

Physical Activity Promotion in Children Using a Novel Smartphone Game:
A Pilot Randomized Controlled Trial

by

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Abstract

Background: Regular physical activity (PA) is critical for children's health and wellbeing. Despite the numerous health benefits, most Canadian children do not meet the Canadian PA guidelines. The emergence of the COVID-19 pandemic and social restrictions added new challenges to meeting the PA guidelines. Mobile health (mHealth) technology can be leveraged to promote PA among children. Combining gamification with mHealth interventions has the potential to further improve program effectiveness. Thus, "Draco" was developed as a virtual pet smartphone app to increase PA in children using self-determination theory as a framework to promote intrinsic motivation for PA.

Objective: The primary objective is to evaluate the satisfaction and acceptability of the Draco app after four weeks. Secondary objectives include evaluating the preliminary effectiveness of the Draco app to improve average daily steps, average daily MVPA, perceived autonomy for PA, perceived competence for PA, and perceived relatedness to the app.

Methods: 43 Canadian children, aged 8-14 years old, not meeting the Canadian PA guidelines of 60min of MVPA per day were randomly allocated to an intervention or control group. Participants in the control group used a step-tracking app for four weeks. Intervention participants were instructed to use the Draco app. Participants completed a baseline and follow-up questionnaire. PA outcomes were tracked using a Fitbit provided to each participant. Intrinsic PA motivation was assessed using an adapted version of the Intrinsic Motivation Inventory (IMI). Intrinsic motivation was assessed using the satisfaction subscale. Exit interviews were completed to determine app acceptability.

Results: Participants demonstrated high levels of satisfaction and acceptability with the Draco app 2.83 (1.29). Intervention participants increased their average daily steps by 909 (1701). The

control group increased their steps by 46 (1507). The Draco app had a small effect on promoting steps, MVPA, relatedness and small effects at increasing autonomy and competence.

Conclusion: Participants demonstrated high levels of satisfaction and acceptability with the app.

Participants in the intervention group showed greater increases in PA with small effect sizes.

Preliminary evidence highlights the importance of tailoring game design to the users. Technical limitations impacted recruitment and user experiences. Additional development time should be taken to stabilize the app and add new game features for a definitive RCT.

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Chapter 1: Introduction

1.1 Background

Regular physical activity (PA) is critical for children's development and wellbeing. Regular PA offers protection from chronic diseases such as cardiovascular disease, hypertension, obesity and diabetes (Carson et al., 2016; Warburton et al., 2006). However, only 35% of children aged 5-17 years old are meeting the daily Canadian PA guidelines for 60min of moderate-to-vigorous physical activity (MVPA) (Colley et al., 2017; ParticipACTION, 2018). Further complicating this was the impact of the COVID-19 pandemic. During the outset of the pandemic, approximately 24% of children were meeting the PA guidelines (Moore et al., 2020). The lockdown restrictions limited PA opportunities provided by schools (Pavlovic et al., 2021). Outdoor play and team sports also suffered as children engaged in more activities indoors (Moore et al., 2020).

Common approaches to promote PA among children include school programs, family active play or organized sports (Brown et al., 2016; Kriemler et al., 2011; Messing et al., 2019). Several studies have shown that these approaches are effective in promoting PA among children (Brown et al., 2016; Kriemler et al., 2011; Messing et al., 2019). However, scalable, and cost-effective PA promotion strategies are still needed. The COVID-19 pandemic and quarantine restrictions have further demonstrated the need for alternative methods to deliver PA interventions for children (Moore et al., 2020).

The rapid adoption of smartphones presents an opportunity to use this technology to improve children's PA levels. Previous literature has shown that smartphone applications (apps) can be effective in promoting PA (Romeo et al., 2019). However, the effectiveness of these app varies

depending on the design of app features and use of a theoretical framework (Helf & Hlavacs, 2016; Hosseinpour & Terlutter, 2019).

One method to improve adherence and intervention effectiveness in health apps is the use of design elements characteristic for games in a non-game context, referred to as gamification (Deterding et al., 2011). Gamification may be used in conjunction with behaviour change theories to promote motivation for PA. The use of game features has been developed within the self-determination theory (SDT) construct to promote PA motivation. SDT represents a broad framework of human motivation that is developed through three basic psychological needs: autonomy, competence, and relatedness (Deci & Ryan, 2008). PA interventions are developed to promote intrinsic forms of motivation for PA which are more positively associated with PA engagement (Teixeira et al., 2012). Gamification features can be used to fulfill needs satisfaction within the SDT framework (Xi & Hamari, 2019). The design features within a game, such as achievements, or an avatar, can act as motivational affordances for autonomy, competence, or relatedness.

