Bridging the gap between long-term weight loss maintenance research and practice. *Journal of the American Dietetic Association, 110*(10), 1511-1522.

Allen, K., Zoellner, J., Motley, M., & Estabrooks, P.A. (2011). Understanding the internal and external validity of health literacy interventions: A systematic literature review using the RE-AIM framework. *Journal of Health Communication, 16 Suppl 3*, 55-72.

Antikainen, I., & Ellis, R. (2011). A RE-AIM evaluation of theory-based physical activity interventions. *Journal of Sport Exercise Psychology, 33*, 198-214.

Bull, S.S., Gillette, C., Glasgow, R.E., & Estabrooks, P. (2003). Work site health promotion research: To what extent can we generalize the results and what is needed to translate research to practice. *Health Education & Behavior, 30*(5), 537-549.

Burke, L.E., Styn, M.A., Glanz, K., Ewing, L.J., Elci, O.U., Conroy, M.B.,…Sevick MA. (2009). SMART trial: A randomized clinical trial of self-monitoring in behavioral weight management-design and baseline findings. *Contemporary Clinical Trials, 30* (6), 540-551.

Burke, L.E., Conroy, M.B., Sereika, S.M., Elci, O.U., Styn, M.A., Acharya, S.D.,…Glanz, K. (2011). The effect of electronic self-monitoring on weight loss and dietary intake: A randomized behavioral weight loss trial. *Obesity (Silver Spring),* 19(2), 338-344.

Cheung, P.P.Y., Chow, B.C., & Parfitt, G. (2008). Using environmental stimuli in physical activity intervention for school teachers: A pilot study. *International Electronic Journal of Health Education, 11*, 47-56.

Cisco Systems Inc. (2012).Cisco Visual networking index: Global mobile data forecast, 2011-2016. Retrieved from http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html.

Cohen, J.A. (1960). Coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*(1), 37-46.

Conroy, M.B., Yang, K., Elci, O.U., Gabriel, K.P., Styn, M.A., Wang, J.,…Burke, L.E. (2011). Physical activity self-monitoring and weight loss: 6-month results of the SMART trial. Medicine *and Science in* Sports *and Exercise 43*(8), 1568-1574.

Consolvo, S., Pedrag, K., McDonald, D.W., Avrahami, D., Froehlich, J., LeGrand, L.,…Landay, J.A. (2008). Flowers or a robot army? Encouraging awareness & activity with personal, mobile displays. Proceedings from UbiComp '08: *The 10th International Conference on Ubiquitous Computing*, Seoul, Korea, 54-63.

Davies, C.A., Spence, J.C., Vandelanotte, C., Caperchione, C.M., & Mummery, W.K. (2012). Meta-analysis of internet-delivered interventions to increase physical activity levels. *International Journal of Behavioral Nutrition Physical Activity, 9*, 52.

Dolan, B. (2010). Smartphones to drive mHealth to 500 million users. Retrieved from http://mobihealthnews.com/9523/smartphones-to-drive-mhealth-to-500-million-users/.

Dzewaltowski, D.A., Estabrooks, P.A., Klesges, L.M., Bull, S., & Glasgow, R.E. (2004). Behavior change intervention research in community settings: How generalizable are the results*? Health Promotion International, 19*(2), 235-245.

Estabrooks, P.E., & Gyurcsik, N.C. (2003). Evaluating the impact of behavioral interventions that target physical activity: Issues of generalizability and public health. *Psychology of Sport and Exercise*, 4(1), 41-55.

Estabrooks, P., Dzewaltowski, D.A., Glasgow, R.E., & Klesges, L.M. (2003). Reporting of validity from school health promotion studies published in 12 leading journals, 1996-2000. *Journal of School Health, 73*(1), 21-28.

Glasgow, R.E., Vogt, T.M., & Boles, S.M. (1999). Evaluating the public health impact of health promotion interventions: The RE-AIM framework. *American Journal of Public Health, 89*(9), 1322-1327.

Glasgow, R.E., Klesges, L.M., Dzewaltowski, D.A., Bull, S.S., & Estabrooks, P. (2004). The future of health behavior change research: What is needed to improve translation of research into health promotion practice? *Annals of Behavioral Medicine, 27*(1), 3-13.

Glasgow, R.E., Bull, S.S., Gillette, C., Klesges, L.M., & Dzewaltowski, D.A. (2002). Behavior change intervention research in health care settings – A review of recent reports with emphasis on external validity. *American Journal of Preventive Medicine, 23*(1), 62-69.

Fanning, J.T., Mullen, S.M., & McAuley, E. (2012). Increasing physical activity with mobile devices: A meta-analysis. *Journal of Medical Internet Research, 14*(6), e161.

Fischer, S., Stewart, T.E., Mehta, S., Wax, R., & Lapinsky, S.E. (2003). Handheld computing in medicine. *Journal of the American Medical Informatics Association, 10*(2), 139-149.

Fjeldsoe, B.S., Marshall, A.L., & Miller, Y.D. (2009). Behavior change interventions delivered by mobile telephone short-message service. *American Journal of Preventive Medicine, 36*(2), 165-173.

Fjeldsoe, B.S., Miller, Y.D., & Marshall, A.L. (2010). MobileMums: A randomized controlled trial of an SMS-based physical activity intervention. *Annals of Behavioral Medicine, 39*(2), 101-111.

Fukuoka, Y., Vittinghoff, E., Jong, S.S., & Haskell, W. (2010). Innovation to motivation-pilot study of mobile phone intervention to increase physical activity among sedentary women. *Preventive Medicine, 51*(3-4), 287-289.

Fukuoka, Y., Kamitani, E., Dracup, K., & Jong, S.S. (2011). New insights into compliance with a mobile phone diary and pedometer use in sedentary women. *Journal of Physical Activity and Health, 8*(3), 398-403.

Fukuoka, Y., Lindgren, T., & Jong, S. (2012). Qualitative exploration of the acceptability of a mobile phone and pedometer-based physical activity program in a diverse sample of sedentary women. *Public Health Nursing, 29*(3), 232-240.

Heron, K.E., & Smyth, J.M. (2010). Ecological momentary interventions: Incorporating mobile technology into psychosocial and health behavior treatments. *British Journal of Health Psychology, 15,* 1-39.

Hurling, R., Catt, M., Boni, M.D., Fairley, B.W., Hurst, T., Murray, P.,..Sodhi, J.S. (2007). Using internet and mobile phone technology to deliver an automated physical activity program: Randomized controlled trial. *Journal of Medical Internet Research, 9*(2), e7.

Kessler, R.S., Purcell, E.P., Glasgow, R.E., Klesges, L.M., Benkeser, R.M., & Peek, C.J. (2012). What does it mean to "employ" the RE-AIM model? *Evaluation & the Health Professions.*

King, A.C., Ahn, D.K., Oliveira, B.M., Atienza, A.A., Castro C.M., & Gardner, C.D. (2008). Promoting physical activity through hand-held computer technology. *American Journal of Preventive Medicine, 34*(2), 138-142.

Kirwan, M., Duncan, M.J., Vandelanotte, C., & Mummery, K. (2012). Using smartphone technology to monitor physical activity in the 10,000 steps program: A matched case-control trial. *Journal of Medical Internet Research, 14*(2): e55.

Klesges, L.M., Estabrooks, P.A., Dzewaltowski, D.A., Bull, S.S., & Glasgow, R.E. (2005). Beginning with the application in mind: Designing and planning behavior change interventions to enhance dissemination. *Annals of Behavior Medicine, 29 Suppl,* 66-75.

Klesges, L.M., Dzewaltowski, D.A., & Glasgow, R.E. (2008). Review of external validity reporting in childhood obesity prevention research. *American Journal of Preventive Medicine, 34*(3), 216-223.

Krishna, S., Boren, S.A., & Balas, E.A. (2009). Healthcare via cell phones: A systematic review. *Telemedicine and e-Health, 15*(3), 231-240.

Lau, P.W.C., Lau, E.Y., Wong, D.P., & Ransdell, L. (2011). A systematic review of information and communication technology-based interventions for promoting physical activity behavior characteristics in children and adolescents. *Journal of Medical Internet Research, 13*(3), e48.

Lenhart, A., Ling, R., Campbell, S., & Purcell, K. (2010). Teens and mobile phones. *Pew Internet & American Life Project,* April 20, 2010. Retrieved from http://pewinternet.org/Reports/2010/Teens-and-Mobile-Phones.aspx.

Liu, W.T., Wang, C.H., Lin, H.C., Lin, S.M., Lee, K.Y., Lo, Y.L.,…Kuo, H.P. (2008). Efficacy of a cell phone-based exercise programme for COPD. *European Respiratory Journal, 32*(3), 651-659.

Lubans, D.R., Morgan, P.J., Dewar, D., Collins, C.E., Plotnikoff, R.C., Okely, A.D.,…Callister T. (2010). The nutrition and enjoyable activity for teen girls (NEAT girls) randomized controlled trial for adolescent girls from disadvantaged secondary schools: Rationale, study protocol, and baseline results. *BMC Public Health, 10*, 652.

Lubans, D.R., Morgan, P.J., Okely, A.D., Dewar, D., Collins, C.E., Batterham, M.,…Plotnikoff RC. (2012). Preventing obesity among adolescent girls: One-year outcomes of the nutrition and enjoyable activity for teen girls (NEAT Girls) cluster randomized controlled trial. *Archives of Pediatrics & Adolescent Medicine, 166*(9), 821-827.

McMahon, S., & Fleury, J. (2012). External validity of physical activity interventions for community-dwelling older adults with fall risk: A quantitative systematic literature review. *Journal Advanced Nursing, 68*(10), 2140-2154.

Militello, L.K., Kelly, S.A., & MeInyk, B.M. (2012). Systematic review of text-messaging interventions to promote health behaviors in pediatric and adolescent populations: Implications for clinical practice and research. *Worldviews on Evidence Based Nursing, 9*(2), 66-77.

National Institutes of Health. (2012). NIH clinical research trials and you: The basics. Retrieved from http://www.nih.gov/health/clinicaltrials/basics.htm.

Newton, K.H,, Wiltshire, E.J., & Elley, C.R. (2009). Pedometers and text messaging to increase physical activity randomized controlled trial of adolescents with type 1diabetes. *Diabetes Care, 32*(5), 813-815.

Nguyen, H.Q., Gill, D.P., Wolpin, S., Steele, B.G., & Benditt, J.O. (2009). Pilot study of a cell phone-based exercise persistence intervention post-rehabilitation for COPD. *International Journal of Chronic Obstructive Pulmonary Disease, 4*, 301-313.

Prestwich, A., Perugini, M., & Hurling, R. (2010). Can implementation intentions and text messages promote walking? A randomized trial. *Health Psychology, 29*(1), 40-49.

Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton-Mifflin.

Shapiro, J.R., Bauer, S., Hamer, R.M., Kordy, H., Ward, D., & Bulik, C.M. (2008). Use of text messaging for monitoring sugar-sweetened beverages, physical activity, and screen time in children: A pilot study. *Journal of Nutrition Education and Behavior, 40*(6), 385-391.

Sirriyeh, R., Lawton, R., & Ward, J. (2010). Physical activity and adolescents: An exploratory randomized controlled trial investigating the influence of affective and instrumental text messages. *Br J Health Psychology, 15*(Pt 4), 825-840.

Smith, A. (2010). Mobile Access 2010. *Pew Internet & American Life Project*, July 7, 2010. Retrieved from http://pewinternet.org/Reports/2010/Mobile-Access-2010.aspx.

Smith, A. (2012). 17% of cell phone owners do most of their online browsing on their phone, rather than a computer or other device. *Pew Internet & American Life Project*, June 26, 2012. Retrieved from http://pewinternet.org/Reports/2012/Cell-Internet-Use-2012.aspx.

The Cochrane Collaboration (2002). Intention to treat issues. Retrieved from http://www.cochrane-net.org/openlearning/html/mod14-4.htm.

The World Bank. (2011). Mobile cellular subscriptions. Retrieved from http://data.worldbank.org/indicator/IT.CEL.SETS.P2. 2011.

Trojano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise*, *40*(1), 181-188.

Tucker, J.M., Welk, G.J., & Beyler, N.K. (2011). Physical activity in the U.S.: Adults compliance with the physical activity guidelines for Americans. *American Journal of Preventive Medicine, 40*(4), 454-461.

White, S.M., McAuley, E., Estabrooks, P.A., & Courneya, K.S. (2009). Translating physical activity interventions for breast cancer survivors into practice: An evaluation of randomized controlled trials. *Annals of Behavioral Medicine, 37*(1), 10-19.

World Health Organization. (2008). Physical inactivity a global public health problem. Retrieved from http://www.who.int/dietphysicalactivity/factsheet_inactivity/en.

CHAPTER 3: MANUSCRIPT 2

Engaging adolescents from low socioeconomic status households in the design and development of smartphone game-based applications for physical activity promotion

Authors: Kacie Allen, B.S.,[1] Judith Harlow, M.S.,[2] Woodrow Winchester, Ph.D.,[2] D. Scott McCrickard, Ph.D., [3] Jamie Zoellner, Ph.D.,[1] Jennie L. Hill, Ph.D.,[1] and Paul A. Estabrooks, Ph.D.[1]

Affiliations: Departments of [1]Human Nutrition Foods, & Exercise, [2]Industrial & Systems Engineering, [3]Computer Science, Virginia Tech, Blacksburg, VA

A user-centered design process was followed throughout the development and design efforts of smartphone game application for PA promotion (SPAGA) in adolescents. It was evident that in order for adolescents to be interested in our idea, that we would need their input throughout iterations. First, we would need to know if our idea was culturally appropriate. If so, then what components or characteristics were desired? Lastly, this paper describes the process of gaining access to adolescents attending a community center and engaging their parents and community center staff in relevant topics, while adding value in the guidance towards the development and design of SPAGA

Additionally, some principles of community-based participatory research (CBPR) guided how we interacted with the community center. CBPR is a "partnership approach to research that equitably involved" in our case community members and researchers "in all aspects of the research process and in which all partners contribute expertise and share decision making and ownership" (Israel et al., 1998, 2003). The aim is to increase knowledge and understanding of a given phenomenon and integrate the knowledge gained with interventions…to improve the health…of community members" (Israel et al., 1998, 2003). Some of the principles that we incorporated were "building on strengths and resources within the community" and "integrating and achieving a balance between knowledge generation and intervention for the mutual benefit of all partners".

Before the development of the game idea

Getting cleared to volunteer at the Boys & Girls Club (BGCA) was a fairly short process. I submitted the necessary volunteer application materials (e.g. application, finger print, background check). It took less than a week for me to be cleared. I had no intentions on conceiving the idea for my dissertation project at the BGCA. But since I was in graduate school and developing skills as a researcher, I unknowingly observed the BGCA staff and adolescents in their day-to-day activities. In order to work with this population, I had to immerse myself in their infrastructure. Moreover, they had to be able to trust me.

Being present and making myself available to the adolescents was one way that I built trust. They had to feel like I was not a stranger nor that I was not trying to harm them. The adolescents had to

perceive that they could confide in me. Moreover, even though I was younger than the teen center staff, the adolescents still needed to perceive me as an authoritative figure. I had to balance not being the same age as the adolescents with not acting "too old" or I would be perceived as not relatable to them. During the homework hour, I tutored the adolescents. Also after the homework hour, I volunteered in the other programming activities (e.g. cooking/baking, talking causally with the adolescents and teen center staff).

The afterschool program consisted of a homework hour, a programming hour, and an hour of free time. Sometimes the schedule varied in terms of what they did after the homework hour. Some of the activities included computer game usage, cooking/baking, playing exergames (e.g. Michael Jackson Experience, Zumba, Sports Champions), baked goods sale, and running a store located in a section of the golf room.

While participating in various activities, many times the adolescents would attempt to use their mobile phones, despite the no mobile phone usage community center rule. So when their rule breaking was eventually noticed, they were instructed to put their mobile phones in their backpacks. Of course, none of the adolescents liked when they got in trouble. In fact many of the adolescents debated with the staff on this issue.

The Aha Moment!/An Idea is Born

After careful audible and visual observation at the BGCA, the idea came about using mobile phones for PA. I was most interested in increasing PA in adolescents since this is when PA begins to decline (Trojano et al., 2008). From a practical standpoint, it made sense to incorporate mobile phones to act as a motivator since these devices were what seemed to captivate the adolescents' attention. Furthermore, mobile phone gaming is popular among adolescents (Lenhart, 2010) but at the time there was no commercially available game application (apps) that targeted adolescent PA promotion. Thus, we desired to find a way to incorporate mobile phone gaming and PA for adolescents.

Next I worked with my advisors (PAE and JZ) to identify experts who could collaborate with us to turn this idea into action. Meetings were held with a Computer Science (CS) and Industrial & Systems Engineering (ISE) (DSM and WW) faculty member who were directors of a summer research

undergraduate experience for undergraduates in Human Computer Interaction and a masters-level ISE student (JH). They identified a summer undergraduate group (DC, CE, and AM) that would be suitable to work with us, of which JH would be their supervisor. Though novice to smartphone app development, these undergraduates were very eager and open to our ideas. But, before development could begin we had to go back to the BGCA so that our newly formed team could get a better understanding of adolescents' opinions and behaviors.

Meeting with the staff

Eight months since I began my initial volunteering at the BGCA passed until I actually introduced the idea to various BGCA staff members. Moreover, we wanted to make sure that we were respectful in our actions so as not to disrupt the day-to-day operations with our new idea. Furthermore, through volunteering, I gained a better understanding of the power structure and identified key informants who would permit access into this population. These individuals included the chief professional officer, director of operations, unit director and teen center staff. I needed the aforementioned individuals' approval before proceeding. All of the staff members that I approached seemed very open to the idea and were all for it, because the activity seemed "positive" and for the adolescents. Though few in number, the concerns were around internet monitoring, making phone calls and text messaging. I made it very clear that those functions would be deactivated while the adolescents were using the phones. Fortunately, my initial meeting with the staff members went over well and we could proceed with our next steps.

Team members visit the BGCA

We wanted to make sure that culturally appropriate apps would be created so the three undergraduates, masters ISE student and I ventured to the BGCA. The team went several times to get a better understanding of the setting and learn more about the opinions and behaviors of the adolescents. To develop a couple of initial apps, we informally asked the adolescents questions such as "what motivates you to play smartphone games", "what characteristics do you like and dislike about the smartphone games you play", "what are some improvements that you would like to see in the smartphone games that you currently play", and "what type of reward system do you prefer". Field notes were taken as we observed

the adolescents in their routine at BGCA and characteristics. The demographics of the adolescents consisted primarily of low socioeconomic status or race/ethnic minority background. There was slightly more females and the ages varied from junior high to high school sophomores.

The BGCA staff were very open to the other team members visiting the BGCA and the adolescents were receptive to the questions we asked. One factor that may have helped us engage more with the adolescents was that the majority of team were of race/ethnic minority that was similar to many of the adolescents. For many of the adolescents it was their first time meeting minority engineering students. Some of them were so intrigued that they asked questions to the engineering students about their life as a college student and engineering program. Though not anticipated, it was insightful to see how adolescents could be potentially motivated academically just by being able to interact with college students with surface level similarities. Many times, we often underestimate the value of brief interactions that can actually have a lasting impact.

Initial App evaluation

Based on the information collected from our visits, the three undergraduates made three apps (i.e. Color Hunt, Apple Tree Shaker, and Speed of Light) which have been described elsewhere (Clark et al., 2012). In addition to the information provided from the adolescents, we needed to make sure that our apps were designed to promote PA. Some characteristics of the games included time-dependency and more points were rewarded with the less time it took to complete a task.

Color Hunt and Apple Tree Shaker were generally described to adolescents and parents so that they could try them out. In Color Hunt, participants chose a color between red, green, and blue and then used the camera on the smartphone to take pictures of objects of the chosen color. Level progression was based on if the player completed the amount of tasks within the specified time period. In Apple Tree Shaker, which used the accelerometer, participants shook the smartphone to make apples fall off the apple tree. Points were awarded based on how fast players shook the phone within the designated time length.