Consequently, I worked with computer programmers at the Digital Health Lab at the University of Victoria to develop a smartphone game designed to promote PA in children, Draco. The Draco app was developed to target the three psychological needs of motivation while incorporating a range of gamification techniques such as progression, points, goals, and rewards. The feasibility of the Draco app to promote PA is currently unknown. The purpose of this pilot randomized controlled trial (RCT) is to evaluate the acceptability and explore the potential effectiveness of Draco in promoting PA behaviour in children between the ages of 8 and 14. The specific research questions include the following:

1.2 Primary Research Question

1. What is the acceptability and satisfaction with the Draco app after 4 weeks of use among children?

1.3 Secondary Research Questions

2. Does the Draco smartphone app promote greater daily steps relative to a control group after 4 weeks of use?
3. Does the Draco app promote greater moderate-to-vigorous physical activity (MVPA) relative to a control group after 4 weeks of use?
4. Does the Draco app change PA motivation, perceived autonomy, competence, and relatedness among children relative to a control group after 4 weeks of use?

1.4 Hypothesis

1. I hypothesize that children would show high levels of satisfaction and acceptability with the Draco app after the four weeks determined by a score of 2.50 or higher on the IMI scale.
2. I hypothesize that the Draco app will have a medium effect at promoting average daily steps in children relative to a control group.
3. I hypothesize that the Draco app will have a medium effect at promoting average daily MVPA minutes in children relative to a control group.
4. I hypothesize that the Draco app will have a medium effect at promoting perceived autonomy for PA, perceived competence for PA and relatedness towards the app.

1.5 Significance of Study

This study aims to provide further evidence to the growing body of literature on the potential effectiveness of using gamification to promote PA. Additionally, few novel gamification apps intently designed for children have been developed.

1.6 Assumptions

1. Participants will respond to the questionnaire items accurately and honestly.
2. Participants will play the smartphone apps honestly.

1.7 Limitations

1. The researcher acknowledges the following limitations for the study that may impact results:
2. The effectiveness of a longer intervention using a novel smartphone app directed towards children remains unclear.
3. Some participants experienced technical issues with step syncing which may have affected app usability

1.8 Delimitations

1. Additionally, the researcher is aware of the following delimitations:
2. Participants are children aged 8-14 years old.
3. Participants are all individuals who are not meeting the Canadian PA guidelines for 60min of MVPA per day.
4. Participants have no injury or illness that prevents increased PA participation.

1.9 Operational Definitions

Physical Activity: Any bodily movement produced by the skeletal muscles that require energy expenditure

MVPA: Physical activity that ranges from moderate to vigorous intensity.

Moderate-Intensity: activities that cause an elevation in heart rate, slight sweat and increased breathing.

Vigorous-Intensity: activities that cause a substantial increase in heart rate and cause one to sweat and become out of breath.

Smartphone: A type of mobile device with a computing system that can run applications, and perform cellular activities (phone, SMS, MMS, etc.).

Application (app): Software designed to operate on a mobile device.

Gamification: The use of features characteristic of games in non-game contexts (Deterding et al., 2011). Examples of this include using points, achievements, goals, or competition to modify a target behaviour.

Chapter 2: Review of Literature

2.1 Introduction: Physical Activity Benefits

The benefits of physical activity (PA) have been well reported across all age groups. Children display developmental, social, and mental benefits to PA (Carson et al., 2016; Colley et al., 2017; Janssen & LeBlanc, 2010). Current evidence is strong to support the beneficial effect of PA on musculoskeletal and cardiovascular health (Janssen & LeBlanc, 2010). There is further support suggesting that regular PA is important to preventing childhood obesity (Janssen & LeBlanc, 2010). Short intervals of activity between 10-20min are sufficient to accumulate movement time (Janssen & LeBlanc, 2010). The benefits of engaging in PA further extend to mental health as the benefits have also shown improvements in self-esteem, depressive symptoms and working memory (Lees & Hopkins, 2013; Rathore & Lom, 2017). Along with numerous benefits, engaging in PA is a useful preventative technique for chronic diseases. PA can drastically reduce one's likelihood of developing metabolic syndrome and obesity (Brien & Katzmarzyk, 2006; Janssen & LeBlanc, 2010). PA can also aid in preventing risk factors leading to diabetes by improving glycemic control, insulin resistance and blood pressure in youth (Fedewa et al., 2014; Janssen & LeBlanc, 2010). It is clear that children should be engaging in a variety of activities from aerobic, strengthening, or high intensity to provide the greatest physical health benefits (Janssen & LeBlanc, 2010).

The Canadian 24-Hour Movement guidelines are the most commonly accepted recommendations to achieve these activity levels (Chaput et al., 2014). They are an integrated guideline providing recommendations for PA, sleep, and sedentary screen-time within a full 24-hour day (Chaput et al., 2017). These guidelines suggest that children should reach 60min of MVPA each day (Tremblay et al., 2011).

Physical Activity Prevalence in Children

Reaching the minimum of 60min of MVPA has been a long-standing issue among Canadian children. Although more than 80% of preschool-aged children are meeting the guidelines, this behaviour does not continue through childhood (Colley et al., 2013). Overall, across Canada, only 35% of children aged 5-17 years old meet the PA recommendations (ParticipACTION, 2018). Only 16.5% of children aged 9 to 11 years old met the daily MVPA requirements (Chaput et al., 2014; Colley et al., 2017; Roman-Viñas et al., 2016). This rate remained stagnant for 10 years as children have not demonstrated any considerable increase since 2005 (ParticipACTION, 2018). Only recently in the 2020 report, prior to the COVID-19 pandemic, did children's PA rates increase to 39% meeting the recommendations (ParticipACTION, 2020). This was supported by the importance of active play and team sport during a child's school years (ParticipACTION, 2020).

Further complicating the issue of children's PA rates, was the emergence of the COVID-19 pandemic. Due to the pandemic, many services in Canada closed or restricted access to limit the spread of the virus. Notably, schools were closed for extended periods due to the various restrictions. Schools that did remain open saw drastic cuts in the physical education curriculum and requirements for activity minutes (Pavlovic et al., 2021). Standard activities like sport or outdoor play lowered while indoor activities rose during this time (Mitra et al., 2020; Moore et al., 2020). Inside activities such as arts, crafts, games, video games, and screen-based activities increase during this time (Mitra et al., 2020; Moore et al., 2020). Recreational facilities also faced the same closures, limiting access to programs and sports normally used in the summer months for activity. Compounding this is overcoming fears related to the health impacts of COVID-19 and maintaining social distance (Pavlovic et al., 2021).

2.2 Physical Activity Promotion among Children

Physical Activity during School

Schools are an important environment relied upon by families to increase children's PA (Gao et al., 2016; Kriemler et al., 2011). A common strategy is providing time in the curriculum for PA either by offering mandatory classes or additional time for physical education (PE) (Messing et al., 2019; Trudeau & Shephard, 2008; Weatherson et al., 2017). Schools provide value in providing a base level of activity minutes through a mandated curriculum for physical education (Gao et al., 2016). This can be further bolstered by enrolling in sports and after-school programs offered by schools (Gao et al., 2016). Though the level of the increase may vary in different schools. Watson et al., (2017) attempted to quantify activity increase which ranged from 2% to 12% during the school day and peaking slightly higher during PE lessons to 16%. However, PA completed during classroom time had limited influence on PA rates (Watson et al., 2017). Most school-time activity minutes take place during dedicated PE time, team sports and are supported by after-school activities (Andermo et al., 2020; Atkin et al., 2011; Watson et al., 2017). Above all, the school environment provides a reliable means to reach a large group of individuals and promote greater activity levels (Gao et al., 2016; Kriemler et al., 2011).

However, there are limitations to relying on schools as the sole source of PA. Some issues that impede children's activity levels within the school environment are PE classes that do not grade performance, the quality of the classes being low or a lack of time for inclusion (Messing et al., 2019; Trudeau & Shephard, 2008; Weatherson et al., 2017). Certain school districts perform better at promoting PA within the curriculum (Weatherson et al., 2017). Hands-off strategies relying on children to engage in PA themselves by offering open access to facilities or increasing the break time are inconclusive and are likely dependent on the child's interests

(Weatherson et al., 2017). Tailoring the experiences is crucial as girls are more likely to engage in PA when in a structured environment of sport whereas males value un-structured leisure activities (Lawler et al., 2017). While schools can provide an overall positive influence on activity levels, there is a drop-off during the summer where activity rates do fall.

Active Play with Family

While PA promotion is primarily done through schools, the home environment plays a role in developing PA behaviour (Brown et al., 2016; Messing et al., 2019). Most of a child's free time is spent within the family environment (Naisseh et al., 2015). Parents offer opportunities for engagement with transport, co-participation, and encouragement (Brown et al., 2016; Messing et al., 2019). Additionally, parents' perceptions and discourse on a children's activity can influence activity levels (Naisseh et al., 2015). Established intervention techniques such as goal setting and education were particularly useful (Brown et al., 2016). More unique to home programs is the positive influence of spending a greater amount of active time together with your family (Brown et al., 2016; Messing et al., 2019). Parents can be role models where decreasing their sedentary time can lead to decreased sedentary time for their children (Mendonça et al., 2014; Messing et al., 2019). Children are more likely to be enrolled in a similar activity or imitate their parents (Naisseh et al., 2015). Related to this is the positive impact that parents have with general support to find and provide PA opportunities for their children (Edwardson & Gorely, 2010).

While these are the positive traits of traditional programs, support related to these programs is not thoroughly concluded (Brown et al., 2016; van Sluijs et al., 2011). A review by Brown et al., (2016) demonstrated a small effect for family-based interventions to increase PA-related outcomes. There was a lack of definitive PA behaviour change beyond benefitting an intermediate outcome like knowledge or education (Brown et al., 2016). Whereas the studies

included by Esther et al. (2011) had only a single family-based intervention demonstrate positive significant results. It is also unclear what the best approach is for the family environment (Brown et al., 2016; Edwardson & Gorely, 2010; O'Connor et al., 2009). Parental involvement consistently shows positive associations with overall PA (Edwardson & Gorely, 2010). Both father and mother modeling impacted children's willingness for PA (Edwardson & Gorely, 2010). Educational formats are also positively associated with children's PA but may be dependent on the format of the material (Edwardson & Gorely, 2010; O'Connor et al., 2009; van Sluijs et al., 2011). Formats that rely on homework have shown to have minimal effectiveness (O'Connor et al., 2009; van Sluijs et al., 2011). Organized events like workshops that combine these two approaches than solely relying on educational materials