Adolescents and their parents generally liked the Color Hunt game more than the Apple Tree Shaker game. Color Hunt was relatively easy to play, regardless of variations in amount of participant

movement and adolescents primarily had positive responses about it including the graphics. When asked what they thought about playing Color Hunt regularly, one sample meaning unit (MU) from a male was, "That'd be awesome" and a from female was, "That'd be really cool". Females, in particular, did not like how the Apple Tree Shaker game was played. The game captured more of the male participants' movements than females. For example, in reference to how many apples had been shaken off of the tree, one female stated, "Nine" and a male replied, "144". Thus, it was easier for the males to earn points faster.

Focus Groups and Interviews

After the initial evaluation we still needed to know more about if playing SPAGA would be socially acceptable, so we planned to conduct 60-90 minute adolescent and parent focus groups. However due to the challenges of finding a time that worked best for parents to meet at the same time, we decided to conduct one-on-one parent interviews. Some of the parents who wanted to participate but were unavailable due to the following reasons: work schedule or other competing activities (e.g. child sports/music/play practice or church choir practice/Vacation Bible School). These qualitative approaches would allow for the emergence of rich data descriptions. It was very important that we conveyed to the adolescents and parents that we wanted their honest opinions, perceptions, and experiences with using mobile phones in general and for PA. At times we can forget as individuals in academia that we may be perceived as arrogant, pompous, or intimidating. Further, we needed to be cautious in our tone and using unfamiliar terminology which may be seen as trying to belittle non-academics. Moreover, we tried to clearly inform them that we were not judging them but rather they had a safe space for discussion. Additionally, this qualitative data collection was approved by the Virginia Tech Institutional Review Board. There were hardly any questions in regards to clarification or further explanation of the proposed study. The adolescents were enthusiastic and anxious to when they were actually going to get to play with the apps. Furthermore, they wanted to play with many apps and really liked that their opinions and perceptions were taken into consideration for developing apps.

Conducting of the parent interviews and adolescent focus groups occurred at the Boys & Girls Club in a boardroom and a vacant office room. This was the most feasible location since it was where the adolescents regularly attended. Another advantage was that the while the parent interviews were conducted parents could have their children monitored by the BGCA staff. Prior to participation, parents provided signed informed consent and adolescents provided a signed assent along with signed parent permission.

Interviews were conducted using methods suggested by Seidman (2006) and focus groups were conducted using methods suggested by Kreuger (2009). Three focus groups (n= 14; 45-60 minutes per group) and seven interviews (one interview with each of the seven adults; approximately 30 minutes per adult) were conducted at one Boys & Girls Club. Two trained graduate students moderated (KA) and co-moderated (EC) the focus groups. Though both moderators had conducted adult focus groups and interviews previously, this was the first time for doing so in a younger population. Overall, we both felt comfortable since we were adequately trained and the adolescents welcomed us. Like any focus group, at times the participants discuss off-task topics but we respectfully guided them back to the topics. They were very open about their feelings and were comfortable with having diverse opinions. To our knowledge they gave more honest opinions than adult focus groups that we had conducted in previous studies. It was evident that these adolescents were not concerned about their peers nor moderators evaluating them.

A semi-structured script was developed for the focus groups and interviews, including 26 and 24 questions, respectively. The script asked questions about their general perceptions and experiences with gaming, music, online social networking, maps, GPS, camera, and text messaging on mobile phones. Additionally, it asked about their perceptions and ability to use a smartphone and its features for physical activity and the feedback (e.g. quantitative: points and/or qualitative: messages) desired from the SPAGA. To promote clarity and accuracy of responses, appropriate follow-up probes were asked based on interviewee responses. Data saturation was sufficiently achieved after conducting three focus groups and seven interviews. The sessions were audio recorded and transcribed verbatim.

Focus groups and interviews: data analysis

The transcribed focus groups and interviews were analyzed by inductive and deductive coding for thematic development by two graduate students (KA and JH) and one senior researcher (PE). Each transcript was independently reviewed by KA and JH. These investigators met to identify major themes and develop a distinct coding system. KA, JH, and PE met multiple times to review assigned codes and reconcile disagreements. The process was recursive, as it guided decisions for further exploration and analysis. Coding occurred at multiple steps to lead to the major themes.

In total there were 19 adolescents (53% male; 58% Black) eligible, of which 15 consented and 14 completed the study (n=1 absent on day of study). The 14 adolescents participants ranged from ages 11-16 ($\underline{m}_{age}$=13.4 years; 57% male; 57% Black). The seven adult parents (86% Black) including six females and one male.

[Insert Table 3-1. Adolescent and Adult Responses]

Table 3-1 displays discussions from the focus groups and interviews. There were numerous comments related to attractive phone qualities (n= 74 MU). Within this theme, the four most frequently mentioned categories were downloading apps/games (n= 15 MU), online social networking (n= 11 MU), ease of use (n= 11 MU), and portability of smartphones (n=11 MU). The remaining categories included music, GPS, and texting. A statement related to the most discussed category was, the app "gives you something new to do. It's like a new toy that you get for Christmas." In terms of portability: games, music and social network apps were highlighted. Texting was the most mentioned code related to ease of use. Conversations on online social networks revealed that adolescents mostly used them for social interaction/flirting and communication.

The type of points that adolescents desired from the prototype games was also assessed. There were many comments related to points (n= 37 MU). Participants were asked questions in regards to the type of feedback they wanted. A participant stated that, "Points would make me feel healthier." In addition to wanting positive points, negative points were sought. An example statement was, "When you get that negative feedback it makes you want to work harder." Lastly, competitive feedback against others

(n= 9 MU) was the least discussed category. One participant in reference to this category, exclaimed, "I'd be bragging. Ooh, I'm beating you! I'd beat everybody."

Lastly, parents' responses that related to adolescent PA and use of SPAGA were inquired. There were many comments related to the feedback desired from the adolescents playing with SPAGA (n=27 MU). One participant stated that "...give me feedback and let me know what game they're playing and that they have played, are they really interested in the game? How long did they play it? And um are they mastering the game to where they can go onto another game." For an example of feedback to adolescent, a parent suggested, "They can earn points based on how they play the games that they play." Another theme that was related to parental perception of SPAGA was perception of prototype (n=20 MU). Overall, most of the comments were positive (n= 18 MU). For example, one parent indicated, "I think they [adolescents] should use it…I don't see anything wrong with them [adolescents] using it." Though unintended consequences for using the smartphones was not assessed, one parent noted her concern. A parent noted, "…have to monitor him [adolescent] because he [adolescent] will get on the wrong websites." The data from the focus groups and interviews suggested that the adolescents and parents thought it was acceptable to play SPAGA. Thus, we continued with our next development steps.

Idea generation sessions

The aim of idea generation sessions was to brainstorm SPAGA for adolescents that are culturally relevant, enjoyable, theory-based and promote PA. The Fogg Behavioral Model components (motivation and ability) were used to guide the idea generation sessions. These sessions were held to identify desirable features for the adolescents and what would be considered simple game rules for adolescents. Two members of the design team (KA and JH) conducted five game idea generation sessions. A session was facilitated at three Boys & Girls Clubs (n=30), and two in the Virginia Tech Department of Human Nutrition, Foods, & Exercise including one undergraduate class (n=30) one graduate student group (n=20). Due to the smaller number of adolescents enrolled at the BGCA, we decided to expand input from others. The undergraduate population was not much older (<10 years) than the adolescents so they could provide expertise in features that they liked without having perceived outdated opinions. Moreover, the

graduate student group consisted of scholars in health promotion (e.g. PA and nutrition) so that would benefit them in providing input.

At the beginning of each session, participants were informed of each phone features' function. They were instructed to think of games that could be played on a smartphone while promoting PA. Additionally, ground rules were established such as be respectful, listen, all ideas are welcomed, everyone should equitably participate, and do not talk while another person is talking in your group. Due to the larger number of participants (~20-40 people), the Crawford slip method (Crawford & Demidovich, 1983) was used. Moreover, the BGCA staff was available to handle any behavioral problems. Fortunately, there were none. For the first ten minutes, participants individually brainstormed game ideas and wrote them on small sticky notes. Then for the next five minutes, they were split into groups of four to five people where they each explained their game idea(s). For the next ten minutes in their groups, they thought of game ideas collectively. Participants were instructed that the games could be a modification/extension of an individually created game or a completely new game that the group invented together. Lastly, each group came up with a decision-making process of how to select the game that they would work on during the session.

Participants included the name of the game, features to use, rules of the game and level and reward description. All participants were very diligent and individuals worked well within their groups. Participants drew upon their strengths. Individuals who possessed more leadership qualities, facilitated the group discussion and synthesized the ideas, while more artistic individuals drew out the ideas. Each group illustrated screenshots of their game by using large sticky notes. Towards the end of the sessions, each group presented their game ideas to the other groups. Other groups provided feedback and asked questions related to the game ideas presented. Game ideas are presented in Table 3-2.

Participants came up with various game ideas that fell within the categories: recreation (e.g. Dancing Game, Cheer Mania) and sports (e.g. Softball Mania, Basketball for Dummies). Both of these categories had the same amount of game ideas. The most frequently identified sport was basketball (n=3) and for recreation was tag (n=2). Some groups explicitly reported how points were rewarded. For

example, The “Whack-a-mole” group stated that “you get points when you whack your selected mole”. Participants came up with simple rules and the majority of games used the GPS, Bluetooth, and the camera.

[Insert Table 3-2]

User-centered inspiration

This study described the process used to gain entry and engage adolescents and their parents in the development of SPAGA at the BGCA. The process mentioned was very interactive through adolescents and their parents providing invaluable input. The aforementioned activities and processes were instrumental in gaining a deeper understanding of the adolescents attending the BGCA and their culture. The information they provided helped guide our development and design efforts so that the SPAGA created would be suitable for them.

Future steps

We plan to test a number of game apps in the adolescents at the BGCA and to record their feedback. Since the activities vary daily at many community centers, such as the BGCA, we recommend obtaining a monthly schedule from the BGCA staff. In this manner, one can plan accordingly to make sure that one can minimize scheduling conflicts and not disrupt any of community centers’ programming activities. Additionally, before developing your own frequency and duration of testing days, it is vital to discuss this with the community center staff especially the individuals that work closest with the adolescents (e.g. adolescent staff). Overall, continued symbiotic dialogue between designers/developers, researchers, and users is important so that trust can be established and maintained and mutual benefit achieved.

Table 3-1 Adolescent and adult qualitative responses

Theme	Category (MU)	Sub-code (MU)	Sample meaning unit
Attractive phone qualities (n=65)	Downloading apps/games (n=15)	Fun (n=8)	• "I'd like them. They can be fun."
		Variety (n=5)	• "Gives you something new to do. It's like a new toy that you get for Christmas."
		Cost (n=1)	• "I like that I get everything for free."
		Family time (n=1)	• "Something that me and my parents can do."
	Portable (n=11)	Games (n=7)	• "They can be portable."
		Music (n=3)	• "Could listen to it anywhere."
		Social Networks (n=1)	• "Portable."
	Ease of use (n=11)	Texting (n=10)	• "If you had a problem with your speech than they'd be able to understand you better texting."
		GPS (n=1)	• "Type in the address and show me where it is."
	Online social network likes (n=11)	Social interaction Flirting (n=3) Communication (n=3) Socially in touch (n=1)	• "To keep track of my friends and stuff."
		Up to date (n=1)	• "Keeps you updated."
		Popular (n=1)	• "It's so popular."
		Ease of communication (n=1)	• "If I get a (Facebook) message or an alert, then I can, it just comes straight to my phone as a text message."
		Family connection (n=1)	• "To talk to my other family members that I never met."
	Music likes (n=8)	Sleep aid (n=2)	• "Music helps me go to sleep."
		Chilling (n=1)	• "If I'm in my room chillin'."
		Relaxing (n=1)	• "It's relaxing."
		Calm (n=1)	• "It calms me down."
		Love it (n=1)	• "I love music."
		Multipurpose (n=1)	• "You can still get calls so you don't have to worry about carrying two things around."
		Rock out (n=1)	• "To rock out!"

	GPS likes (n=5)	Voice capability (n=4)	• "You can get any voice that you want to."
		Convenient (n=1)	• "It's convenient."
	Texting likes (n=4)	Fun (n=2)	• "Fun."
		Quiet (n=2)	• "Talk privately in public."
Type of Points (n=46)	Points (n=37)	Type (n=18)	• "Points would make me feel healthier."
		Positive (n=11)	• "Bad if it was like Weight Watchers."
		Negative (n=8)	• "When you get that negative feedback, it makes you want to work harder."
	Competitive feedback against others (n=9)	Competitive feedback against others (n=9)	• "I'd be bragging. Ooh, I'm beating you! I'd beat everybody."
Feedback (n=27)	Feedback to parent (n=21)		• "...give me feedback and let me know what game they're playing and that they have played, are they really interested in the game? How long did they play it? And um are they mastering the game to where they can go onto another game."
	Feedback to adolescent (n=6)		• "They can earn points based on the games that they play."
Perception of Prototype (n=20)	Positive (N=18)		• "I think they [children] should use it…I don't see anything wrong with them [children] using it."
	Negative (N=2)		• "…have to monitor him [child] because he [child] will get on the wrong websites."

Table 3-2 Idea Generation Sessions Results

Type	Game	Description
Recreation (n=10)	Cheer Mania	Similar to Dance Dance Revolution™ but cheerleading moves instead
	Deer Hunter	Simulates deer hunting
	Musical Freeze Tag	Run around and hide while music plays from the phone and when it stops, everyone has to freeze or stop where they are. The "it" person can see on the phone where the "un-it" persons are and tag them.
	Obstacle Course	Virtual obstacle course where the player jumps, runs and dodges obstacles
	ZADAT Tag (Musical/flashlight tag)	Team or Individual tag. Music plays when person is tagged or if in the dark phone lights up.
	Funky Chicken	You can be different colored chickens and you do the funky chicken dance to the funky chicken song.
	Exercise Twister & Dance	Different types of music are played. The faster you move, the faster the tempo of the music is, the more points you get.
	Dancing Game	A series of dance moves are displayed and the player has to recreate the moves. Scores are given in points or a letter grade based on accuracy of the dance moves.
	Color Hunt	Pick a color. Use the camera phone to take pictures of the things that are the same color as the selected color.
	Whack-a-mole	Select a mole. Different moles stick their head out of their ground hole. You get points when you whack your selected mole.
Sports (n=6)	Track/Field	Simulates events done during track like hurdles, discus, running

	Volleyball	Simulates a volleyball game
	Basketball for Dummies	Move around and shoot baskets. More than one basket; Baskets move further away or side to side
	Softball Mania	Play softball by pitching or if on offense hit the ball and run around bases.
	Football/Basketball/NASCAR	Simulates real-life
	Basketball	5-on-5 game

References

Clark, D., Edmonds, C., Moore, A., Harlow, J., Allen, K., Winchester III, W.,… Estabrooks P. (2012). Android application development to promote physical activity in adolescents. *Proceedings from CTS12: International Conference on Collaborative Technologies and Systems.* Denver CO.

Crawford, C.C., Demidovich, J.W. (1983). Crawford slip method: How to mobilize brainpower by think tank technology. Los Angeles, CA: School of Public Administration: University of Southern California.

Israel, B.A, Schulz, A.J., Parker, E.A, & Becker, A.B. (1998). Review of community-based research: Assessing partnership approaches to improve public health. *Annual Review of Public Health*, 19, 173-202.

Israel, B.A., Schulz, A.J., Parker, E.A., Becker, A.B., Allen, A., & Guzman, J.R. (2003). Critical issues in developing and following community-based participatory research principles. In M. Minkler & N. Wallerstein (Eds.), Community-based participatory research for health (pp.56-73). San Francisco: Jossey-Bass.

Kreuger, R.A., Casey, M.A. (2009). *Focus groups: A practical guide for applied research (4th Ed.).* Thousand Oaks, CA: SAGE Publications.

Lenhart, A., Ling, R., Campbell, S., and Purcell, K. (2010). Teens and Mobile Phones. *Pew Internet & American Life Project*, Retrieved from http://www.pewinternet.org/Reports/2010/Teens-and-Mobile-Phones.aspx.

Lenhart, A. (2012). Teens, smartphones, & texting. *Pew Internet & American Life Project*, Retrieved from http://pewinternet.org/Reports/2012/Teens-and-smartphones.aspx.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences (3rd Ed.).* New York, NY: Teachers College Press.

Trojano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise, 40*,181-188.

CHAPTER 4: MANUSCRIPT 3

Testing smart phone game applications for physical activity promotion in middle school students in afterschool programs at Boys & Girls Clubs

Authors: Kacie Allen BS[1], Adil Kadir[2], Brandon Dockery BS[2], Sarah Elizabeth Johnson MPH, MCHES[1], Fabio Almeida PhD[1], Jamie Zoellner PhD[1], D. Scott McCrickard PhD[2], Jennie L. Hill, PhD[1], Wen You PhD[3], and Paul A. Estabrooks PhD[1]

Affiliations: Departments of [1]Human Nutrition, Foods, and Exercise, [2]Computer Science, [3]Agricultural and Applied Economics, Virginia Tech, Blacksburg, VA

Abstract

Background: Due to the ubiquitous nature of mobile phones, mobile phone game applications that encourage physical activity (PA) may have the ability to motivate adolescents to participate in PA. The games tested in this study were based on persuasive technology design principles which utilized several factors that may contribute to promoting PA including competition, intrinsically motivating players through the use of levels or earning points, and increasing social interactions between players.

Objective: The purpose was to determine the effectiveness of smartphone PA game-based applications' potential in promoting PA in adolescents in afterschool programs.

Design: This 6-week study used a mixed-method, quasi-experimental design without a control group.

Participants: A total of 27 adolescents (mean age (range) 13 years (10-16 years), 41% minority race/ethnicity, 44% female) participated in the testing of smartphone PA game-based applications at two community centers.

Methods: Four distinct games were tested including Space Rayders (SR), Fish out of Water (FOW), Whack a Mole (WAM), and Scavenger Hunt (SH). After an initial baseline week, adolescents were provided the opportunity to play each game at an afterschool program for one week. During a final week, the participants could choose to play any of the 4 games. The primary outcome was PA intensity (i.e. mean weekly accelerometer counts/15seconds) over the course of the afterschool program and questionnaires were used to measure secondary outcomes evaluating motivation for PA and for the games. Furthermore, perceptions and experiences of interactions with the games were assessed through exit focus groups that were audio recorded and transcribed verbatim. Meaning units were coded to the major themes and were weighted on a 5 point scale (1=very negative/poor quality, 5= very positive/excellent quality).

Results: Baseline mean accelerometer counts were 695 counts/15s. Mean accelerometer counts for players in each smartphone game week ranged from 764.9673 counts/15s to 992.5100 counts/15s). For two of the games, mean accelerometer counts were significantly higher compared to baseline mean accelerometer counts. Though no significant differences were found between baseline and smartphone

game weeks, mean PA Motivation scores were higher and mean PA Amotivation scores were lower in smartphone games compared to baseline. The emerging themes included affective responses (n= 50 meaning units, mean code weight= 2.45), feature (n= 38 meaning units, mean code weight= 2.36) and function (n= 90 meaning units, mean code weight= 2.90). Overall, ratings of the games across themes were low (mean code weight= 2.57), but participants did enjoy playing Space Rayders (mean code weight across themes= 3.43).

Conclusion: Smartphone games seem to show some preliminary promise as a motivational tool in adolescents to increase PA, though even among games differences in PA are present.