The primary drawback to these programs to promote PA is their limited reach and scalability. Schools have limited capacity to modify curriculums due to their structure and need to offer other subjects (Weatherson et al., 2017). Even during open-time, schools may not have the facilities to support their student body (Trudeau & Shephard, 2008; Weatherson et al., 2017). There is also little reach to children on the weekends, where daily step counts can decrease as much as 15% from the school year (Bastian et al., 2015). These weekend periods are more reliant on the actions of the children's parents and their perceptions of PA (Brown et al., 2016; Messing et al., 2019). Parental involvement is valuable in numerous types of PA but requires the parent to be willing and available to be involved (Edwardson & Gorely, 2010).

2.3 Mobile Health

Mobile health (mHealth) initiatives are defined as promoting health objectives using mobile devices, monitoring systems, digital assistants, or other wireless devices (WHO, 2011). Voice, short messaging services (SMS), multimedia messaging services (MMS), GPS, Bluetooth and

mobile applications are commonly used methods of mHealth programs (WHO, 2011). This field has shown promise for engaging individuals in a variety of health domains such as PA, cessation, diabetes, heart health, sleep or nutrition (Kumar et al., 2020). mHealth is sought for its accessibility and scalability to reach many people (Buchholz et al., 2013; WHO, 2011).

Brief Messages

Low-cost techniques such as brief messages have shown positive results influencing simple behaviours related to adherence like taking medication or appointment visits (Arambepola et al., 2016; Boksmati et al., 2016). They can successfully prompt self-care activities related to diabetes (Agboola et al., 2016; Connelly et al., 2013; Fanning et al., 2012). They can also be useful in providing supplemental support as reminders, informational messages or and offering encouragement (Buchholz et al., 2013; Shaw & Bosworth, 2012). Several reviews have been conducted to examine the effectiveness of SMS-based interventions. Reviews have indicated the potential for brief messages to positively influence PA (Buchholz et al., 2013; Ludwig et al., 2018; Shaw & Bosworth, 2012). However, the interventions vary across frequency, duration, content, and samples making it difficult to establish the best use (Buchholz et al., 2013; Ludwig et al., 2018; Shaw & Bosworth, 2012).

Activity Trackers

Activity trackers have been used as another tool to modify PA behaviour. Devices such as Fitbit, Vivofit or Apple Watch are successful commercially but there is a lack of empirical data on its true long-term effectiveness, especially in youth (Böhm et al., 2019; Ridgers et al., 2016). There is support to suggest that they are useful in the short term as a motivational tool (M. Kang et al., 2009). The use of pedometers to promote walking has a moderate positive effect in a variety of intervention styles (M. Kang et al., 2009). They were shown useful when paired with a

goal-setting technique like attempting to reach 10,000 steps (M. Kang et al., 2009). Wearable activity trackers can be used in conjunction with other techniques as well (Ridgers et al., 2016). Trials pairing a wearable device with a smartphone, or a website have displayed significant intervention effects (Lee et al., 2019). In particular, the intervention utilizing both a wearable and a smartphone was able to increase daily steps by 2000 and usage days of the wearable device (Lee et al., 2019). However, there is a persistent issue of non-adherence to continue using wearable devices (Ridgers et al., 2016). One-third of US men will stop using their activity trackers within 6 months of use (Ridgers et al., 2016). Attempts such as these are often paired with another resource which clouds its true effectiveness (Fanning et al., 2012; Lee et al., 2019).

Smartphones

Alternatively, smartphones have received increased interest from researchers and are becoming the primary platform for mHealth interventions (Edwards et al., 2016; Helf & Hlavacs, 2016). Over 85% of Canadian households own a mobile device and use it predominantly as their main form of communication (Canadian Radio-television and Telecommunications Commission, 2018). This level of access extends to children with 69% of Canadian children having a personal smartphone by 12 years old (ParticipACTION, 2020). With such a large number of existing consumers, apps are a sought-after method to influence many individuals. There have been various types of apps created to target a variety of different chronic conditions. Smoking cessation, alcohol consumption, diabetes management and nutrition and PA have all had apps created to improve lifestyles (Cotton & Patel, 2019; Crane et al., 2015; Kitsiou et al., 2017; Mendiola et al., 2015).

However, numerous health apps have lacked a theoretical framework to accomplish persistent behaviour change (Cotton & Patel, 2019; Cowan et al., 2013; Crane et al., 2015; Edwards et al.,

2016; Garnett et al., 2016; Helf & Hlavacs, 2016; Hosseinpour & Terlutter, 2019; Payne et al., 2015). A gap in smartphone app development is finding ways to incorporate behaviour change specialists in the development process (Cotton & Patel, 2019). It is becoming more common in recent years for apps to contain motivational theory within their design (Hosseinpour & Terlutter, 2019). Less than half of the interventions examined by Lee et al., (2019) and Romeo et al., (2019) demonstrated a significant intervention effect in increasing PA-related outcomes. Several of the effective implementations relied on the use of a wearable as a key intervention component (Lee et al., 2019). Similarly, SMS messages are used with many smartphone-based interventions (Fanning et al., 2012). Of concern is a risk of a drop-off in engagement with health apps after 3 months (Romeo et al., 2019). mHealth interventions have less upfront accountability compared to face-to-face formats because it limits the personal interaction between individuals (Romeo et al., 2019). Continued engagement with apps did show increased PA which implies the importance of ongoing motivation through additional features (Romeo et al., 2019). There is a wide variety of interpretations, platforms and techniques that can be used to influence PA on smartphones (Lee et al., 2019). One of these interpretations that has gained increased interest past decade is using video games.

Active Video Games

Active video gaming, otherwise known as exergames, is the use of digital games that require bodily movement that function as a form of PA (Benzing & Schmidt, 2018). Recent examples of this is the commercially successful Ring Fit Adventure for the Nintendo Switch, Wii Fit for the Nintendo Wii and WiiU, and Xbox Kinect for the Xbox 360 and Xbox One. This has been viewed as an appealing option to increase PA by engaging in a playful game that requires movement (Ramírez-Granizo et al., 2020; Tuomas, 2015). It also provides an opportunity to

reach sedentary individuals who spend time playing video games to increase their activity levels (Oliveira et al., 2020; Peng, Crouse, et al., 2012; Ramírez-Granizo et al., 2020; Tuomas, 2015). Similar to other mHealth designs, there is potential for scalability that limits other types of health programs (Benzing & Schmidt, 2018). However, this requires that the individuals have access to the console, peripherals, and the game itself, which can be costly (Benzing & Schmidt, 2018).

Early reports examining exergaming demonstrated value in their ability to promote PA. Barnett et al., (2011) evaluated the Wii, XaviX, Play, XaviX, PlayStation 2 EyeToy and, then recently released, Xbox Kinect in a review. Across the various games, children were able to reach moderate PA, the amount of time dependent on the playing time (Barnett et al., 2011). Peng et al. (2012) corroborated similar results where children were able to reach or exceed moderate PA activities. However, reaching impactful PA intensities is dependent on the activities within the game and the player's interest. An example of this, Dance Dance Revolution (DDR), displayed numerous non-significant results, lowered engagement among children and feelings that the game was boring (Peng, Crouse, et al., 2012). Whereas Wii games primarily require players to use their upper bodies to complete the game. As such the energy expenditure is less compared to lower-body or full-body activities (Peng, Crouse, et al., 2012).

Exergames are seen as an appealing option to children due to the gameful elements (Ramírez-Granizo et al., 2020). They have become more pervasive in homes over time (Ramírez-Granizo et al., 2020). Exergames have a positive association at promoting weight loss in the short term (Hernández-Jiménez et al., 2019; Oliveira et al., 2020). However, the effectiveness of exergames to provide a significant difference at increasing PA is inconsistent (Oliveira et al., 2020). Oliveira et al., (2020) found no significance at exergames to promote PA relative to control groups. Whereas Comeras-Chueca et al. (2020) demonstrated that a variety of exergames were

able to achieve moderate intensities of PA. Notably, the Ring Fit Adventure for the Nintendo Switch was released to commercial success (*Top Selling Title Sales Units - Nintendo Switch*, 2021). Players defeat enemies using lower-body, upper-body and core strength-based exercises alongside yoga poses using peripherals (Comeras-Chueca et al., 2020). Cardiorespiratory exercises such as skipping or knee raises are needed to move in the game (Comeras-Chueca et al., 2020). Due to its recent release, literature is scarce on the game. However, the full-body movement required from this game has demonstrated potential in increasing PA. Preliminary evidence has shown it is comparable to standard exercise at achieving moderate-intensity PA (Comeras-Chueca et al., 2020). The importance of integrating full-body movements into exergames can improve its potential to reach higher intensities of activity.