Introduction

Nationally representative surveys consistently have shown that adolescents are not meeting physical activity (PA) guidelines (e.g. 60 minutes of moderate to vigorous PA) or Healthy People 2020 (HP 2020) objectives (Centers for Disease Control and Prevention [CDC], 2011a; 2012). According to the 2011 Youth Risk Behavior Surveillance, only 13.8% of students had not participated in at least 60 minutes of PA on any day of the week, approximately half had been physically active at least 60 minutes per day on 5 or more days, 28.7% had been physically active at least 60 minutes on all 7 days, and a little over half (55.6%) had participated in muscle strengthening activities on 3 or more days (CDC, 2012). Furthermore, the 2010 National Youth Physical Activity and Nutrition Study showed that only 15.3% of students in grades 9-12 met the aerobic objective, 51% met the muscle-strengthening objective and 12.2% met both objectives (CDC, 2011a). Similarly, in Virginia where this project took place, 15.6% of students had not participated in at least 60 minutes of PA on any day of the week and 45.6% had been physically active at least 60 minutes per day on 5 or more days. Lastly, it has been shown that PA declines with increasing age with this decline beginning in adolescence (CDC, 2012). Despite the well-known and numerous benefits of PA (CDC, 2011b), it is evident that PA guidelines are not being adopted by many adolescents.

PA levels have been consistently lower for adolescents in racial/ethnic minority group (Broderson, Steptoe, Boniface, Wardle, 2007; CDC, 2011a). A higher percent of Black (19.6%) and Hispanic (15.9%) high school students did not participate in at least 60 minutes of PA on any day of the week compared to their White (11%) counterparts. Similarly, a lower percent of Black (44.4%) and Hispanic (45.4%) high school students participated in PA at least 60 minutes/day on 5 or more days than Whites (52.7%) (CDC, 2011a) Moreover, a smaller percent of Black (26%) and Hispanic (26.5%) high school students have been physically active at least 60 minutes per day on all 7 days compared to Whites (CDC, 2011a).

Socioeconomic status (SES) also plays a role in PA. Low SES has been identified as a potential determinant of physical inactivity (Gordon-Larsen, Nelson, Page, & Popkin, 2006; Kristjandottir &

Vilhjalmsson, 2001; Lasheras, Aznar, Merino, & Lopez, 2001; McVeigh & Norris, & de Wet, 2004). Additionally, unequal access to recreation facilities has been negatively associated with high levels of PA (Gordon-Larsen et al., 2006).

PA promotion interventions delivered via in-person sessions during afterschool (Beets, Beighle, Erwin, & Huberty, 2009) and web-based sessions (Lau, Lau, Wong, & Ransdell, 2011) have demonstrated positive effects for PA outcomes. But since PA rates have been steadily lower for minorities and low SES adolescents, newer approaches with a higher reach are needed. A greater number of adolescents may be reachable with healthy behavior (e.g. PA) interventions using mobile phones (Bull, 2010). In fact, approximately 77% adolescents (12-17 year olds) own a mobile phone (Lenhart, 2012). Additionally, this population is comfortable with using mobile phones for daily functions such as playing games, sending and taking pictures, text messaging, listening to music, and sharing and recording videos (Lenhart, Ling, Campell, & Purcell, 2010).

Mobile phone ownership is not specifically for adolescents of middle to high SES households. Though mobile phone ownership is lower in adolescents in households earning less than $30,000 annually, a considerable amount of those teens (59%) still own a mobile phone compared to wealthier adolescents (75%) (Lenhart et al., 2010). Furthermore, mobile phone usage has been shown to be higher in adolescents from lower SES backgrounds with fathers with low education and non-nuclear family types compared to adolescents with high SES, highly educated fathers, and nuclear family homes (Koivusilta, Lintonen, & Rimpela, 2007). There are no differences by race or ethnicity in mobile phone ownership (Lenhart et al., 2010). Additionally, more Black adolescents (44%) and Hispanic adolescents (35%) use their mobile phones to go online, compared with White adolescents (21%) (Koivusilta et al., 2007). Thus, promoting PA via mobile phones could be an effective approach and has the potential to reach more adolescents with varying demographics.

Many adolescents engage in screen-based sedentary activities (Vandewater, Shim, & Caplovitz, 2004), so requiring them to stop these activities may be difficult. Moreover, a national survey of adolescents aged 12-17 found that 99% of boys and 97% of girls play video games (Rideout, Roberts, &

Foehr, 2005). Another national survey of children aged 8-18 found that boys play video games for an average of 16.4 hours/week and girls play for an average of 9.2 hours/week (Lenhart et al., 2008). The data from the Lenhart survey (Rideout et al., 2005) showed that 48% of adolescents use a mobile phone or handheld organizer to play games. Thus, literature suggests that video gaming is popular among adolescents and could possibly be used as a tool to motivate adolescent to participate in PA.

One approach that has been used is exergaming. Exergaming combines play and exercise (Bogost, 2005) and is perceived as socially acceptable by adolescents (Fogel, Mitenberger, Graves, & Koehler, 2010). It has been shown to increase energy expenditure (Bailey & McInnis, 2011; Daley, 2009; Fogel et al., 2010; Guy, Ratzki-Leewing, & Gwardy-Sridha, 2011) when compared to activity in sedentary screen time. Furthermore, playing exergames can result in light to moderate PA intensity similar to walking, skipping, and jogging in adolescents (Bailey & McInnis, 2011; Daley 2009; Fogel et al., 2010; Straker & Abbott, 2007; Staiano & Calvert, 2011). Moreover, exergaming is preferred by adolescents who are more sedentary and less likely to participate in traditional PA (Daley, 2009). Exergames have been shown to increase motivation through competition, increase opportunities for positive social interactions, are intrinsically motivating via responding to a player's actions and challenging them at multiple levels of expertise (Staiano & Calvert, 2011)and can be used as a mediator between player motivations and behavior change goals (Xu et al., 2012). Lastly, some factors that may be present in video games and have potential benefits to motivate behavior change include perceptions that video games are interesting, energizing, visually appealing, interactive, challenging, and rewarding (Baranowski, Buday, Thompson, & Baranowski, 2008). Despite the effectiveness of exergaming, these systems can be expensive, require a lot of equipment (e.g. video game console, television, and controllers), and are limited in portability due to the needed electrical connectivity.

In contrast, utilizing mobile phones to promote PA may be a useful approach for increasing access to PA resources. According to a recent review, of the 204 health & fitness application(s) (app(s)) assessed, approximately 55 apps recommended or provided a tool for keeping a PA journal and 43 apps suggested regular PA (Breton, Fuemmeler, & Abroms, 2011). For example, geocaching, a free real world-

outdoor treasure hunt where participants use a Global Positioning System (GPS) receiver or mobile phone to hide and seek geocaches (objects), is a widely popular game (Groundspeak, Inc., 2012). Other mobile phone apps on iTunes App Store have been used to replicate traditional outdoor games such as Simon Says; Hide and Seek, and Red Light, Green Light (Wildcat Apps, 2010). In another game, MarioFit, to make the Mario character jump, run, walk, and arm throw, the player must physically do those movements (Jayant & Saponas, 2005). Similar games to MarioFit include Feeding Yoshi (Bell et al., 2006) and Paranoia Syndrome (Heumer et al., 2006). Moreover, in Neat-O-Games, the game is controlled with data from an accelerometer (Fujiki et al., 2007, 2008). So, the more the player moves, the faster the player progresses in the game (Fujiki et al., 2007, 2008). UbiFit Garden is an app that was tested in adults and displays non-intrusively a participant's PA level as a pictorial display of a garden on the mobile phone background (Consolvo et al., 2008). Fish 'n' Steps, was a game where adult PA amount was linked to a virtual pet (Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006). While these apps exist, there is limited information in terms of the demographics and behavioral information of players (with existing demographic information referring primarily to adults), the modes of transportation of how players are travelling to destinations for the location-based games, and a paucity of research evaluating the PA level during game play.

There have been some studies for PA promotion in adolescents via mobile phones (Arteaga, Kudeki, Woodworth, Kurniawan, 2010; Dunton, Liao, Intille, Spruijt-Metz, & Pentz, 2011; Newton, Wiltshire, & Elley, 2009; Shapiro et al., 2012; Toscos, Faber, An, & Gandhi, 2006; Toscos, Faber, Connelly, & Upoma, 2008). A recent mobile health (mhealth) systematic review and meta-analysis showed that mobile technologies had the ability to promote PA in adolescents and adults (Fanning, Mullen, & McAuley, 2012). PA outcomes have increased when PA was monitored via short message service (SMS) (Dunton et al., 2011; Shapiro et al., 2012), when participants received motivational SMS reminders to wear pedometers (Newton et al., 2009) and when adolescents recorded their step count in a mobile phone app designed to create a social support group (i.e. participants were requested to send other participants motivating text messages) for PA (Toscos et al., 2008). Yet, few studies have examined the

potential of movement-based apps that take advantage of telephone features, beyond logging data and sending messages, to promote PA through games.

Preliminary qualitative data collected as part of a user-centered design approach indicates that using game-based apps on mobile phones would be appealing to adolescents and their parents when used in afterschool settings for adolescents from lower-income families (Allen et al., n.d.). Specifically, the adolescents in the study indicated that downloadable mobile phone apps were highly valued and provided opportunities to try new things. The adolescents also expressed the value that games on mobile phones were portable, that they could be used any time and in any place. Parent feedback included a positive perception of mobile phone games that would get their children active and that could potential provide feedback to the parent on the amount of physical activity being completed by the child. Based upon these data and previous research in the area, the present study conceptualized a mobile phone as an additional piece of equipment that could be used to promote PA during the afterschool hours using simple games that take advantage of the positive perceptions adolescents express in terms of the portability of the phone and interest in downloadable apps. The specific purpose of this study was to determine the effectiveness of smartphone PA game-based apps (SPAGA) in promoting PA in adolescents at afterschool programs. We hypothesized that the participants would be receptive to using smartphones to increase PA. Furthermore, we hypothesized that exposure to SPAGA would result in an increase of PA intensity and higher motivation compared to before exposure.

Methods/Design

Study design

A mixed-methods, quasi-experimental design using the participants as their own controls was used to achieve the study purpose. Two Boys and Girls Clubs of America (BGCA) in southwest Virginia participated in the study and adolescent participants between 10 and16 years old were recruited to join the study. This study was approved by the Virginia Tech's Institutional Review Board.

Device and software

The software used to develop the SPAGA were various Android versions (SDK, 2.0.1 (eclaire), and 2.2 (froyo); Google Inc., Mountain View, CA). An Android plugin for Eclipse Indigo (Eclipse Foundation, Inc., Ontario, Canada), an integrated development environment, to provide extra tools for writing and organizing Android code was used to develop the apps. The Motorola A855 (Droid) smartphone (Motorola Mobility, Inc., Libertyville, IL), a part of the Android series, was used was to execute the SPAGA. The slide-out full QWERTY keyboards was not used during game play.

The applications

Through a user-centered approach, the design and development of the apps were informed by earlier adolescent focus groups, parent interviews and idea generation sessions (Allen et al., n.d.). In addition to being informed by a user-centered process the app design was theoretically based on the concepts in the Fogg Behavior Model (FBM) (Fogg, 2009). The concepts used to encourage PA from the FBM were "motivation," "ability," and "trigger;". From these data and theoretical approach the research team determined that the SPAGA would include games titled Fish out of Water (FOW), Space Rayders (SR), Whack-a-Mole (WAM), and Scavenger Hunt (SH).

Two undergraduates in the department of Computer Science developed the four SPAGA for Android using the abovementioned software. Briefly, each of the games was intended to have broad appeal and result in increased moderate to vigorous PA. FOW included adolescents completing the game's directions on how to "save the fish" (e.g. turn left/right) before time ran out. In SR the objective for the adolescents was to gain as many points when they were "it" by getting in close proximity of other players. In turn, when players were "not it" they had to maintain their distance away from the "it" person so, that the "it' person did not take their points from them. WAM involved adolescents moving around in a testing area until they found pre-set virtual mole hills. Once one of these hills was found, they moved the mobile phone as fast as they could to "whack the mole" and gain points. Finally, during SH adolescents used the camera on the mobile phone to take pictures of specified colors within an indicated time period.

Intervention costs

Five Motorola A855 (Droid) smartphone (~$50/each), five mini SD cards (~$10/each), and seven phone cases (~$10/each) were purchased for this study. Each ActiGraph GT3x+ accelerometer costs approximately $249. The ActiGraph GT3x+ accelerometers, the lite license for ActiLife 6, and the full license for ActiLife 6, and three Motorola A855 (Droid) smartphones were borrowed from one of the graduate research investigator's (KA) dissertation committee members.

Inclusion/exclusion criteria

The eligibility criteria were as inclusive as possible. The inclusion criteria required participants to be English-speaking, in middle school or high school, be an enrolled BGCA member, and regularly be attend the afterschool program at the specified BGCA throughout the duration of the study. Regular attendance was operationalized as attendance on most days of the week. The target population was low SES or ethnic minority middle school and high school students living in southwest Virginia.

Setting

The study was conducted at two BGCA (Site A & Site B) located in two urban areas of southwest Virginia. According to the United States Census Bureau (2012), urban areas are designated places of 2,500 or more persons. BGCA are community centers that provide afterschool and summer care to all children (ages <18 years old), "especially those most in need" (BGCA of Southwest Virginia, 2013). Their mission is "to enable all young people to reach their full potential…" and one of their organization's goals is to "help develop fitness" (BGCA, 2013). So, the objectives of the SPAGA study aligned with the organizational mission of BGCA. Participating afterschool sites were recruited through convenience sampling based on the following criteria: willingness to allow the research study to occur for six weeks at their location, have attendees who were in middle school or high school, and adequate space to play the SPAGA. Two sites were approached for participation and both agreed. Site A was adjacent to and had access to a public park. The public park had an asphalt court, basketball court, an open grass field, baseball field, and two playgrounds with swings, slides, etc. This site was made up of four standard size classrooms and a larger classroom. Indoor equipment available during free time included an air hockey table, pool table, golf room with a tee box, sedentary and exergame consoles, and a basketball

arcade game with two basketball hoops. Site B was located within a middle school. This middle school had a gymnasium with six basketball hoops, multipurpose room, cafeteria that could be used as a play space, open grass fields, two areas with playground equipment, and an outdoor cement area with four basketball hoops and two tennis nets which could be used during free time. For the most part activities during free time are unstructured. When the adolescents are outside for free time, the BGCA staff members provide athletic balls and it is up to the adolescent to decide if they want to play. Other activities at both sites that are available during free time include arts & crafts, reading books/magazines, playing board games, constructing puzzles, watching TV/movies, baking/cooking (site A only), and playing on computers.

Site A serves first grade through 10th grade students, while Site B serves sixth through eighth grade students. According to student enrollment papers, Site A had approximately 47 enrolled students and Site B had approximately 45 enrolled students that met the grade inclusion criterion. At Sites A and B, the number of regular attenders was 28 and 33, respectively. In terms of race/ethnicity, Site A had roughly 46% Caucasian, 40% African-American, 14% Bi-racial, 1% Hispanic and Site B had around 74% Caucasian, 20% Bi-racial, and 3% African-American. In regards to gender, Site A had 47% males and Site B 72% males. Seventy-four percent and 60% of Sites A and B, respectively, were eligible for free/reduced priced lunch. Lastly, 65% of Site A and 50% of Site B were from single parent households.

Recruitment and enrollment

At both sites, participants were recruited from preteen/teen classrooms. For approximately two weeks, recruitment occurred in September 2012 and October 2012 in Sites A and B, respectively. Eight Android phones were available for the project which dictated the targeted sample size. We determined that to accommodate for any mishaps with the phones, groups of 7 adolescents at each site would be ideal. At Sites A and B, respectively, 13 and 14 adolescents agreed participant, completed a signed assent form, and had a parent that returned a signed permission for participation. Recruitment strategies included posting flyers at the two sites, sending information about the program with potential participants to take home and to discuss with their parents, and an information session. In Site A, 26 individuals attended the

information session and all met inclusion criteria. The two persons not in attendance were provided the SPAGA intervention information. They also met inclusion criteria but declined participation. In Site B, 35 individuals attended the information session and all met inclusion criteria. The 10 persons who were not in attendance were provided the SPAGA intervention information. All of those persons met the inclusion criteria but declined participation.

Lastly, to minimize cancellation of SPAGA play days, efforts were made to maintain correspondence between SPAGA testing team and the sites' staff. This was done mainly by each site providing a calendar of activities and a member of the SPAGA testing team checking in daily with the sites' staff. An assent from each adolescent participant and a permission slip from his/her parent were obtained prior to conducting the study.

Procedures and Intervention

After obtaining written consent and post baseline, a Motorola A855 smartphone installed with the SPAGA was provided to all participants to use for five weeks during the afterschool program. This intervention was solely delivered by the SPAGA via the smartphone. Strategies consisted of increasing motivation towards playing the SPAGA and PA. For the baseline week, participants wore accelerometers while engaging in their regular afterschool program but did not play SPAGA. There were a total of four SPAGA that participants played with during the subsequent five weeks. At the beginning of game play of the first day of each game play, members of the research team briefly demonstrated how to play. Each SPAGA was randomly assigned to one week (see Table 4-1). Participants were asked to play each SPAGA for 30 minutes a day on four days (Monday-Thursday) for the week while at their designated afterschool site. During week six, participants chose which SPAGA, they wanted to play.

During game play, participants were split into two groups with a maximum of seven people in one group. After the first group played for the 30 minutes, the second group played. Weather permitting (e.g. rain, snow, cold), all games were scheduled to be played outside. If the weather was not permitting, all games could be played indoors except for WAM that required GPS to function. Prior to testing the games in the sample, test runs were done within the research team and by colleagues of the research team

who were undergraduate and graduate students. During test runs, participants were encouraged to "break the (game) system" by playing the games in unintended ways. If and when the system was broken, developers went back to fix the problems and more test runs were conducted. Additionally, test runs were done to minimize any technical problems.

Measures/Outcomes

Physical Activity

The primary outcome was objectively-measured PA across the entire time the adolescents were at the afterschool program. The entire program time was used rather than simply the 30 minutes of game time to ensure that activity was increased and no compensatory sedentary time resulted as a result of higher activity during game play. The ActiGraph triaxial GT3x+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) which measures change in velocity over time (acceleration)($m.s^{-2}$) (Freedson, Pober, Janz, 2005), was released September 2010. This is a lightweight (19g) and compact (4.6cm x 3.3cm x 1.9cm) device that can store over 40 days of raw data and has a battery life of 31 days. The accelerometer is also water resistant and can be submersed at depths to 1 meter for up to 30 minutes. While worn around the waist, the GT3x+ model has been shown to measure accelerometer counts and time spent in MVPA in strong agreement with other ActiGraph models (e.g. GT1M and GT3X) and has been evaluated in adolescents (Robusto & Trost, 2012). A sampling rate of 30 times per second (30 Hertz) was chosen and data were processed into 15 seconds (15s) epochs post download.

PA intensity was measured using ActiGraph triaxial GT3x+ accelerometers (ActiGraph LLC, Pensacola, FL, USA), which is a device that has been worn on the wrist in past studies (Dunton, Whalen, Jamner, Henker, Floro, 2005). Participants wore these devices on four days a week (Monday-Thursday) over six weeks. While each participant arrived at their designated site, an accelerometer was placed on their non-dominant wrist and was removed once it was time for him/her to depart the BGCA. Thus, the duration of accelerometer wearing depended on how long each day each participant stayed at the BGCA. Outcome variables included mean weekly accelerometer counts of all present study participants and players for each week. The Evenson cut-points (Evenson, Catellier, Gill, Ondrak, McMurray, 2006),

which used 15s epochs were selected because they have been used in past studies (Robusto & Trost, 2012; Garriguet, Colley, 2012) among children of different ages. Moreover, longer epoch lengths may decrease accuracy and not capture more vigorous PA (Evenson et al., 2006).

Technical issues or adaptations to SPAGA play days

To minimize cancellation of SPAGA testing because of technical issues, an undergraduate developer was at the site for each game play day and noted the presence of technical difficulties, accordingly. Moreover, adaptations to SPAGA play days were recorded.

Participation

While a specific SPAGA was available each of the 4 days in a given week, not all study participants chose to play each game each day. As such, the proportion of study participants who played each game on a given day was also recorded.