2.4 Gamification

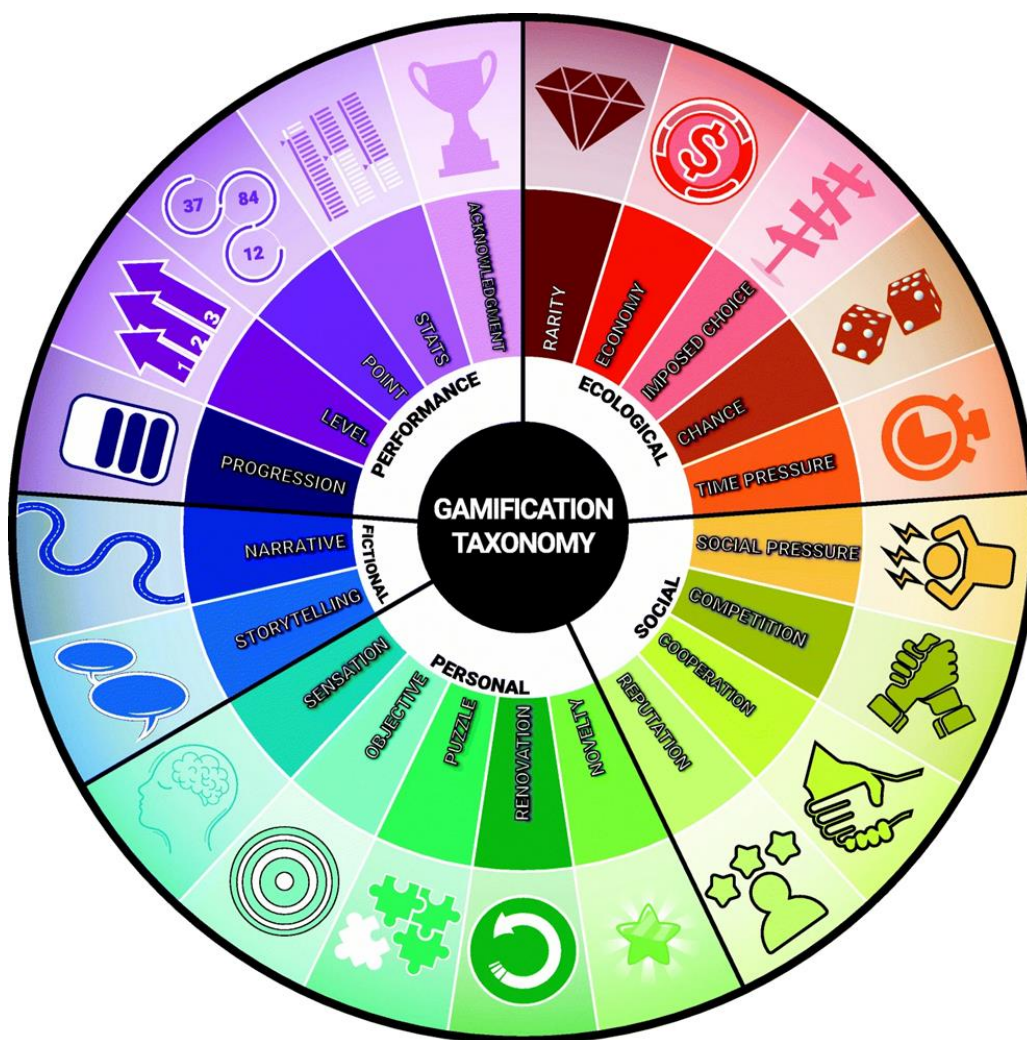
The use of gamification is a growing method of promoting PA. Deterding et al, (2011) defined this concept as “...the use of design elements characteristic of games in a non-game context” (Deterding et al., 2011). Gamification can exist within the mHealth field as a unique method to provide an entertaining experience with game features (Deterding et al., 2011). Gamification works by offering users challenges which they must overcome through their actions while pursuing an in-game goal (Deterding, 2015). In the wider context of games, a shooting game requires hand-eye coordination from the user to aim at targets (Deterding, 2015). A platforming game requires precise inputs from the player to overcome a puzzle. In either instance, the difficulty is specific and requires non-trivial effort from the individual playing (Deterding, 2015). An advantage to implementing gamification is its potential to improve retention by offering an enjoyable experience (Chan et al., 2019; Hosseinpour & Terlutter, 2019; Looyestyn et al., 2017). Common reasons for ending app usage are when it is seen as difficult,

annoying, unhelpful or not rewarding (Chan et al., 2019; Crane et al., 2017). To appeal to users, developers will apply gamification techniques using game elements to achieve their desired behavioural outcomes (Schmidt-Kraepelin et al., 2018).

Characteristics of Gamification

The use of gamification techniques has rapidly increased from 2015 onwards as studies classify and examine their effectiveness to promote PA (Looyestyn et al., 2017). These techniques can be viewed as the mechanics, dynamics and aesthetics that comprise a smartphone

Figure 1. Gamification taxonomy adapted by Toda et al. (2019)



game (Hunicke et al., 2004). A player will input a behaviour on a component of the game evoking the desired emotional response (Hunicke et al., 2004).

Examples of these game elements are points, achievements, avatars, or stories. Gamification taxonomies have been created to classify the numerous game techniques that make up smartphone games (Schmidt-Kraepelin et al., 2018). Taxonomies can be used to both conceptualize and adapt theories for smartphone apps using gamification (Schmidt-Kraepelin et al., 2018). They have been created for a variety of settings such as businesses, education, health outcomes or general contexts (Toda et al., 2019).