Motivation

Motivation for PA and SPAGA were secondary outcomes. Motivation was measured utilizing a tailored version of the validated Behavioural Regulation in Exercise Questionnaire 2 (BREQ-2; Markland & Tobin, 2004) which has been assessed previously in adolescents (Hashim, Golok, Ali, 2011). More specifically, responses from earlier focus groups with this population (Allen et al., n.d.) were used to tailor this assessment. Utilizing this questionnaire, Motivation for PA and to play the SPAGA were each assessed with three items on a five-point Likert scale (ranged from not true for me - very true for me), twice a week (Monday and Thursday) over five and six weeks, respectively. The PA Motivation items were: “I am physically active because it's fun, I like trying different physical activities, and I am physically active because I want to compete with my friends”. The SPAGA Motivation items were: “I play this game because it's fun, I play this game because it is different from other games I have played before, and I play this game because I want to beat my friend's score”. Motivation for SPAGA was not assessed at baseline because the SPAGA were not played during that week.

Amotivation

Amotivation for PA and SPAGA were secondary outcomes. Amotivation is defined as "a state of lacking any intention to engage in a behavior and is a completely non-self-determined form of regulation" (Markland & Tobin, 2004). The questionnaire was tailored from the validated BREQ-2 (Markland & Tobin, 2004) and some of the questionnaire items were composed from responses from earlier focus groups with this population (Allen et al., n.d.). Amotivation for PA and to play the SPAGA were each assessed with two items on a five-point Likert scale (ranged from not true for me - very true for me), twice a week (Monday and Thursday) over five and six weeks, respectively. Amotivation for PA items were: "I don't see the point in participating in physical activity and I think being physically active is a waste of time". Amotivation for SPAGA items were: "I don't see the point in playing this game and I think playing this game is a waste of time". Amotivation for SPAGA was not assessed at baseline because the SPAGA were not played during that week.

Post-trial Participant Focus Groups

Following the termination of game play, the participants were invited to participate in a semi-structured focus group discussion, asking about their SPAGA playing experiences, likes/dislikes of SPAGA and its features. The focus group questions focused on each game separately. This was done to minimize any confusion or potential overlap, and to help stimulate the participant's memory of playing each SPAGA. Specific questions included 1) what were your initial reactions while playing, 2) what did you like/dislike most, 3) what did you like/dislike about the sound effects, 4) what did you like/dislike about the graphics, 5) what would you have changed, 6) how did playing help you be more physically active, and 7) what SPAGA would you recommend to your friends.

One trained graduate student (KA) moderated the focus groups, while another trained graduate student (KG) co-moderated by observing and taking notes. Each focus group was audio recorded and transcribed verbatim. The focus groups were designed to achieve data saturation, which was achieved after two focus groups, comprised of one Site A and one Site B focus group.

Qualitative focus group data were analyzed through an iterative process. Deductive and inductive approaches were used. The deductive approach included using the focus group script and a priori coding

of the data back to the script question. Additionally, an inductive approach was used which allowed for the emergence of themes and categories from the meaning units (MU). Both of these approaches were completed using Dedoose (SCRC, 2013), a web-based data managing and analysis program. Data were independently reviewed and coded for recurrent patterns by 2 graduate students (KA and SBJ). These two research assistants met to resolve any discrepancies and reviewed findings with a senior researcher (PA). Researchers developed a theme criterion, which required at least 35 MU. To display data saturation across each theme, the total number of MU was calculated (Graneheim & Lundman, 2004). Sample MU are provided in the results.

Responses to the experiences and perceptions of the current game were weighted on a five point Likert scale by the independent coders. Depending on the excerpt, code weights indicated sentiment, quality, or time. Weighted scores for responses that displayed participants' feelings were categorized as sentiments. More positive responses were rated as a 5 and more negative responses were rated as a 1. Moreover, for responses that dealt with the smartphone feature (e.g. camera), SPAGA aesthetics (e.g. sound effects/graphics), or functions of smartphone features, weighted scores were based on the quality rating (i.e. 1=poor, 5=excellent). Responses that mentioned changes to the current SPAGA were not weighted as they were typically expressed simply as an idea for change. To account for if there were unequal numbers of individual cases across each sub-group the data could be normalized. 'Normalization' adjusts each descriptor (female, male) bar in the chart based on the relative numbers of cases in each sub-group (SCRC, 2013). This is useful when reviewing the frequency of codes by descriptor.

Statistical analysis

Statistical analyses were conducted using IBM SPSS version 21 (IBM Corp, 2012). The significance level was set at $P \leq 0.05$. Analyses were performed using present at follow-up. A paired samples t-test was used to compare mean accelerometer counts/15 seconds for baseline, FOW, SR, WAM, and SH. Additionally, a paired samples t-test was used to compare the mean PA Motivation and PA Amotivation scores at baseline and across each game. A paired samples t-test was also used to compare the mean SPAGA Motivation and SPAGA Amotivation scores during FOW, SR, WAM, and SH

game weeks. Analyses were conducted on all study participants who were present on a given day initially and a second analysis of just participants who played the games on a given day.

Results

Demographics

Twenty-seven adolescents consented to participate in the study. In the two participating sites the demographic distribution was 22% African-American, 60% Caucasian, 17% Bi-racial (African-American and Caucasian), and 1% Hispanic which indicates the sample (30% African-American, 59% Caucasian 7% Biracial, and 4% Hispanic was fairly representative of the BGCA membership. Participants were primarily male (56%) and almost half (44%) owned a mobile phone. The mean age was 12.2 years old (range 10-16). Of the 27 adolescents who consented, 12 participated in the exit focus groups (six from each site). These participants were primarily male (67%) and in eighth grade (42%). Half of the individuals were minorities and half owned a mobile phone.

PA and player status

Figure 4-1 shows the daily number of players, non-players, and those study participants who were absent at baseline and in each SPAGA week. The weekly average number of players in descending order were as follows: SH (14), FOW (13), SR and WAM (11), and ALL (10). The weekly averages for minutes/day of accelerometer wear time were similar across weeks. The averages in descending order were as follows: SH (120.14), SR (116.66), FOW (116.62), Baseline (115), WAM (113.06), and ALL (106.99). Figure 4-2 shows the four-day average accelerometer counts/15s for all present participants and players across each week. All of the average weekly accelerometer counts fell into at least the moderate PA intensity range. SR yielded the highest average accelerometer counts (992.5100 counts/15s) and almost produced vigorous PA intensity ($\geq$ 1003 counts/15s). Average accelerometer counts were lowest at baseline (695.41 counts/15s). When comparing games, FOW had the lowest average accelerometer counts (764.9673 counts/15s).

Tables 4-2 shows mean accelerometer counts changes between baseline and SPAGA and between SPAGA among all present participants. The mean accelerometer counts for participants present in SR and

SH weeks were significantly greater compared to baseline. While, the only significant differences between games was a significantly greater mean SR accelerometer counts as compared to FOW. Relative to baseline, there was a small effect (0.295; 0.411) shown in all present individuals during WAM and ALL games week and a moderate effect size (0.488; 0.633) was seen in all present individuals during SR and SH weeks. There was also a small effect size (0.150; 0.389) shown in all present individuals during SR week compared to WAM or SH weeks. Moreover, there was a small effect size (0.318; 0.425) in all present individuals during WAM and SH weeks and a large effect size (0.806) in the SR week when compared to the FOW week.

Tables 4-3 shows mean accelerometer counts changes between baseline and each SPAGA and between SPAGA. The mean accelerometer counts for SR and SH players were significantly greater compared to baseline and SR mean accelerometer counts were significantly greater compared to FOW and WAM. There was a small effect size (0.241; 0.246; 0.255) for participants playing FOW, WAM, or ALL games and a moderate effect size (0.717; 0.715) for participants playing SR and SH relative to baseline. Additionally, a small effect size (0.162) was shown for players in the SH week compared to FOW and for players in the SR week (0.387) compared to SH. Large effect sizes (0.983; 0.806) were demonstrated in players in the SR week relative to FOW and WAM.

Motivation and Amotivation

Figure 4-3 shows the mean scores for PA and SPAGA Motivation and Amotivation. Table 4-4 compares the mean differences of PA Motivation scores across weeks. Though, participants were asked a total of 14 questions on PA and SPAGA Motivation and Amotivation, due to a small sample size and variances of answers, it was hard to detect an adequate Cronbach's Alpha between all items that were intended to measure the corresponding variable. Thus, we only analyzed items with a sufficient Cronbach's Alpha (≥ 0.70). Though we found no significant differences in PA Motivation mean scores at baseline and SPAGA weeks, PA Motivation mean scores were non-significantly greater in the FOW and SR weeks compared to baseline. In terms of PA Motivation mean scores between games, the decrease in mean scores for SR ($P<0.05$) compared to mean scores in the SH week was the only significant

difference. Though not significant, the PA Motivation mean score for SR was greater and that for WAM was lower than the PA Motivation for the other SPAGA. Tables 4-5 through 4-7 compare the mean differences of PA Amotivation, SPAGA Motivation, and SPAGA Amotivation across weeks, respectively. We found no significant differences in baseline and across SPAGA weeks for those variables. For the majority of the time (75%), PA Amotivation mean score at baseline was non-significantly higher compared to SPAGA. For PA Amotivation mean scores, FOW was non-significantly higher and SR was non-significantly lower compared to the other SPAGA. Also, for SPAGA Motivation mean scores, SR was non-significantly higher and WAM was non-significantly lower compared to the other SPAGA. For SPAGA Amotivation mean scores, SH was non-significantly higher and SR was non-significantly lower compared to the other SPAGA.

Post-trial Focus Groups

Figure 4-4 shows the frequency and mean code weights of focus group themes. The major themes were affective responses, feature, and function. For affective responses (n= 50 MU), the code weights ranged from 1 to 5 and the mean code weight was 2.45. It was most frequently weighted as a 2 (n= 21 MU), followed by as a 4 (n= MU) and 1 (n= 15 MU). Affective response was only weighted as a 5 when participants referenced SR (n= 2 MU) and SH had the most responses (n= 9 MU) that were weighted a 1. The codes that emerged within affective responses were enjoyment, frustration, and motivating. For enjoyment (n= 38 MU), the code weights ranged from 1-5 and the mean code weight was 2.35. A sample MU from a female that represented a positive perception (code weight=5) of one (SR) of the games is, "I liked that once we finally started going that everybody started to participate. That it actually became like an actual game of tag and it was more fun." On the other hand, a MU from a female that displayed a negative perception (code weight=1) of one of the games (FOW) is, "That was the worst game in the world. It was so boring." For frustration (n= 6 MU), the code weights ranged from 1-2 and the mean code weight was 1.8. Participants only referred to becoming frustrated while playing WAM and SH. One female who expressed frustration (code weight =2) while playing WAM commented that, "So, it was frustrating when it (phone didn't vibrate to indicate the presence of an activated mole hill) happened to

me. I got mad because I couldn't get the points." For motivating (n= 8 MU), the code weights ranged from 1-5 and the mean code weight was 3.63. In this category, SR and FOW were the only games that participants mentioned. A sample MU of a negative perception (code weight=1) from a male who played one (FOW) of the games, is "Yeah, it didn't give us any motivation to run." In contrast, a sample MU of a positive quote (code weight=4) for one (SR) of the games was "Tag was more motivating you actually had to do more moving around and catch somebody." Another SR quote from a male (code weight=5), exclaimed that, "I wanted to win so that I would be better than everyone else!"

Another theme that emerged was feature (n= 38 MU), of which the code weights ranged from 1-5 and the mean code weight was 2.36. It was most frequently coded as a 2 (n= 18 MU). Feature was only weighted as a 5 when participants talked about SH (n= 1 MU) or SR (n= 1 MU). Across games it was similarly weighted as a 1, with 2 MU for each SPAGA. The categories within feature were camera, graphics, and sound effects. For camera (n= 5 MU), the code weights ranged from 2-3 and the mean code weight was 2.2. SH was the only game where the camera was talked about since this is the only game that uses the phone's camera. One female mentioned the poor quality of the camera. She reported, "…when you took a picture of something and it (SH) said it (picture) wasn't the right shade." For graphics (n= 18 MU), the code weights ranged from 1-5 and the mean was 2.22. One male (code weight=2) stated that, "You couldn't see where the mole was. So you couldn't rush to it (mole). On the other hand one male that commented on FOW (code weight=4) said, "I think the picture of the fish was good." For sound effects (n= 13 MU), the code weights ranged from 1-5 and the mean code weight was 2.28 across games. A female (code weight=2) declared, "Its (SPAGA voice) so robotic. Yeah, it's so monotone. Like he doesn't change his tone or anything. It's just like "turn left, turn right." While, a male (code weight=4) talked about WAM and responded, "Well I like that it (phone) made noise when we were whacking it (mole)."

The last theme that emerged was function (n= 90 MU), of which the code weights ranged from 1-4 and the mean was 2.90. It was most frequently coded as a 2 (n= 37 MU), followed by as a 4 (n= 30 MU). For ease of use (n=15 MU), the code weights ranged from 1-4 and the mean code weight was 2.08

across SPAGA. Participants only mentioned "ease of use" in reference to WAM and SH. One male (code weight=2) explained, "It was hard because the mole would be there (mole hill activated), but wouldn't be there on other people's phones." Contrary to the previous statement, a male (code weight=4) replied, "Well I wish it made it like a little more challenging because I was sitting in one spot for a while and I got the mole, like tons of times." For game play mode (n= 75 MU), the code weights ranged from 1-5 and the mean code weight was 3.08. A sample MU of a negative perception from a male (code weight =2) in reference to WAM, was "I didn't like it. You had to help other people." Yet, a sample MU of a positive perception from a female (code weight =5) who mentioned that, "I like it (WAM) very much because you get to help other people, and also every time you complete a level it goes faster. Because the number is going up, so the moles are going quicker to each one (mole hill)." Subcategories were identified within game play mode and included game play PA level and game play length acceptability. For game play PA level (n= 28 MU), the code weights ranged from 1-5 and the mean code weight was 3.08. In reference to SH, a male (code weight =1) responded, "No, it (SH) didn't really have us moving around, cause [in the room where the game is played], [male participant] and I would just sit down and use this picture that had a bunch of colors, so we would just stay there." Unlike the previous statement, a male (code weight =5) commented, "I had to move around. I didn't think it (SPAGA) was going to be that much (movement)". For game play length acceptability (n= 11 MU), the code weights ranged from 1-5 and the mean code weight was 2. A sample MU of a positive quote from a male (code weight =4) was "I think it (SR game play length) was okay. It gave me more chances to win." A negative sample MU from a female (code weight =2) was "No the (WAM) timing was not good."

Gender differences

Affective responses. Overall, males provided a slightly higher percentage of affective responses (54.9% v. 45.1%) and more positively weighted affective responses (2.5 v. 2.4) compared to females. Within this theme, females responded more positively toward the SPAGA enjoyment (2.5 v. 2.3) and motivating (4.0 v 3.6). Females were more frustrated (2.0 v. 1.5) while playing the SPAGA. There was hardly a gender difference in percentage of enjoyment responses, with males having a higher percentage

(50.2% v. 49.8%). Additionally, there was a higher percentage of comments related to frustration by females (61.9% v. 38.1%) but a higher percentage in motivating by males (86.6% v. 13.4%).

Feature. Overall, female responses were rated as higher quality for features (2.9 v. 2.1) but had a smaller percentage of features responses (64.9% v. 35.1%) compared to male responses. No differences existed in terms of rating the quality of points (code weight=4). Compared to males, females had higher quality ratings for graphics (3.8 v. 1.8) and for sound effects (2.5 v. 2.3) but a lower quality rating for camera (2.0 v. 2.3). In terms of points, females had a higher percentage of points responses (52.0% v. 48.0%) but a lower percentage of camera (58.1% v. 41.9%), graphics (76.4% v. 23.6%), and sound effects (55.2% v. 44.8%) responses.

Function. Overall, females had a higher quality rating of the functions (3.4 v. 2.8) but a smaller percentage of function responses (62.4% v 37.6%) compared to males. While, males had a slightly higher quality rating for ease of use (2.1 v. 2.0) of the features. In contrast, females had a higher quality rating of game play mode (3.5 v. 3.0), game play PA level (4.2 v. 3.2) and game play length acceptability (2.2 v. 2.0). Lastly, males had a higher percentage of responses related to ease of use (83.5% v. 16.5%), game play mode (59.3% v. 40.7%), game play PA level (56.1% v. 43.9%), and game play length acceptability (52.6% v. 47.4%).

Changes

The number of responses for changes to the current games was the most talked about (n= 227 MU). Participants most frequently mentioned changes for SH (35.1%) and least frequently for SR (16.4%). Categories that emerged from the responses included changes to the game play mode (n= 90 MU), graphics (n= 73 MU), sound effects (n= 48 MU), game play length (n= 24 MU), customization (n= 18 MU), more violent (n= 14 MU), camera (n= 3 MU), and phone features (n= 1 MU). One game play mode quote from a male stated, “For SH, maybe the colors can change each level…Like level 1 is the basic colors, then when you get to level 5, it’s more difficult colors.” For graphics, a female made the following suggestion for FOW: “I think the background behind the fish should actually be a fish aquarium or the ocean…”One male commented in terms of sound effects for WAM, “It (mole) could

tease you and could say 'Ha ha, you missed me'…when you tried to hit it." While SR was the game that participants said they could play the longest. This SPAGA had the most customization suggestions (44%). One female described, "You could have like (pre) set avatars and you could just pick one." In terms of more violent responses, one male commented, "And then once it (fish) dies, it should be that hospital noise, like the flat line." A male provided feedback on the camera noting that, "Yeah, it (camera) needs to have more variety of shades that it can pick up." A male suggested the use of a phone feature while playing SR stating that, "…you can actually have a laser pointing at someone." Many gender differences in changes did exist. Overall males, suggested the most changes (77%). In all sub-categories, males suggested considerably more changes. Lastly, all of the more violent responses came from the males.

PA perception

Responses were made on how participants perceived the PA yielded from the games. However, there were not enough MU (n=33 MU) to make it a theme. One female who had a positive PA perception stated that, "I like that we ran or jogged so that we could get our energy out a little bit." On the other hand, another female commented that, "If you didn't have to move then I would play it (SPAGA). Then it would be my favorite game."

Recommended apps

Participants emphasized which SPAGA they recommended, with SR and FOW being the only SPAGA mentioned. SR was the most frequently recommended (90%). Some reasons for recommendation were level of fun (n= 3 MU), and the ability to chase people (n= 3 MU), and play together (n= 2 MU). One male commented, "I recommend FOW, after the changes where you can customize your fish…because it's more of a…take care of your fish type deal."

Technical difficulties or adaptations to SPAGA play days

On Day 2 of SR at site A, there were technical difficulties with the SPAGA and it could not played. As a result site A, had three SR play days instead of four. On Day 1 of WAM at site A, WAM was not played because of inclement weather. WAM has to be played outside because a crucial game component is that it requires the use of GPS. As a result, site A also had three WAM play days instead of

four. Site 2 also had three WAM play days because, it was closed on Day 4. Site 1 did not have four game play days during ALL games play week due to a field trip on one day and site closure because of early dismissal for the city and county schools. No smartphones were lost because they were collected at the end of SPAGA testing sessions. Two accelerometers were lost due to two participants going home with an accelerometer and not returning them.

Discussion

The primary purpose of this study was to determine the effectiveness of SPAGA' potential in promoting PA in adolescents at afterschool programs. These SPAGA were developed, designed, and tested based on a user-centered approach and guided by theoretic models (FBM). Moreover, PA was objectively measured. Though participants were already at moderate intensity at baseline, we were able to increase their PA intensity while playing each SPAGA above baseline levels. Specifically, relative to baseline levels, PA intensity for SR and SH and PA Motivation mean scores for FOW and SR were significantly higher. PA Amotivation mean scores were consistently higher at baseline compared to the majority (n=3) of the SPAGA.

In the current study each SPAGA was tested four times, objectively measured PA was collected for each game, and significant increases in PA intensity were reported. Past research tested games for a maximum of one hour for every weekend for four weeks in only five participants (Arteaga et al., 2010). Furthermore, the following is unknown: PA intensity during game play, total game play length during each testing session; and participant demographics or behavioral information. In contrast to previous studies, our study recruited a sample that consisted of a considerable percentage of adolescents from minority populations and low SES households.

PA (mean accelerometer counts) was higher in each SPAGA week compared to at baseline. An increase in PA after exposure is similar to that reported in past studies. However, some studies did not report whether the increase was statistically significant (Toscos et al., 2008) or reported non-significant increases in PA (Newton et al., 2009; Shapiro et al., 2008). Even though the purpose of the SPAGA was to promote PA, one study did not state that PA was collected, and therefore did not report on PA (Arteaga

et al., 2010). Another finding similar to past literature (Newton et al, 2009) is that PA intensity yielded from the SPAGA was in the moderate range. Our data suggest that SPAGA can be motivating for adolescents to engage in moderate PA intensity.

Our data also suggests that more SPAGA options may not be better for increasing PA, with data indicating that more options might lower PA amount and intensity. This finding is inconsistent with another study with what was alluded to from Arteaga and colleagues (2010), where adolescents desired a wide range of game apps. Though desires were not reported in this study, in earlier focus groups participants also stated that they wanted large variations (Allen et al., n.d.). Thus, more research is needed to determine how to leverage participant desires (e.g. large variations) with mobile phone app testing.

The competition-based game (SR) was preferred over a more collaborative game (WAM) or individual games (SH or FOW). While, qualitative data complemented quantitative data and showed that SR was rated highest across themes. Enjoyment of competition is consistent with one study (Arteaga et al., 2010) but there were mixed findings in an adult study where some people enjoyed competition, while others did not (Lin et al., 2006). In the current study, the majority of adolescents did not like that when they played WAM, their individual points/pace of progression depended on other adolescents' performance and game play pace. Furthermore, they desired to play SPAGA but wanted to earn individual points based on individual performance. Therefore, our data implies that more competitive games should be created to better suit adolescent desires and perhaps increase engagement.

Additionally, our data suggests that the role of virtual characters as motivators can decrease and affect participant motivation to perform well while playing SPAGA. One participant was not interested in saving the fish while playing FOW, so this affected her motivation to compete in the game. This finding is dissimilar for participants in another study, who still competed despite not caring about the virtual character, fish (Lin et al., 2006). Yet, for individuals who are less competitive, they may need options for different virtual characters to suit their desires.

Aesthetics such as sound effects can play an important role in terms of motivation. Participants disliked if the game voice sounded robotic because that was perceived as demotivating. Instead, some

wanted human, animal or cartoon voices. Though, they were not in support of the current game voices, they did like the other sound effects (e.g. water splashing in FOW, sound when whacking the mole). Overall, the rating of the sound effect quality was fair (mean code weight= 2.28). This is inconsistent with the findings in another study where the participants liked the game agent and the agent's phrases were perceived as motivating and nice (Arteaga et al., 2010) Thus, in the revamping of the games, specific sound effect feedback will need to be incorporated.

Graphics also play a vital role in motivation. Overall the average quality rating of the graphics was fair (mean code weight=2). Participants wanted the games to look more realistic even if it was in cartoon form. Specifically, for WAM, some male adolescents had explicit violent graphical desired changes (e.g. blood) and some male adolescents emphasized that they liked how WAM was "semi-violent". The desire for more realistic graphics is consistent with Arteaga and colleagues (Arteaga et al., 2010). In conclusion, higher quality graphics will need to be designed in the newer versions of the SPAGA but precautions still must be taken when inappropriate suggestions are made.

Participants wanted all aspects of the SPAGA revealed to them. In WAM, the presence of an activated mole hill was indicated with a vibration of the mobile phone. In addition to this vibration, the majority of participants desired for there to be a visual of the mole popping out of the mole hill on the phone's screen to signify that they needed to begin whacking the mole. This recommendation is similar with another study (Arteaga et al., 2010). To prevent the adolescents from looking down at the mobile phone screen, we utilized several audio and touch cues. Targeting those senses was done to increase safety during game play. However, visual cues may need to correspond with audio or touch cues to increase ease of use and enjoyment.

To minimize playing the game in ways that differed from the way the games were intended to be played, we did practice runs. Generally, ease of use is supposed to be seen as a positive attribute, but in the quote in the results with a weight score of 4, the participant was able to be sedentary while playing WAM and still earned points, despite not playing the game as designed. Moreover, we did not account for

someone playing in that manner and will have to make adjustments to make sure that this does not occur in future game play.

The setting can also effect PA of adolescents. Our field notes of participant comments suggest that adolescents were more active indoors than outdoors while playing SPAGA. Perhaps the indoor space confined adolescents so they perceived that they could move more without the daunting feeling of an endless space to play. For some individuals running in a perceived endless space or too large of an area could be perceived as a barrier to PA. For example, for SR one's chances increase in the amount of points earned based on the proximity one is from another player. Moreover, Evenson and colleagues (2008) demonstrated that children/adolescents move in short quick bouts. Thus, our data suggests that a more confined setting (e.g. indoors) can help to facilitate PA.

This study is not without limitations. One limitation is that it had a small sample size. Researchers had to put a cap on the sample size because of limited number of smartphones and to potentially enhance informal behavior observation by researchers during game play. We also had a considerably smaller amount of girls (n=4) in the focus groups than boys (n=9), so when looking at the frequency of codes by gender, the data were normalized.

Conclusion

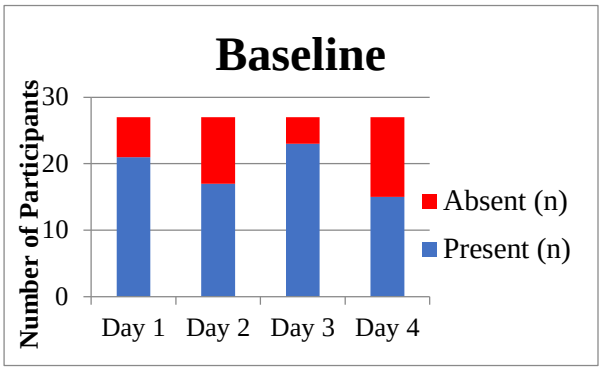
Mobile phones offer a unique opportunity for social interactions, and for interaction with the participant anytime (Arteaga et al., 2010) and are ubiquitous in nature. Additionally, adolescents playing SPAGA increased their PA level and motivation for PA and SPAGA. To our knowledge, before the creation of our SPAGA, there were no commercially available SPAGA that specifically targeted adolescents. The SPAGA created have implications that value is added with adolescent input. Moreover, our data suggests that continued engagement with the target population makes it easier to create technology that is culturally relevant. Future analysis includes determining if PA level is influenced by attendance and if any gender or age effects exists. We hope to revamp the current SPAGA and develop more SPAGA based on our findings and literature recommendations. Furthermore, we hope to increase the access to free PA resources (e.g. SPAGA) by releasing them into the Android market. Our data

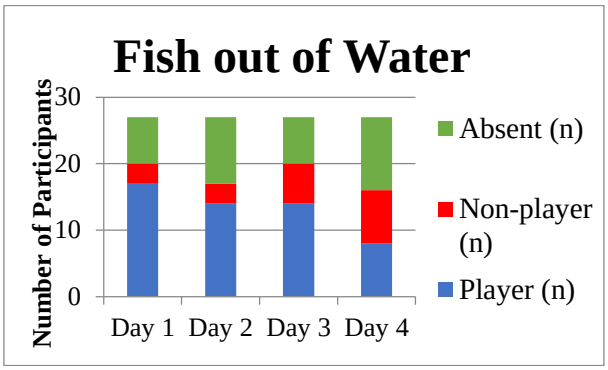
suggests that using mobile apps may be an effective strategy in promoting PA adolescents and a useful motivation tool while being simple to use. Also adolescents are very familiar with downloading apps so this may be a beneficial approach for future investigators. Moreover, future work includes testing SPAGA in a larger sample size for a longer time frame, providing PA information to parents, and validating the mobile phone accelerometer data with the ActiGraph data. Though more research is needed in the area of mobile phone gaming and PA, we demonstrated that SPAGA were able to increase PA in adolescents. We are not implying that technology should replace traditional forms of PA but rather be used as an alternative approach to meet participants' desires. Thus, it is recommended that more SPAGA be designed and developed based on adolescents' desires and that the effectiveness of PA maintenance and long-term adoption of SPAGA be determined.

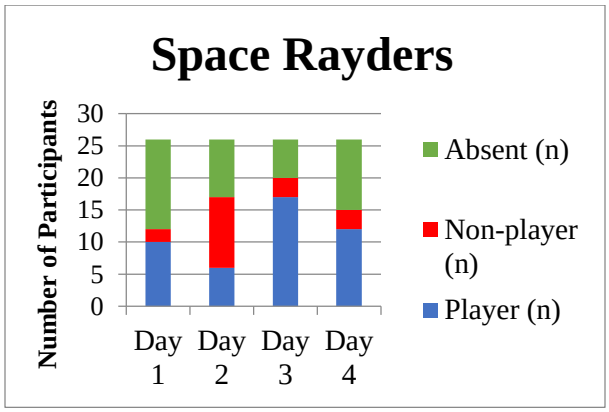
Table 4-1 Game play and survey schedule

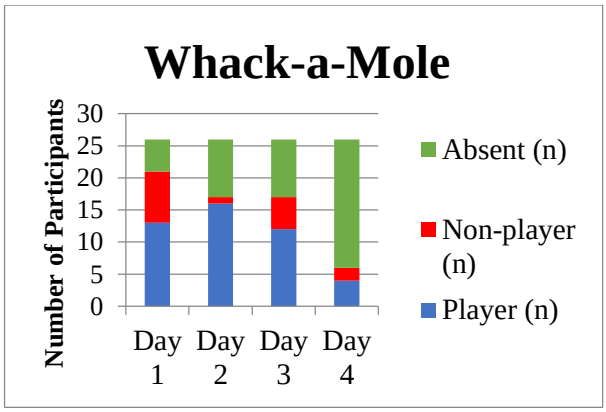
Game play and survey schedule				
	Monday	Tuesday	Wednesday	Thursday
Baseline	*	✓	✓	*
Fish out of Water	*✓	✓	✓	*✓
Space Rayders	*✓	✓	✓	*✓
Whack-a-Mole	*✓	✓	✓	*✓
Scavenger Hunt	*✓	✓	✓	*✓
ALL Games	*✓	✓	✓	*✓
*indicates that a survey was administered; ✓indicates SPAGA game play days				

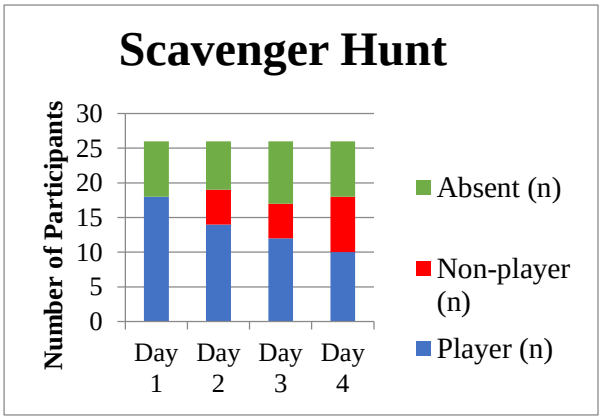
Figure 4-1 Daily Attendance and Game Play Status











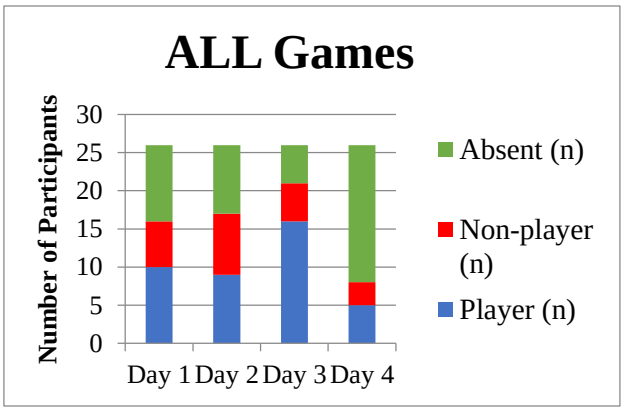
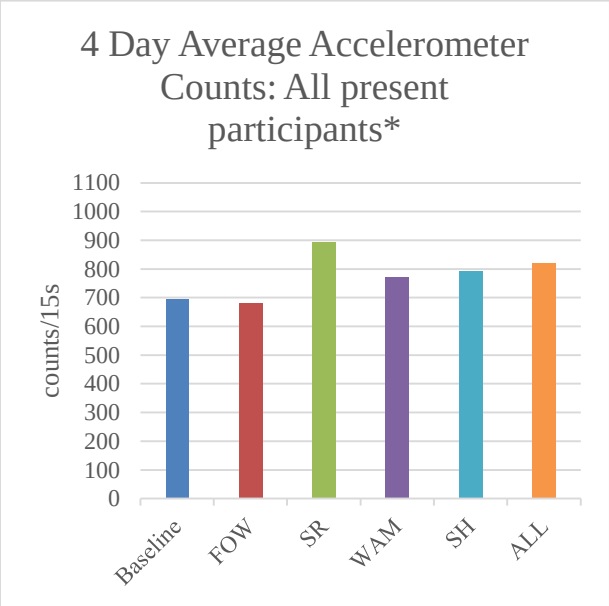
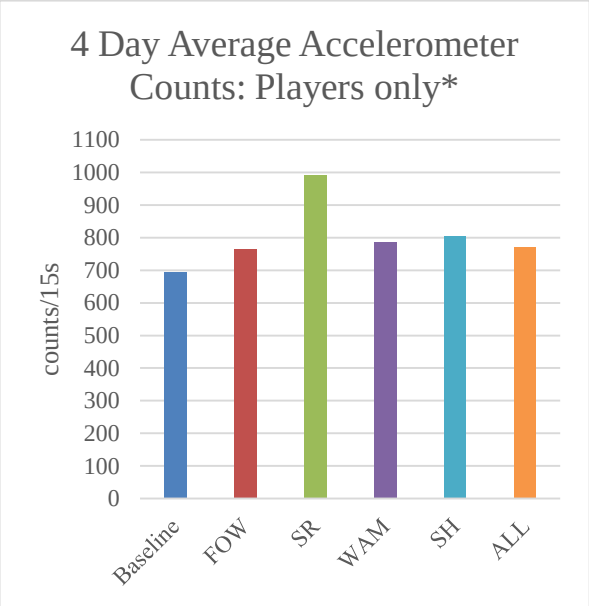


Figure 4-2 4 Day Average Accelerometer Counts for All Present Participants and Players





*FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games

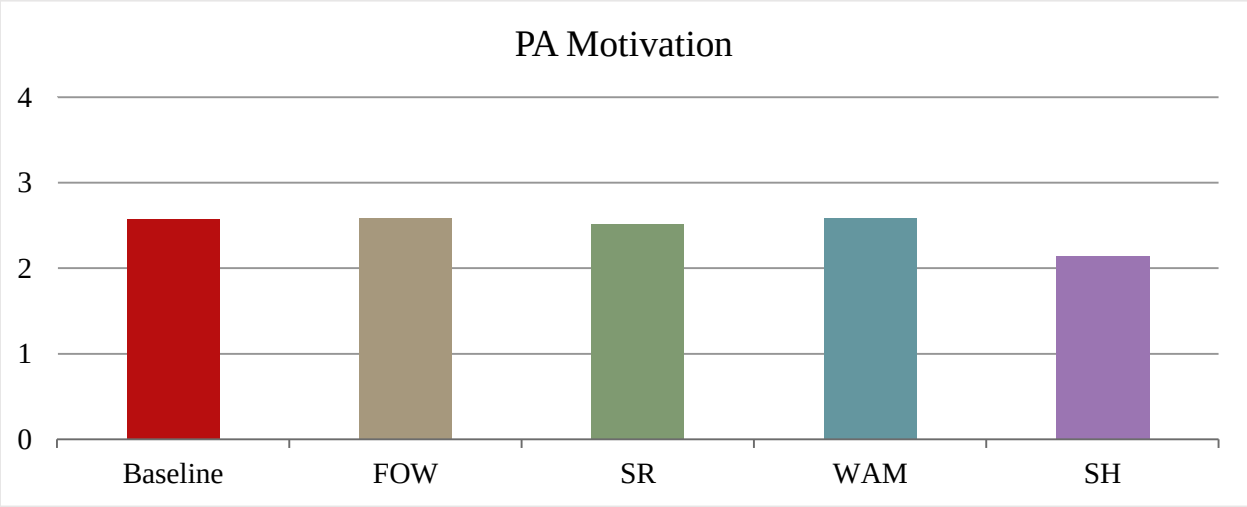
Table 4-2 Mean Accelerometer Counts: All present participants

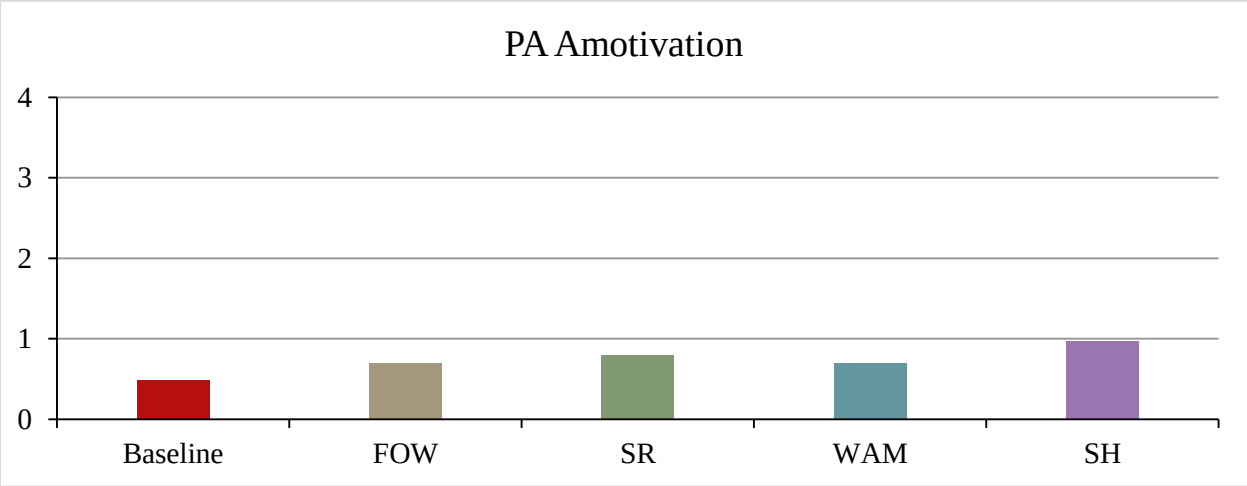
Mean Accelerometer Counts: All present participants					
Paired t	Mean difference (counts/15s)	Standard effect size	t	df	P-value
FOW-Baseline	-7.49783	0.025	0.122	22	0.904
SR-Baseline	170.87588	0.488^	2.126	18	0.048
WAM-Baseline	80.88732	0.295`	1.415	22	0.171
SH-Baseline	181.38730	0.663^	3.036	20	0.007
ALL-Baseline	139.46023	0.411`	1.927	21	0.068
FOW-SR	-205.48042	0.806#	-3.604	19	0.002
FOW-WAM	-80.46875	0.318`	-1.556	23	0.133
FOW-SH	-105.42765	0.425`	-1.994	21	0.059
SR-WAM	113.64958	0.389`	1.739	19	0.098
SR- SH	60.32939	0.150`	0.652	18	0.523
WAM-SH	-33.68152	0.0995	-0.477	22	0.638
FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games `indicates a small effect size; ^indicates a moderate effect size; #indicates a large effect size					