The taxonomy developed by Toda et al., encompasses the majority of gamification elements seen in trials. It is a basic view of how each category of game elements fits within a specified dimension (Toda et al., 2019). For example, performance-based game elements can be used to offer feedback to a user's actions which can provide a sense of direction within the game (Toda et al., 2019). Likewise, the fictional category can help the users focus on the content of the app (i.e., context, story, and game-world) outside of the specific game elements (Toda et al., 2019). A user helping a virtual pet by exercising is a unique narrative context compared to a user exercising because it's viewed as healthy (Toda et al., 2019). Each of these game elements acts to provide a sense of context to increase engagement towards the desired outcome specified by the game (Schmidt-Kraepelin et al., 2018; Toda et al., 2019)

Goals and points are the most common gamification elements that appear in clinical trials (Koivisto & Hamari, 2019a). Leaderboards, rewards, and badges also appear frequently (Koivisto & Hamari, 2019a; Looyestyn et al., 2017). The use of goals as a concept is regarded as an active ingredient of change making it a straightforward inclusion (Michie et al., 2013). Though goals are simple to implement, the goals themselves must be both tailored to the user

and targeted to a specific behaviour (Cugelman, 2013). Effectiveness is dependent on an appropriate difficulty for the player (Hosseinpour & Terlutter, 2019). There are few gamification apps solely developed for goal setting and the results are influenced by other mechanics in play. Despite this, when the goals are implemented in a personalized manner to engage the user, it has shown a positive relationship with PA outcomes (Dadaczynski et al., 2017; Hosseinpour & Terlutter, 2019). Goal setting was associated with positive effects, especially when the goals were determined by the user (Beemer et al., 2019; Hosseinpour & Terlutter, 2019; Koivisto & Hamari, 2019a). An issue with goal setting is users becoming frustrated by a goal that is too difficult, highlighting the importance of a tailored experience to the user (Hosseinpour & Terlutter, 2019).

For instances of multiplayer games or competitive games, leaderboards are often implemented. A sense of competition, especially towards peers, shows improvement in motivation and PA (Koivisto & Hamari, 2019a; Looyestyn et al., 2017). Leaderboards can provide a tangible context of one's performance in the app (Looyestyn et al., 2017). Leaderboards rank players based on a measured success criterion (Sailer et al., 2017). Players can be encouraged to achieve the top ranking of a leaderboard or reach the next ranking if the criteria are achievable (Sailer et al., 2017). However, non-competitive individuals may be non-responsive to the game or evoke a negative response to this technique (Hosseinpour & Terlutter, 2019; Koivisto & Hamari, 2019b; Sailer et al., 2017). Similarly, leaderboards can be a demotivator if a player is on the low end of the leaderboard (Sailer et al., 2017). A popular feature like points can be viewed as an arbitrary indicator of performance but if viewed in comparison to a peer's point totals can spark motivation to play (Looyestyn et al., 2017; Mekler et al., 2017). There is a risk that providing arbitrary points as a reward is a gimmick that may

leave players feeling disappointed (Hosseinpour & Terlutter, 2019). A possible alternative is providing positive reinforcement in the form of a message as a reward alongside points or as a replacement (Hosseinpour & Terlutter, 2019).

Points are heavily reliant on the context of their use (Cugelman, 2013; Morschheuser et al., 2017). They can be represented by experience points, redeemable points, reputation, scoring or indicators of progress (Sailer et al., 2017). Comparison trials have shown the effect of points are low, especially at influencing psychosocial factors (Ahn et al., 2019; Attali & Arieli-Attali, 2015; Buisman & van Eekelen, 2014; Mekler et al., 2017). Points are too simple of a technique on their own to adequately target influencers of internalization towards an activity (Ahn et al., 2019). However, they do show promise in increasing the basic performance of a task (Mekler et al., 2017). As such, they are better suited as an indicator of progress or as a goal-marker alongside other mechanisms (Koivisto & Hamari, 2019a; Schmidt-Kraepelin et al., 2018; Toda et al., 2019). Therefore, techniques such as points or badges can easily be added to existing frameworks to use gamification design (Deterding, 2015; Koivisto & Hamari, 2019b). This bodes the risk of relying too heavily on extrinsic features for the primary measure of motivation (Deterding, 2015; Koivisto & Hamari, 2019b). When apps are successful, they can pair different techniques together within an appropriate context (Schmidt-Kraepelin et al., 2018). A combination of diverse features provides an opportunity for emotional fulfillment that users will continue to take part in (Cugelman, 2013; Koivisto & Hamari, 2019b).

2.5 Behavioural Theories in PA

The use of behavioural theories in PA interventions provides a framework for understanding the variables that influence PA behaviour (Michie et al., 2014). They are used alongside interventions to identify conditions to be changed to elicit behaviour change (Michie et al.,

2014). Numerous frameworks exist to such as the dual process, socioecological frameworks or one of the leading frameworks in PA interventions: the social cognitive approach (Rhodes et al., 2019).