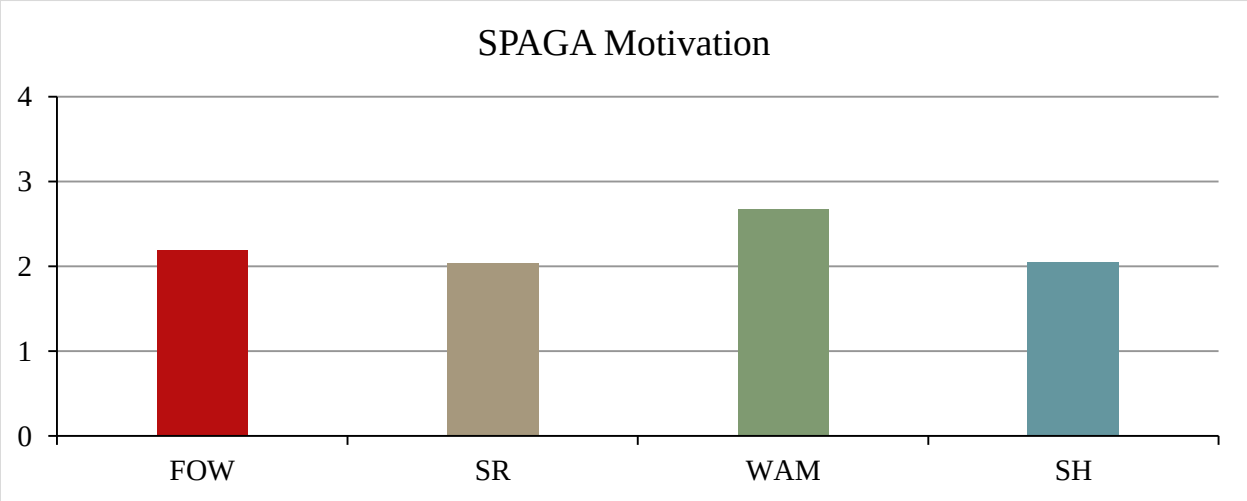
Table 4-3 Mean Accelerometer Counts: Players only

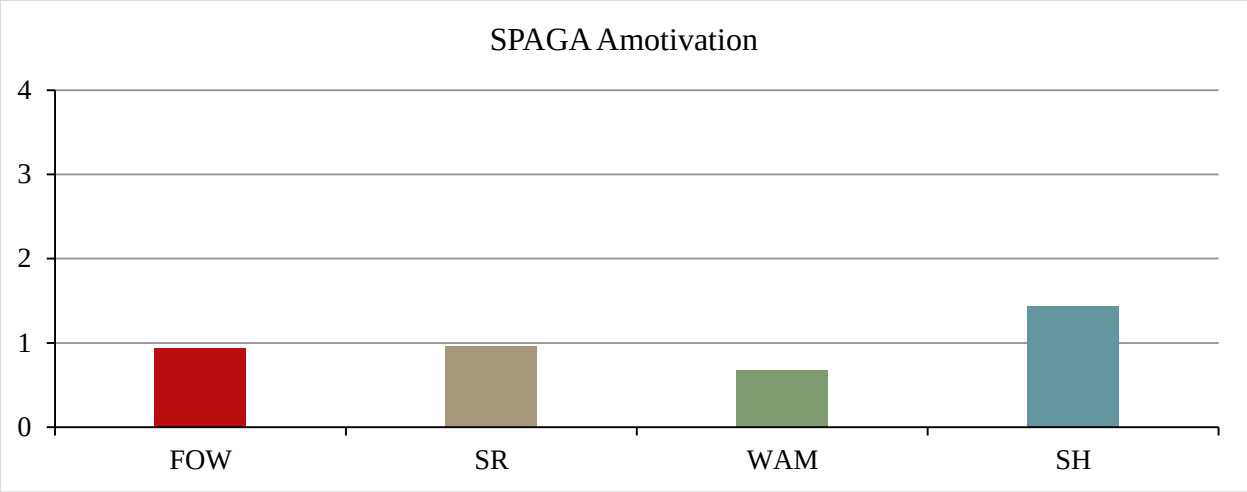
Mean Accelerometer Counts: Players only					
Paired t	Mean difference (counts/15s)	Standard effect size	t	df	P-value
FOW-Baseline	76.68106	0.241`	1.134	21	0.270
SR-Baseline	260.75648	0.717^	3.042	17	0.007
WAM-Baseline	72.35875	0.246`	1.098	19	0.286
SH-Baseline	191.05750	0.715^	3.198	19	0.005
ALL-Baseline	93.60147	0.255`	1.053	16	0.308
FOW-SR	-247.285	0.983#	-4.287	18	0.000
FOW-WAM	19.846	0.087	0.399	20	0.694
FOW-SH	-42.216	0.162`	-0.705	18	0.490
SR-WAM	231.197	0.806#	3.325	16	0.004
SR- SH	161.569	0.387`	1.596	16	0.130
WAM-SH	-32.503	0.093	-0.407	18	0.689
FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games `indicates a small effect size; ^indicates a moderate effect size #indicates a large effect size					

Figure 4-3 Motivation and Amotivation Mean Scores









PA =physical activity; FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games
Responses were on a 5 point scale: 0, not true for me; 2, sometimes true for me; 4, very true for me

Table 4-4 Paired t-test of comparing the mean difference of PA Motivation variables

Paired t-test of comparing the mean difference of PA Motivation variables*					
Paired t	Mean difference	Standard effect size	t	df	P-value
PA Motivation FOW – PA Motivation Baseline	0.06667	0.0700	0.271	14	0.790
PA Motivation SR – PA Motivation Baseline	0.28571	0.407	1.522	13	0.152
PA Motivation WAM – PA Motivation Baseline	0.44444	0.556	1.668	8	0.134
PA Motivation SH– PA Motivation Baseline	0.03333	0.0342	0.108	9	0.916
PA Motivation FOW – PA Motivation SR	-0.12821	0.165	-0.595	12	0.563
PA Motivation FOW – PA Motivation WAM	0.13333	0.126	0.399	9	0.699
PA Motivation FOW – PA motivation SH	-0.20000	0.163	-0.514	9	0.619
PA Motivation SR – PA Motivation WAM	0.76667	0.735	2.325	9	0.045
PA Motivation SR – PA Motivation SH	0.33333	0.369	1.168	9	0.273
PA Motivation WAM – PA Motivation SH	-0.79167	0.599	-1.696	7	0.134
PA =physical activity; FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games *Responses were on a 5 point scale: 0, not true for me; 2, sometimes true for me; 4, very true for me					

Table 4-5. Paired t- test of comparing the mean difference of PA Amotivation variables

Paired t- test of comparing the mean difference of PA Amotivation variables*					
Paired t	Mean difference	Standard effect size	t	Df	P-value
PA Amotivation FOW – PA Amotivation Baseline	2.3333	0.182	0.706	14	0.492
PA Amotivation SR – PA Amotivation Baseline	0.25000	0.230	0.860	13	0.405
PA Amotivation WAM – PA Amotivation Baseline	0.33333	0.385	1.155	8	0.282
PA Amotivation SH– PA Amotivation Baseline	0.25000	0.303	0.958	9	0.363
PA Amotivation FOW – PA Amotivation SR	0.61538	0.444	1.600	12	0.136
PA Amotivation FOW – PA Amotivation WAM	0.25000	0.211	0.667	9	0.521
PA Amotivation FOW – PA Amotivation SH	0.20000	0.316	1.000	9	0.343
PA Amotivation SR – PA Amotivation WAM	-0.60000	0.492	-1.555	9	0.154
PA Amotivation SR – PA Amotivation SH	-0.20000	0.172	-0.545	9	0.599
PA Amotivation WAM – PA Amotivation SH	0.31250	0.313	0.886	7	0.405
PA =physical activity; FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games *Responses were on a 5 point scale: 0, not true for me; 2, sometimes true for me; 4, very true for me					

Table 4-6 Paired t- test of comparing the mean difference of SPAGA Motivation variables

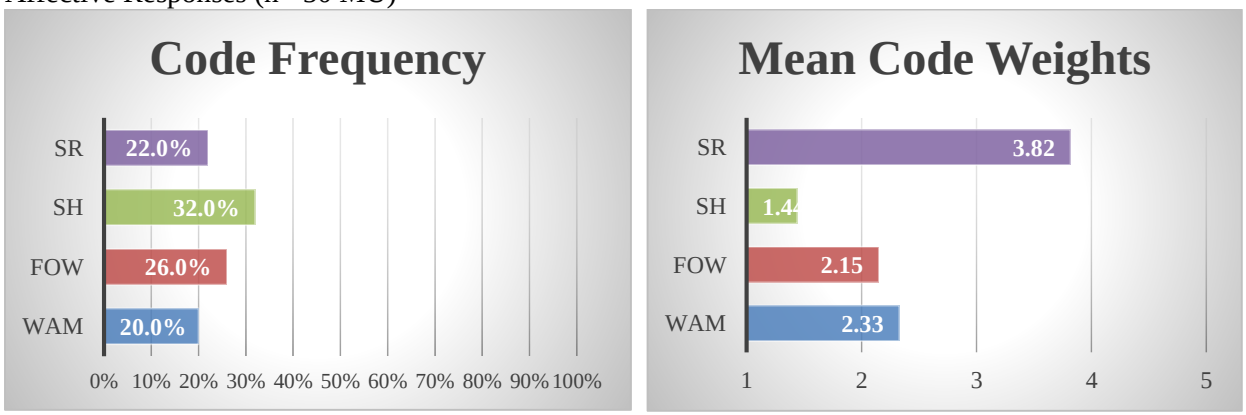
Paired t- test of comparing the mean difference of SPAGA Motivation variables*					
Paired t	Mean difference	Standard effect size	t	Df	P-value
SPAGA Motivation FOW – SPAGA Motivation SR	-0.28205	0.192	-0.691	12	0.503
SPAGA Motivation FOW – SPAGA Motivation WAM	0.60000	0.590	1.868	9	0.095
SPAGA Motivation FOW – SPAGA motivation SH	0.00000	0.000	.000	9	1.000
SPAGA Motivation SR – SPAGA Motivation WAM	0.86667	0.548	1.734	9	0.117
SPAGA Motivation SR – SPAGA Motivation SH	0.46667	0.242	0.764	9	0.465
SPAGA Motivation WAM – SPAGA Motivation SH	-0.70833	0.641	-1.814	7	0.113
PA =physical activity; FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games *Responses were on a 5 point scale: 0, not true for me; 2, sometimes true for me; 4, very true for me					

Table 4-7 Paired t- test of comparing the mean difference of SPAGA Amotivation variables

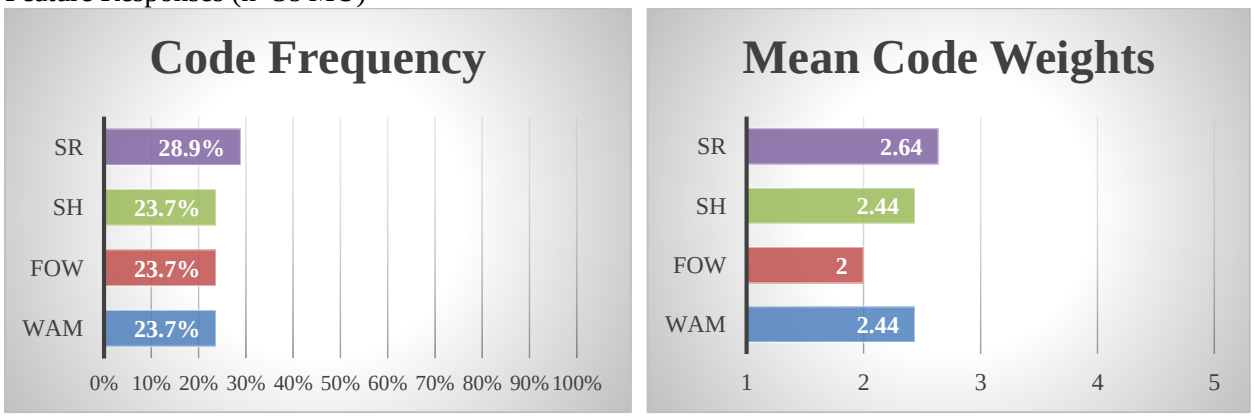
Paired t- test of comparing the mean difference of SPAGA Amotivation variables					
Paired t	Mean difference	Standard effect size	t	df	P-value
SPAGA Amotivation FOW – SPAGA Amotivation SR	0.15385	0.084	0.301	12	0.768
SPAGA Amotivation FOW – SPAGA Amotivation WAM	-0.35000	0.360	-1.137	9	0.285
SPAGA Amotivation FOW – SPAGA Amotivation SH	-0.85000	0.396	-1.251	9	0.242
SPAGA Amotivation SR– SPAGA Amotivation WAM	-0.20000	0.199	-0.629	9	0.545
SPAGA Amotivation SR – SPAGA Amotivation SH	-0.45000	0.203	-0.642	9	0.537
SPAGA Amotivation WAM– SPAGA Amotivation SH	-0.18750	0.108	-0.306	7	0.768
PA =physical activity; FOW=Fish out of Water; SR= Space Rayders; WAM= Whack-a-Mole; SH= Scavenger Hunt; ALL= All games *Responses were on a 5 point scale: 0, not true for me; 2, sometimes true for me; 4, very true for me					

Figure 4-4 Focus Group Themes

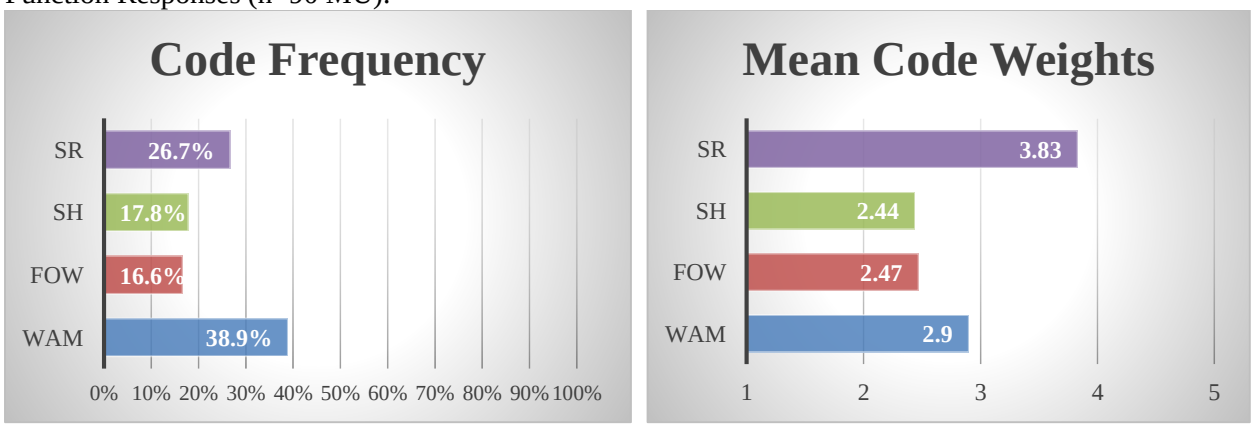
Affective Responses (n= 50 MU)



Feature Responses (n=38 MU)



Function Responses (n=90 MU).



References

Allen, K., Harlow, J., Winchester III, W., McCrickard, D.S., Zoellner, J., Hill, J.L., & Estabrooks, P.A. (n.d.). Development of smartphone game-based applications for the physical activity promotion in low socioeconomic status adolescents.

Arteaga, S.M., Kudeki, M., Woodworth, A., & Kurniawan, S. (2010). Mobile system to motivate teenagers' physical activity. Proceedings from ICD ’10: *The 9th International Conference on Interaction Design and Children.* Barcelona, Spain.

Bailey, B.W., & McInnis, K. (2011). Energy cost of exergaming: A comparison of the energy cost of 6 forms of exergaming. *Archives of Pediatrics & Adolescent Medicine, 165(7), 597.*

Baranowski, T., Buday, R., Thompson, D.I., & Baranowski, J. (2008). Playing for real: Video games and stories for health-related behavior change. *American Journal of Preventive Medicine, 34*, 74-82.

Beets, M.W., Beighle, A., Erwin, H.E., & Huberry, J.L. (2009). After-school program impact on physical activity and physical fitness. A*merican Journal of Preventive Medicine, 36*(6), 527-539.

Bell, M., Chalmers, M., Barkhuus, L., Hall, M., Sherwood, S., Tennent, P.,…Hampshire, A. (2006). Interweaving mobile games with everyday life. Proceedings from CHI ’06: *The Conference on Human Factors in Computing Systems.* Montréal, Canada.

Breton, E.R., Fuemmeler, B.F., & Abroms, L.C. (2011). Weight loss-there is an app for that! But does it adhere to evidence-informed practices? *Translational Behavioral Medicine, 1*(4), 523-529.

Brodersen, N.H., Steptoe, A., Boniface, D.R., & Wardle, J. (2007). Trends in physical activity and sedentary behaviour in adolescence: Ethnic and socioeconomic differences. *British Journal of Sports Medicine, 41*(3), 140–4.

Bogost, I. (2005). *The rhetoric of exergaming.* Paper presented at the Digital Arts and Cultures Conference. , Copenhagen, Denmark.

Boys & Girls Clubs of Southwest Virginia. (2013). Who we serve and what we do. Retrieved from http://www.bgcswva.org.

Boys & Girls Clubs of America. (2013). Mission. Retrieved from http://www.bgca.org.

Bull S. (2010). *Technology-based Health Promotion*. Los Angeles, CA: SAGE Publications.

Centers for Disease Control and Prevention. (2011a). Physical activity levels of high school students---United States, 2010. *Morbidity and Mortality Weekly Report, 60*(23), 773-777. Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6023a1.htm?s_cid=mm6023a1_w

Centers for Disease Control and Prevention, Division of Nutrition, Physical Activity and Obesity, National Center for Chronic Disease Prevention and Health Promotion. (2011b). Physical activity for everyone: The benefits of physical activity. Retrieved from http://www.cdc.gov/physicalactivity/everyone/health/index.html

Centers for Disease Control and Prevention. (2012). Youth Risk Behavior Surveillance-United States, 2011. *Morbidity and Mortality Weekly Report, 61*(No.SS-4):1-168.

Consolvo, S., McDonald, D.W., Toscos, T., Chen, M.Y., Froehlich. J., Harrison, B.,…Landay, J.A. (2008). Activity sensing in the wild: A field trial of UbiFit Garden. Proceedings from SIGCHI ’08: *The 26th Annual SIGCHI Conference on Human Factors in Computing Systems.* Florence, Italy.

Daley, A.J. (2009). Can exergaming contribute to improving physical activity levels and health outcomes in children? *Pediatrics, 124*(2), 763-771.

Dedoose Version (4.5), web application for managing, analyzing, and presenting qualitative and mixed method research data, 2013, SocioCultural Research Consultants, LLC (SCRC): Los Angeles, CA.

Dunton, G.F., Whalen, C.K., Jamner, L.D., Henker, B., & Floro, J.N. (2005). Using ecologic momentary assessment to measure physical activity during adolescence. *American Journal of Preventive Medicine, 29*(4), 281-287.

Dunton, G., Liao, Y., Intille, S.S., Spruijt-Metz, D., & Pentz, M. (2011). Investigating children's physical activity and sedentary behavior using ecological momentary assessment with mobile phones. *Pediatric Obesity, 19*(6), 1205-1212.

Evenson, K.R., Catellier, D.J., Gill, K., Ondrak, K.S., & McMurray, R.G. (2006). Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences, 24*(14), 1557-1565.

Fanning, J.T., Mullen, S.M., & McAuley, E. (2012). Increasing physical activity with mobile devices: A meta-analysis. *Journal of Medical Internet Research, 14*(6), e161.

Fogel, V.A., Miltenberger, R.G., Graves, R., & Koehler, S. (2010). The effects of exergaming on physical activity among inactive children in a physical education classroom. *Journal of Applied Behavior Analysis, 43*(4), 591.

Fogg, B.J. (2009). *A behavior model for persuasive design*. Proceedings from Persuasive '09: *The Conference on Persuasive Technology*. Claremont, California.

Freedson, P., Pober, D., & Janz, K.F. (2005). Calibration of accelerometer output for children. *Medicine and Science in Sports and Exercise, 37*(11 Suppl), S523.

Fujiki, Y., Kazako, K., Puri, C., Starren, J., Pavlidis, I., & Levine, J. (2007). *NEAT-o-Games: Ubiquitous activity-based gaming*. Proceedings from HCI '07: *The Conference on Human Computer Interaction*. San Jose, CA.

Fujiki, Y., Kazakos, K., Puri, C., Buddharaju, P., & Pavlidis, I., Levine, J. (2008). NEAT-o-Games: blending physical activity and fun in the daily routine. *Computers in Entertainment (CIE), 6*(2), 1-21.

Garriguet, D., & Colley, R.C. (2012). Daily patterns of physical activity among Canadians. Components of Statistics Canada Catalogue no. 82-003-X; 23 (2).

Gordon-Larsen, P., Nelson, M.C., Page, P., & Popkin, B.M. (2006). Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics, 117*(2), 417–424.

Groundspeak, Inc. (2012). Geocaching. Retrieved from http://www.geocaching.com/.

Graneheim, U.H., & Lundman, B. (2004). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today, 24*(2), 105-112.

Guy, S., Ratzki-Leewing, A., & Gwadry-Sridhar, F. (2011). Moving beyond the stigma: Systematic review of video games and their potential to combat obesity. *International Journal of Hypertension*.

Hashim, H.A., Golok, F., & Ali, R. (2011). Profiles of exercise motivation, physical activity, exercise habit, and academic performance in Malaysian adolescents: A cluster analysis. *International Journal of Collaborative Research on Internal Medicine & Public Health, 3*(6), 416-428.

Heumer, G., Carlson, D., Kaligiri, S.H., Maheshwari, S., Hasan, W., Jung, B., & Schrader, A. (2006). *Paranoia Syndrome: A pervasive multiplayer game using PDA¨s, RFID, and tangible objects*. Paper presented at the 3rd International Workshop on Pervasive Gaming Applications on Pervasive Computing. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.84.2619&rep=rep1&type=pdf.

IBM Corp. (2012). *IBM SPSS Statistics for Windows*. Armonk, NY.

Jayant, C., & Saponas, T.S. (2005). *MarioFit: Exercise through mobile entertainment*. Retrieved from http://74.125.155.132/scholar?q=cache:q6OhpHgym_oJ:scholar.google.com/&hl=en&as_sdt=2000.

Koivusilta, L.K., Lintonen, T.P., & Rimpelä, A.H. (2007). Orientations in adolescent use of information and communication technology: A digital divide by sociodemographic background, educational career, and health. *Scandinavian Journal of Public Health, 35*(1), 95-103.

Kristjandottir, G., & Vilhjalmsson, R. (2001). Sociodemographic differences in patterns of sedentary and physically active behavior in older children and adolescents. *Acta Paediatrica, 90*(4), 429-435.

Lasheras, L., Aznar, S., Merino, B., & Lopez, E.G. (2001). Factors associated with physical activity among Spanish youth through the National Health Survey. *Preventive Medicine, 32*, 455-464.

Lau, P.W.C., Lau, E.Y., Wong, D.P., & Ransdell, L. (2011). A systematic review of information and communication technology-based interventions for promoting physical activity behavior characteristics in children and adolescents. *Journal of Medical Internet Research, 13*(3), e48.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A., Evans, C., & Vitak, J. (2008). Teens, video games, and civics. Retrieved from http://www.pewinternet.org/Reports/2008/Teens-Video-Games-and-Civics.aspx

Lenhart, A., Ling, R., Campbell, S., Purcell, K. (2010). Teens and mobile phones. *Pew Internet & American Life Project*. Retrieved from http://pewinternet.org/Reports/2010/Teens-and-Mobile-Phones.aspx

Lenhart, A. (2012). Teens, smartphones, & texting. *Pew Internet & American Life Project*. Retrieved from http://pewinternet.org/Reports/2012/Teens-and-smartphones.aspx.

Lin, J.L., Mamykina, L., Lindtner, S., Delajoux, G., Strub, H.B. (2006). Fish'n'Steps: Encouraging physical activity with an interactive computer game. Proceedings from UbiComp '08: *The 8th International Conference of Ubiquitous Computing.* Orange County, CA.

Markland, D., & Tobin, V. (2004). A modification of the Behavioral Regulation in Exercise Questionnaire to include an assessment of amotivation. *Journal of Sport and Exercise Psychology, 26,* 191-196.

McVeigh, J.A., Norris, S.A.. & de Wet, T. (2004). The relationship between socio-economic status and physical activity patterns in South African children. *Acta Paediatrica, 93*(7), 982-988.

Newton, K.H., Wiltshire, E.J., & Elley, C.R. (2009). Pedometers and text messaging to increase physical activity randomized controlled trial of adolescents with type 1 diabetes. *Diabetes Care, 32*(5), 813-815.

Rideout, V., Roberts, D.R., Foehr, U.G. (2005). *Generation M: Media in the lives of 8-18 year-olds (Publication No. 7250).* Washington DC: The Henry J. Kaiser Family Foundation.

Robusto, K.M., & Trost, S.G. (2012). Comparison of three generations of ActiGraph activity monitors in children and adolescents. *Journal of Sports Sciences, 30*(13), 1429-1435.

Shapiro, J.R., Koro, T., Doran, N., Thompson, S., Sallis, J.F., Calfas, K., & Patrick, K. (2012). Text4Diet: A randomized controlled study using text messaging for weight loss behaviors. *Preventive Medicine, 55*(5), 412-417.

Staiano, A.E., & Calvert, S.L. (2011). Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Development Perspectives, 5*(2), 93-98.

Straker, L., & Abbott, R. (2007). Effect of screen-based media on energy expenditure and heart rate in 9- to 12-year-old children. *Pediatric Exercise Science*, *19*(4), 459–471.

Toscos, T., Faber, A.M., An, S., & Gandhi, M.P. (2006). *Click Clique: Persuasive technology to motivate teenage girls to exercise.* Proceedings from CHI ’06: *The Conference for Human-Computer Interaction.* Montréal, Québec, Canada.

Toscos, T., Faber, A., Connelly, K., Upoma, A.M. (2008). *Encouraging physical activity in teens Can technology help reduce barriers to physical activity in adolescent girls?* Paper presented at the Second International Conference on Pervasive Computing Technologies for Healthcare, 2008, Tampere, Finland.

Vandewater, E.A., Shim, M., Caplovitz, A.G. (2004). Linking obesity and activity level with children's television and video game use. *Journal of Adolescence, 27*(1), 71-85.

Wildcat Apps. (2010). Retrieved from https://itunes.apple.com/us/app/red-light-green-light-fun/id381454994?mt=8.

Xu, Y., Poole, E.S., Miller, A.D., Eiriksdottir, E., Kestranek, D., Catrambone, R., Mynatt, E.D. (2012). This is not a one-horse race: Understanding player types in multiplayer pervasive health games for youth. Proceedings from CSCW ’12: *The 2012 ACM Conference on Computer Supported Cooperative Work.* Seattle, WA.

CHAPTER 5: GENERAL CONCLUSIONS

Though physical activity (PA) is a leading health indicator, is a Health People 2020 Objective, and numerous benefits are well known, the percentage of adolescents meeting PA recommendations continues to be low. Moreover, physical inactivity puts adolescents at risk for developing various chronic diseases (e.g. cardiovascular, cancer, diabetes) and for decreasing mental health status. Furthermore, adolescents in racial/ethnic minority groups or low SES households are at an increased risk of developing these diseases due to reasons such as access or affordability of PA resources. We developed SPAGA based on input from adolescents and demonstrated increases in PA compared to baseline. Our plan is increase accessibility to a PA resource such as SPAGA to all individuals especially adolescents from low SES families. Overall, this dissertation suggests that the SPAGA were simple to play regardless of prior gaming experience. Though, the responses from the focus group highlighted that using smartphones for PA in the manner of which was instructed in the study protocol was different than how the adolescents had used the phones in the past, they still participated regularly. The game testing environment was conducive for PA promotion through smartphone game play. Adolescents were able to play SPAGA among their peers.

Past PA reviews where studies were conducted in-person or via technology (e.g., internet, mobile phone or personal digital assistant) primarily focused on examining effectiveness of PA outcomes. The systematic literature review conducted in this dissertation investigated the degree to which mobile phone PA interventions reported on internal and external validity indicators. This review showed that majority of studies did a good job of reporting on effectiveness of outcomes but few reported on who was adopting the program and characteristics of adopters; the extent of the interventions being implemented as intended and maintenance effects on PA behavior, and maintenance effects of the intervention on the organizational level. Furthermore the included studies mentioned the sample size but need to increase reporting of characteristics of those that were approached but decided not to participate and characteristics of dropouts. Generally, very few of the studies targeted adolescent populations. Very few of the studies primarily focused on health disparate populations such as adolescents of low SES or racial/ethnic

minority households. In addition to the other suggestions, we recommend that cost of effectiveness, implementation and maintenance should be reported on, as this is useful information for future investigators or potential adopters. Overall, this review suggests that greater efforts need to focus on research designs that highlight and report on both internal and external validity indicators, so that investigators can assess the public health impact of interventions.

Manuscript 2 described the process of engaging adolescents and their parents in the design and development of smartphone games to promote PA. The BGCA staff, adolescents, and their parents welcomed us into the community center and were open to the SPAGA idea. Though the engagement process was lengthy, it was rewarding because the design/development team gained a deeper understanding of the BGCA culture and the adolescents sustained their interest in the app development. Overall, it is evident that value is added when adolescent input is queried early in planning and the importance of for future developers to use a user-centered approach.

In the testing of the SPAGA, the PA intensity that was produced was in the moderate range. One of the games, Space Rayders (SR), which was the most enjoyed by the adolescents, also yielded the highest PA intensity. Moreover, more positive perceptions of SR were positively associated with a higher PA intensity. Comments about the games were centered on improvements to the aesthetics of the games. Additionally, there was higher motivation for PA in the majority of the SPAGA weeks compared to at baseline. Participants also provided a variety of changes to the current SPAGA. Our data suggests that adolescents would like to continue to play SR. We plan to continue development on SPAGA by incorporating the changes specified by adolescents. Depending on funding and feasibility, we may choose to just continue development of SR since based on our data is was the SPAGA that "worked the best". Furthermore, an accelerometer application ran while each game was played. We want to validate these data with the ActiGraph GT3x+ accelerometer data. It is our hope that the accelerometer application is accurate and could provide players with useful easy to interpret visuals (e.g. charts) of their daily game usage and PA. We would want to determine the relationship between game play and PA. Since parents can help reinforce healthy behaviors, we would like to provide parents with game play usage and PA

information of their child. Perhaps SPAGA would be something that parents and their children could play together. Lastly, we are interested in what happens when adolescents do not have a structured game play session with SPAGA. For example in their free time at the BGCA, would they play with SPAGA, how many SPAGA would they regularly play with, what would be the daily average game usage duration, and would they play the SPAGA in unintended ways since they would not be monitored by adults.

After further revisions and testing, our goal is to release the SPAGA into the Android market at no cost to the consumer. By no means are we trying to make a profit off of the SPAGA, but rather make it available for all individuals who desire to play SPAGA. Additionally, we want to make SPAGA available as a PA resource in the BGCA, but will have to gauge if this is something that they would want to move forward with. If they do want to continue engagement, collectively we can look into solidifying phones to be donated/purchased for the BGCA. Moreover, quantitative and qualitative findings will be disseminated back to the BGCA. We will show and explain the adolescents and BGCA staff, charts on the effect of SPAGA usage on adolescent PA.

Overall, our data demonstrated that SPAGA could be an effective intervention approach to promote PA in adolescents in meeting PA recommendations. Moreover, SPAGA could be an effective strategy. Further research should explore and assess short-term and long-term outcome effects of game-based and other formats on mobile phones for PA promotion in adolescents via input from adolescents early in the development and design stages.

Appendix A- Coding Sheet for RE-AIM Components for Manuscript 1

Title:		Group Based	Individual	Interactive Technology	Policy
(Author, Journal, Year, Page):		Comments:			
Outcome Measures	Reported (Yes/No)	Data		Comments	
Behavior					
Diet					
Physical Activity					
Sedentary activity/ screen time					
Fruit & vegetable intake					
Sugar sweetened beverages					
Anthropometry					
Weight					
BMI					
BMI z-scores					
BMI percentile					
Waist circumference					
Skinfold					
DEXA					
Other					
Physiological					
Biomarkers					
Reach	Reported (Yes/No)	Data		Comments	

Described target population			
Demographic & behavioral information			
Method to identify target population			
Recruitment Strategies			
Inclusion criteria			
Exclusion criteria			
Target population denominator			
Sample size			
Participation rate			
Characteristics of participants & non-participants			
Cost of recruitment			
Use of qualitative methods to measure reach			
Efficacy/Effectiveness	Reported (Yes/No)	Data	Comments
Design/Conditions			
Efficacy, Effectiveness, Translational?			
Measure of primary outcome			
Comparison to public health goal			
Results (at program completion)			
Intent-to-treat or present at FU?			
Imputation procedures (specify)			
Quality of life measure			

Measure unintended consequences (negative) and results			
Percent attrition (at program completion)			
Cost effectiveness			
Use of qualitative methods to measure efficacy/effectiveness			
Adoption - Diffusion - Setting Level	Reported (Yes/No)	Data	Comments
Setting			
Description of intervention location			
Description of staff who delivered intervention			
Method to identify target delivery agent			
Level of expertise of delivery agent			
Inclusion/exclusion criteria of setting			
Inclusion/exclusion criteria of delivery agent			
Rate (# participating settings/total settings)			
Rate (# of delivery agents/total # of delivery agents)			
Organizational spread (how far into an organization)			
Characteristics of adoption/non-adoption of settings			
Characteristics of adoption/non-adoption of delivery agents			
Measures of cost of adoption			
Dissemination beyond originally planned			
Use of qualitative methods to measure adoption			
Implementation	Reported (Yes/No)	Data	Comments

Theories			
Intervention number of contacts			
Timing of contacts			
Duration of contacts			
Extent protocol delivered as intended (%)			
Consistency of implementation across setting and delivery agents			
Participant attendance/completion rates			
Measure of cost			
Use of qualitative methods to measure implementation			
Maintenance	Reported (Yes/No)	Data	Comments
Was individual behavior assessed at some duration following the completion of the intervention? (give duration of follow-up)			
Measure of alignment to organization mission			
Attrition			
Is the program still in place?			
If no: reason for discontinuation			
If yes: was the program modified? Specify			
Was the program institutionalized?			
Use of qualitative methods to measure maintenance			

Appendix B – Companion Sheet for RE-AIM Components for Manuscript 1

RE-AIM Component	Description
Reach	**The proportion & representativeness of individuals willing to participate in a given intervention**
Described target population	A brief description of the broader target population (i.e., not simply of the study sample). Example: The target population included all women within the community health center who were over the age of 18 and were not meeting the recommended guidelines for physical activity.
Demographic & behavioral information	Gender, age, educational attainment, occupation, SES, behavioral outcomes for the target population
Method to identify target population	Describe the process by which the target population was identified for participation in the study. Example: All patients who were part of the target population were identified using the electronic medical record.
Recruitment Strategies	Describe the methods used to recruit participants into the study. Example: We used a series of flyers; presentations; mass media; and word of mouth strategies to recruit participants.
Inclusion criteria	Explicit statement of characteristics of the target population that were used to determine if a potential participant is eligible to participate. Example: The inclusion criteria are…
Exclusion criteria	Explicit statement of characteristics that would prevent a potential participant from being eligible to participate. Also the percent excluded may be reported. Example: The exclusion criteria are…
Target population denominator	The total number of eligible participants contacted for participation. Example: 300 people were contacted for the study. After a screener was administered, it was found that of those 300 people contacted, 250 people were eligible. Therefore 250 is the denominator.
Sample size	The number of people who agree to participate (e.g. n=)
Participation rate	Sample size divided by the target population denominator. Example: 200 (number of people agree to participate)/250 (number of eligible participants contacted for participation)=80%
Characteristics of participants & non-participants	Explicit statement of characteristics (e.g. demographics; behavioral outcomes) of the participants and non-participants. Example: When compared to participants, non-participants were more likely to be older physically inactive females.
Cost of recruitment	The cost of recruitment can reflect monetary and/or time units. Example: The overall cost of recruitment strategy A (flyers) was $1000 versus the overall cost of recruitment strategy B (newspaper advertisements) was $200. Could also be coded in cost per participant

	recruited.
Use of qualitative methods to measure reach	Reporting on non-quantitative aspects of reach. Observations in words, sentences, descriptions or codes. Some common methods include key informant interviews, focus groups, or even field notes that provide information on perceptions, feelings, opinions, experiences, etc.
Efficacy/Effectiveness	**The influence of an intervention on important outcomes, including potential negative effects, quality of life, & economic outcomes**
Design/Conditions	The explicit description of the contents of the experimental procedure. Example study designs: cross-sectional, quasi-experimental; randomized controlled trials; hybrid. The conditions describe how different groups are treated (treatment versus an alternative condition) in the study.
Efficacy, Effectiveness, Translational?	The explicit statement of the trial type. *Efficacy*: studies conducted by research staff in optimal locations (e.g. clinic) *Effectiveness*: studies conducted by non-research staff in real-world settings (e.g. schools, community settings, etc.) *Demonstration*: studies that determine the effect of an efficacious intervention on public health when delivered in whole systems such as schools, cities, counties, states, or nations. *Translational*: Studies that move interventions along the efficacy-effectiveness-demonstration spectrum and provide information on the process of moving research into practice or vice versa.
Measure of primary outcome	The variable that the study is focused on and that the conclusions of the study will be based on. Is it measured at a time point after baseline? Example: duration, intensity, frequency of PA; BMI at 3 months
Comparison to public health goal	Compare the outcomes to national behavioral recommendations/guidelines Example: At baseline 30% of the participants were meeting the recommended guidelines for PA; after the intervention 50% were meeting the guidelines.
Results (at program completion)	The effect size or amount of change in the primary outcome at the end of the program Example: Post intervention, participants in the experimental group increased, on average, 100 minutes of moderate-to-vigorous PA per week while the control participants saw no increase.
Intent-to-treat or present at FU?	*Intent to treat analysis*: when participants in trials are analyzed in the groups to which they were randomized, regardless of whether they received or adhered to the allocated intervention. Example, will typically use the term intent to treat or will describe an imputation that was used to account for missing data in the analysis.

	Present at Follow-up analysis: when only participants who completed the follow-up assessment are included in the analysis of efficacy/effectiveness. Example: Only those participants who completed both the baseline and follow-up measures were included in the analysis.
Imputation procedures (specify)	Substitution of some value for missing data. Example: Multiple imputation methods were used to impute missing minutes of PA data at 3 months…
Quality of life measure	Includes a measure of quality of life with some latitude for coding articles that refer to well-being or satisfaction with life.
Measure unintended consequences (negative) and results	To evaluate unanticipated consequences and results that may be a product of the intervention and may have caused unintended harm. Example: In a PA promotion program, female participants had an increased rate of injury.
Percent attrition (at program completion)	The proportion that was lost to follow-up or dropped out of the intervention. This is calculated by dividing the number of participants who did not complete the intervention by the number of participants who began the intervention. Example: 100 participants began the intervention and 20 participants did not complete the intervention. So there was 20% attrition.
Cost effectiveness	Code as reported if specific mention and amounts are provided for the cost of the intervention. Example: The new strategy would save $1,000 per life per year when compared to the current practice.
Use of qualitative methods to measure efficacy/effectiveness	Obtaining qualitative feedback from participants on the degree to which they felt the intervention was efficacious/effective. Some common methods include focus groups, interviews, diaries (text/pictures).
Adoption - Diffusion - Setting Level	**The number, proportion & representativeness of locations & intervention staff willing to initiate & adopt an intervention**
Setting	The location(s) where the intervention is delivered. Example: university/clinical/community/faith-based/home/worksite
Description of intervention location	The explicit statement of characteristics of the location of the intervention. Example: size of location; resources available staff information; number of eligible locations; work environment/climate
Method to identify setting	Describe the process by which the location was identified for participation in the study.
Description of staff who delivered the intervention	The explicit statement of characteristics of the staff who delivered the intervention Example: demographics; behavioral outcomes;
Method to identify target delivery agent	Describe the process by which the target delivery agent was identified for participation in the study. Example: All staff at the intervention location that had expertise in leading PA classes was identified by supervisors at the intervention location.

Level of expertise of delivery agent	Training or educational background in relevant area; Degrees, certifications of delivery agents (such as PhD, Masters, Registered Dietitian, etc.); type of delivery agent (research assistant, physician, etc.)
Inclusion/exclusion criteria of setting	The explicit statement of characteristics of the setting that were used to determine if a potential setting is eligible to participate. Example: The inclusion/exclusion criteria are...
Inclusion/exclusion criteria of delivery agent	The explicit statement of characteristics of the delivery agents that were used to determine if a potential delivery agent is eligible to participate. Example: The inclusion/exclusion criteria are...
Rate (# participating settings/total settings)	(Number of participating settings that agree to deliver the intervention) divided by (total number of contacted and eligible settings) = X%
Rate (# of delivery agents/total # of delivery agents)	(Number of agents that agree to deliver the intervention) divided by (total number of contacted and eligible delivery agents) = X%
Organizational spread (how far into an organization)	The movement of the intervention across multiple departments or sites within a given organization
Characteristics of adoption/non-adoption of settings	Description of the characteristics of the setting(s) that decided to adopt vs. the setting(s) that decided not adopt the intervention
Characteristics of adoption/non-adoption of delivery agents	Description of the characteristics of the delivery agent(s) that decided to adopt vs. the delivery agent(s) that decided not to adopt the intervention; who you are
Measures of cost of adoption	The price of adoption across all levels of the intervention. At least some mention of start-up (i.e., not ongoing) costs.
Dissemination beyond originally planned	The spread of the intervention beyond what was planned before the start of the intervention
Use of qualitative methods to measure adoption	Used qualitative methods to understand the process of adoption. Example: focus groups, interviews of adoption settings or delivery agents
Implementation	**How consistently various elements of an intervention are delivered as intended by intervention staff, & the time & cost of the intervention**
Theories	Explicit statement of theories or principles used to develop the intervention Example: social cognitive theory, theory of planned behavior
Intervention number of contacts	Total number of encounters with participants. Could include face-to-face meetings, telephone calls, newsletters etc.
Timing of contacts	Describe when the intervention contacts occur over the course of the intervention. Example: For the first month participants received one telephone call per week and in every month thereafter they received a call a month until the end of the 12 month intervention

Duration of contacts	Length of each intervention contact. Example: The first 4 calls lasted about 20 minutes each, the other 11 lasted about 10 minutes each.
Extent protocol delivered as intended (%)	Description of fidelity to the intervention protocol. Example: a checklist of program components assessed by delivery agent(s)
Consistency of implementation across setting and delivery agents	Description of the degree of similarities between multiple settings sites & delivery agents
Participant attendance/completion rates	The proportion of the intervention that the participants received, on average. Example: Participants attended 4 of the 6 meetings on average.
Measure of cost	The ongoing cost of delivery across all levels of the intervention
Use of qualitative methods to measure implementation	Used qualitative methods to understand the process of implementation. Example: focus groups, interviews
Maintenance	**The extent to which participants make & maintain a behavior change & the sustainability of a program or policy in the setting in which it was intervened**
Was individual behavior assessed at some duration following the completion of the intervention? (give duration of follow-up)	Description of follow-up outcome measures of individuals available at some duration after intervention termination Example: 6 months after the intervention ended participants had returned to baseline levels of PA.
Measure of alignment to organization mission	Report the degree to which the intervention was designed to, or did, align with the delivery organization's mission, values.
Attrition	Describe the degree to which participants were lost to follow-up (and the reasons) during the period in time from the interventions completion to the follow-up.
Is the program still in place?	Description of program continuation after completion of the research study.
If no: reason for discontinuation	Description of why the intervention was terminated
If yes: was the program modified? Specify	Description of any changes that were made to the original program
Was the program institutionalized?	Description of the how the intervention was integrated into the delivery system through methods such as policy changes, job description changes.
Use of qualitative methods to measure maintenance	Used qualitative methods to understand the process of individual level maintenance of changes to the primary outcome. Example: focus groups, interviews

Use of qualitative methods to measure organizational level maintenance	Used qualitative methods to understand the process of intervention sustainability at the organizational level

Appendix C - Focus group and semi-structured interview guide for Manuscript 2

Human Nutrition, Foods & Exercise

Using Features on Smart Phones to Increase Physical Activity in Teens

Focus Group Script

Good afternoon and welcome to our session today. Thank you for taking the time to join our discussion on physical activity and smartphones. My name is _____. Assisting me tonight will be _____. We are both graduate students at Virginia Tech. The insight you provide can be used by us to develop an appropriate and enjoyable physical activity promotion program for students that attend the community center and their parents.

Today, we will be talking about your thoughts, opinions, and experiences with physical activity. We'll also talk about the use of smart phones to increase physical activity. There are no particular answers we are looking for. There are no right or wrong answers. Please share what you think even if you have a different way of seeing things than others in the group.

Before we begin, I just want to remind you to please speak up and we ask that one person speak at a time. It is important that we hear from each person. We will tape record the discussion so we can accurately capture your responses.

My role will be to ask the questions and keep our discussion going. I will ask about ____questions. Read the below paragraph before the child focus group:

Today, I would like to ask you some questions about your physical activity choices in a talk with other teens. Also I will ask questions about smart phone features to increase physical activity. This talk will last around 60 to 90 minutes and will be tape recorded. It is up to you if you want to be in the study. You have the right to stop participating at any time after talking with your parents. It is okay if you do not want to answer a question I ask. There is no more than a small risk with participation in this study. You may feel a little discomfort talking in front of others. There no right or wrong answers. The information that you give me will help our research team make better smart phone apps relating to physical activity. Feel free to ask any questions during the talk. You will be treated the same whether or not you choose to join the talk.

Please go around the table and tell us your first name. No names will be associated with the comments we use. So again please give us your first name and tell us what you like to do for physical activity.

Child Focus Group: 26 questions total

[Individual-Level]

1. How would you describe your participation in physical activity after-school?

2. What types of physical activities do you usually do after-school? Why do you like to that physical activity?

3. Do you think you need to be more physically active after school?

a. If answered yes, how can you be more physically active after-school?

4. What major things stop you from being physically active?

5. What are solutions to the previously mentioned barriers to being physically active?

[Friends & Family]

1. During after school, how important is being physical activity to your friends?

2. In the after school program, what motivates your friends to participate in physical activity?

3. In the after school program, how have your friends helped you engage in physical activity?

4. Are you physically active with your parents? Why or why not?

5. How do you want to engage in physical activity with your parents?

Thank you for providing more information about your physical activity attitudes and behaviors. Next we will talk about your cellular phone usage and smart phones.

Smart phones refer to mobile phones that are capable of doing things that you can do on a computer such as emailing and web browsing. If you have not had any experiences with smart phone capabilities, please answer as related how you think you might use a smart phone or how a smart phone could be helpful to you. Even if you do not have your own mobile phone you can answer as if you did. So in other words pretend…

1. If you have a cellular phone, besides making a call, what do you typically use your phone for?
   [If needed probe: What parts of the phone do you mostly use? (camera, texts)]

2. Without stating the persons names, whom do you contact mostly? (e.g. friends/family)

3. How many times a day do you text message?

4. What do you like about texting? What don't you like about texting?

5. What prior experiences have you had with using smart phones? (Restate the above sentence about what a smart phone is)

6. Do you use the GPS (may need to explain) on your phone? What do you like or dislike about it?

7. Do you use the Google maps? What do you like or dislike about it?

8. How many times a day do you use social network apps? (e.g. Facebook & Twitter) What do you like or dislike about it?

9. How many times a day do you play games on your phone? What do you like or dislike about it?

10. How many times a day do you listen to music on your phone? What do you like or dislike about it?

11. How familiar are you with downloading Apps on your phone? What types do you download (e.g. Games, Lifestyle)? What do you like or dislike about the Apps?

12. How many times a day do you check your phone?
    [If needed probe: For missed calls or messages or time?]

13. As we know, there are different types of applications or apps on smartphones. Some measure physical activity intensity (e.g., basketball v. Baseball). How familiar are you with this App? If applicable, what do you like most or dislike the most about this feature? Why?
    [If needed probe: What would you like about something that could measure how physically active you were?]

We are thinking about using a smartphone and its features to help promote physical activity for teens, so please think of that as you answer these questions.

14. A smartphone app can track how you move and give you points. How would you feel about a program like this? What do you think about being able to use the smartphone features to compete against others in different games?

15. How confident are you that you could use smartphone features regularly to help you be physically active? Similar to the Shake the Apple Tree Game and Scavenger Hunt that either you played or saw other teens playing.

16. What kind of feedback would you want from using a smartphone (e.g. negative/positive) to help you be more physically active? (e.g. positive or negative points)
17. Are they any additional comments or suggestions that you would like to add?

Thank you so much for joining us today.

If there is extra time, we can answer the below questions:

1. How would you describe participation in PA during school?

2. Afterschool, how would you say your PA level is in comparison to your friends?

3. Afterschool, how would you say your PA level is in comparison to your family?

Parent Interview: 24 questions total

[Individual-Level]

1. I'm interested in learning about your physical activity patterns. Can you tell me about your favorite types of physical activity?

2. What do you enjoy most about physical activity?

3. What major things stop you from being more physically active?

4. What are solutions to the previously mentioned barriers to being physically active?

5. Now I'm interested in learning about your child's physical activity patterns. What sort of physical activity do your children enjoy most?

6. What motivates your children to participate in physical activity?

7. At home are you physically active with your child(ren)? Why or why not? Tell me a little about physical activities that you and you're children do together.

8. How have you helped your child participate in PA?

[Friends & Family]

1. Would you be willing to monitor your child's PA? If so, how?

Thank you for providing more information about your physical activity attitudes and behaviors. Next we will talk about your cellular phone usage and smart phones.

1. Do you have a cellular phone?

2. How do you usually communicate with your child?

3. If you communicate with your child using a phone…

   a. How often do you call him/her a day?
   b. How often do you text him/her a day?

Smart phones refer to mobile phones that are capable of doing things that you can do on a computer such as emailing and web browsing. If you have not had any experiences with smart phone capabilities, please answer as if you did have them on your phone.

1. A smartphone app can track how often and the speed your child's body moves (e.g. physical activity) and give him/her points based on this. How would you feel about your child using a program like this?

2. What kind of feedback (e.g. negative/positive) would you want from a smartphone so that you can give your child encouragement/support?

3. Talk to me about receiving text messages about information about your child's participation in physical activity. [If needed probe: For example: if your child inputted a code when they were using a smartphone app after school. This code would send a message to your phone about your child's daily progress.]

4. What do you think you would do with the information provided?

5. If you were using a phone for physical activity what types of things would you want? (If needed probe: For example: visuals/sound effects/music/tracking of behavior; if participants uses a general category listed have them describe what they mean)

6. What sorts of programs help you to be more physically active? (e.g. Wii Fit; Kinect)

7. How would you like to interact with smart phone apps in regards to physical activity with your child?

8. Do you download apps on your phone? If so what kinds of apps (e.g. games, trivia, banking)?

9. Have you ever downloaded an app that had to do with health, PA or nutrition?

10. If you could design an app that could help you be healthier what would that look like?

11. Are they any additional comments or suggestions that you would like to add?

Thank you so much for joining us today.

Appendix D – Youth Smartphone Game Applications and Physical Activity Survey for Manuscript 3

Virginia Polytechnic Institute & State University

Youth Smartphone Game Applications and Physical Activity Survey

This survey will help us learn more about your experiences and perceptions with smart phone game applications and physical activity. There are no right or wrong answers, so please answer the questions honestly. You do not have to answer any questions that you do not want to. Please **CIRCLE** only one answer for each question.

[ID]: □□□

[DATE]: □□/ □□/ □□□□
[RECORD MONTH/DAY/YEAR]

VirginiaTech
Invent the Future

MOTIVATION

SMARTPHONE GAME

	Not true for me		Sometimes true for me		Very true for me
1. I play this game because it's fun	0	1	2	3	4
2. I play this game because my friends do	0	1	2	3	4
3. I don't see the point in playing this game	0	1	2	3	4
4. I play this game because it is different from other games I have played before	0	1	2	3	4
5. I think playing this game is a waste of time	0	1	2	3	4
6. I play this game because I want to beat my friend's score	0	1	2	3	4
7. I play this game because I get to play it on a smartphone	0	1	2	3	4
8. I play this game because it allows me to be physically active.	0	1	2	3	4

PHYSICAL ACTIVITY

Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time. Physical activity can be done in sports, playing with friends, or walking to school. Some examples of physical activity are running, brisk walking, rollerblading, biking, dancing, skateboarding, swimming, soccer, basketball, football, & surfing

	Not true for me		Sometimes true for me		Very true for me
1. I am physically active because it's fun	0	1	2	3	4
2. I participate in physical activity because my friends do	0	1	2	3	4
3. I don't see the point in participating in physical activity	0	1	2	3	4
4. I like trying different physical activities	0	1	2	3	4
5. I think being physically active is a waste of time	0	1	2	3	4
6. I am physically active because I want to compete with my friends	0	1	2	3	4

AFTERSCHOOL PHYSICAL ACTIVITY

The next questions ask about your physical activity in the afterschool program

	Not true for me		**Sometimes true for me**		**Very true for me**
1. I am physically active in the afterschool program because it's fun	0	1	2	3	4
2. I am physically active in the afterschool program because my friends are	0	1	2	3	4
3. I don't see the point in being physically active in the afterschool program	0	1	2	3	4
4. I am physically active in the afterschool program because it is different from other activities I did earlier in the day	0	1	2	3	4
5. I think being physically active in the afterschool program is a waste of time	0	1	2	3	4
6. I am physically active in the afterschool program because I want to compete against my friend's	0	1	2	3	4
7. I am physically active in the afterschool program because I get to play the activities I enjoy	0	1	2	3	4
8. I am physically active in the afterschool program because it allows me to be healthy	0	1	2	3	4

ABILITY

SMARTPHONE GAME

Rate **HOW SURE** you are that you can play this game in each situation.

	I'm sure I can't	I probably can't	Neutral	I probably can	I'm sure I can
1. Play this game well?	1	2	3	4	5
2. Show your friends how to play this game?	1	2	3	4	5
3. Show your parents how to play this game?	1	2	3	4	5
4. Play this game most days afterschool?	1	2	3	4	5

PHYSICAL ACTIVITY

Rate **HOW SURE** you are that you can do physical activity in each situation.

	I'm sure I can't	I probably can't	Neutral	I probably can	I'm sure I can
1. Do most kinds of physical activity?	1	2	3	4	5
2. Show your friends how to be physically active?	1	2	3	4	5
3. Show your parents how to be physically active?	1	2	3	4	5

AFTERSCHOOL PHYSICAL ACTIVITY

Rate **HOW SURE** you are that you can be physically active in the afterschool program in each situation.

	I'm sure I can't	I probably can't	Neutral	I probably can	I'm sure I can
1. When you have too much homework?	1	2	3	4	5
2. When you feel tired?	1	2	3	4	5
3. When you would rather sit and talk with friends?	1	2	3	4	5
4. When the weather is bad?	1	2	3	4	5
5. When you want to watch television, play videogames or play on the computer?	1	2	3	4	5
6. When you have a bad day at school?	1	2	3	4	5

TRIGGER

SMARTPHONE AND PHYSICAL ACTIVITY

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. If we weren't playing this game I probably wouldn't be physically active.	1	2	3	4	5
2. I started playing this game because there wasn't anything else that was interesting to do.	1	2	3	4	5
3. Playing this game reminds me that physical activity is fun.	1	2	3	4	5
4. Before playing this game, I was less physically active.	1	2	3	4	5
5. Playing this game made physical activity easier.	1	2	3	4	5

TRIGGER

AFTERSCHOOL PHYSICAL ACTIVITY

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. If we weren't physically active in the afterschool program I probably wouldn't be physically active.	1	2	3	4	5
2. I started being physically active in the afterschool program because there wasn't anything else that was interesting to do.	1	2	3	4	5
3. Being physically active in the afterschool program reminds me that physical activity is fun.	1	2	3	4	5
4. Before coming to the afterschool program, I was less physically active.	1	2	3	4	5
5. Participating in physical activity afterschool makes physical activity easier.	1	2	3	4	5

PHYSICAL ACTIVITY

1. What type of physical activity did you do ***at school*** today?

2. For how many total minutes did you do physical activity ***at school*** today?

3. Besides playing this game, what type of physical activity did you do ***after school*** today?

Not including this game, for how many total minutes did you do physical activity ***after school*** today?

Appendix E - Focus group and semi-structured guide for Manuscript 3

Human Nutrition, Foods & Exercise

Using Features on Smartphones to Increase Physical Activity in Middle-School Students

Focus Group Script

Good evening and welcome to our session tonight. Thank you for taking the time to join our discussion on physical activity and smartphones. My name is _____. Assisting me tonight will be _____. We are both graduate students at Virginia Tech. The insight you provide can be used by us to make improvements on the games that you played on the smartphones. Today, we will be talking about your thoughts, opinions, and experiences with using the smartphones for physical activity promotion. There are no particular answers we are looking for. There are no right or wrong answers. Please share what you think even if you have a different way of seeing things than others in the group.

Before we begin, I just want to remind you to please speak up and we ask that one person speak at a time. It is important that we hear from each person. We will tape record the discussion so we can accurately capture your responses.

My role will be to ask the questions and keep our discussion going. I will ask about ____questions. Read the below paragraph before the child focus group:

Today, I would like to ask you some questions about playing the games on the smartphones in a talk with other teens. This talk will last around 60 to 90 minutes and will be tape recorded. It is up to you if you want to be in the study. You have the right to stop participating at any time after talking with your parents. It is okay if you do not want to answer a question I ask. There is no more than a small risk with participation in this study. You may feel a little discomfort talking in front of others. There no right or wrong answers. The information that you give me will help our research team make better smart phone apps relating to physical activity. Feel free to ask any questions during the talk. You will be treated the same whether or not you choose to join the talk.

Please go around the table and tell us your first name. No names will be associated with the comments we use. So again please give us your first name.

<u>Tag</u>

1. What were your initial reactions about tag? Why?
2. What would you have changed about tag? Why?
3. What did you like most about tag ? Why?
4. What did you think of the sound effects while playing tag?
5. What did you think of the graphics while playing tag?
6. How did playing tag help you be more physically active?

<u>Whack-a-mole</u>

7. What were your initial reactions about whack-a-mole? Why?
8. What would you have changed about whack-a-mole? Why?
9. What did you like most about whack-a-mole? Why?
10. What did you think of the sound effects while playing whack-a-mole?

11. What did you think of the graphics while playing whack-a-mole?
12. How did playing whack-a-mole help you be more physically active?

Fish out of water

13. What were your initial reactions about fish out of water? Why?
14. What would you have changed about fish out of water? Why?
15. What did you like most about fish out of water? Why?
16. What did you think of the sound effects while playing fish out of water?
17. What did you think of the graphics while playing fish out of water?
18. How did playing fish out of water help you be more physically active?

Scavenger Hunt

19. What were your initial reactions about scavenger hunt? Why?
20. What would you have changed about scavenger hunt? Why?
21. What did you like most about the scavenger hunt? Why?
22. What did you think of the sound effects while playing scavenger hunt?
23. What did you think of the graphics while playing scavenger hunt?
24. How did playing scavenger hunt help you be more physically active?

General

25. From, the list of game apps, what game would you recommend your friends play? Why?
26. What final comments or thoughts do you have related to the games?