The theory of planned behaviour (TPB), focuses on intention as the primary determinant for a behaviour (Ajzen, 1991). Within TPB, intention is predicted by one's attitudes, subjective norms, and perceived behavioural control towards a behaviour such as PA (Ajzen, 1991). TPB has been shown to have a small to moderate effect to influence PA behaviour (Mummery et al., 2000; Steinmetz et al., 2016). The transtheoretical model proposes that individuals fluidly move through multiple unique stages of change: pre-contemplation, contemplation, preparation, action, and maintenance (Prochaska et al., 1997). This model was originally developed for smoking cessation but has been used in PA intervention design (Hutchison et al., 2009; Kleis et al., 2020). Evidence has shown significance for the transtheoretical model to promote PA (Hutchison et al., 2009; Kleis et al., 2020). However, the effectiveness varies depending on the implementation of the transtheoretical model within the intervention design (Hutchison et al., 2009; Kleis et al., 2020). However, one other framework has endured and continued to remain relevant in PA research. The humanistic perspective is centered on an individual's needs and potential for growth (Rhodes et al., 2019). One of the most prevalent humanistic behavioural theories implemented within PA interventions is self-determination theory (SDT).

SDT describes one's motivation to engage in an activity through their natural growth within their psychological needs along a continuum of internalization (Deci & Ryan, 2008). The continuum of motivation ranges from amotivation to intrinsic motivation (Deci & Ryan, 2008). Intrinsic motivation is fulfilled when an individual is engaging in a behaviour for the inherent enjoyment, and development of one's potential growth (Deci & Ryan, 2008). Whereas

amotivation is a form of unregulated motivation where an individual has a complete lack of any intent to engage in a behaviour (Deci & Ryan, 2008). Four types of extrinsic motivation exist within the continuum. External regulation concerns the motivation of an individual from unrelated circumstances such as receiving a reward or avoiding punishment (Deci & Ryan, 2008). Introjected regulation is the internalization of external consequences based on self-worth or ego such as guilt or approval to engage in a behaviour (Deci & Ryan, 2008). Identified regulation occurs when one values the outcome of a behaviour as personally important (Deci & Ryan, 2008). Lastly, integrated regulation is the most autonomous form of extrinsic motivation where an individual's sense of self aligns with a particular behaviour (Deci & Ryan, 2008).

To meet intrinsic motivation and transition to autonomous forms of motivation along the continuum, three psychological needs must be met: autonomy, competence, and relatedness. Autonomy concerns one's own volition and willingness to have control in their actions (Deci & Ryan, 2008). Competence refers to one's experience of proficiency, mastery and capability of an activity (Deci & Ryan, 2008). Relatedness involves socially connecting and the sense of bonding and care to another (Deci & Ryan, 2008). These three needs act as mediators between one's motives and resulting motivation to engage in an activity (Deci & Ryan, 2008).

Evidence has supported SDT as a framework to predict PA and exercise behaviour (Ng et al., 2012; Teixeira et al., 2012). More autonomous motivation (e.g., integrated regulation) has shown to have a stronger positive association with predicting exercise behaviour (Ng et al., 2012; Teixeira et al., 2012). In contrast, activities that foster introjected regulation or amotivation have a weak to negative correlation with PA (Teixeira et al., 2012). Similar support is found for SDT predicting PA behaviour in children (Owen et al., 2014; Sebire et al., 2013; Vasconcellos et al., 2020). Effects range from small-to-moderate and have a positive association for increasing PA in

both school and leisure times (Owen et al., 2014; Vasconcellos et al., 2020). Autonomous forms of PA have a positive association with children engaging in increased PA (Owen et al., 2014; Vasconcellos et al., 2020).

Self-Determination Theory & Gamification

Empirical support has shown the value of SDT and its application within traditional PA interventions. It is also a commonly used theory in the field of mHealth and gamification (Hosseinpour & Terlutter, 2019). Smartphone games have the potential to evoke intrinsic PA motivation by targeting the same psychological needs of autonomy, competence, and relatedness (Chan et al., 2019). Instances of apps using SDT have shown positive results at improving PA levels and fostering motivation (Ahn et al., 2019; Corepal et al., 2018; Höchsmann et al., 2019). To develop this motivation, an app must overcome the perceived cost of PA (Deterding, 2015). Gamification techniques can be used to specifically target the appropriate aspect of SDT (Hosseinpour & Terlutter, 2019). Relying on game features that only are ill-suited or are only a novelty will slowly decrease one's willingness to continue playing (Looyestyn et al., 2017). Numerous studies have highlighted the association between autonomy needs satisfaction and participation in PA (Adie et al., 2008; Chatzisarantis & Hagger, 2009; Thøgersen-Ntoumani & Ntoumanis, 2007). Similarly, competence needs satisfaction is associated with greater adherence and enjoyment to PA (Peng, Crouse, et al., 2012).

The primary enjoyment of playing a game is evoking a sense of competence in completing a challenge shared by the game designers (Deterding, 2015). Satisfying competence is accomplished by an individual experiencing confidence, effectiveness, and mastery (Malo de Molina Ruiz & Martos Gisbert, 2017). Reinforcing messages have been shown to improve competence whether they are autonomy-supportive or controlling (Malo de Molina Ruiz &

Martos Gisbert, 2017; Muynck et al., 2017). Likewise, improvement or progression in an activity can fulfill one's feeling of competence (Xi & Hamari, 2019).

The need to satisfy competence and autonomy can account for a large percentage of player motivation and enjoyment for engaging with a video game (Deterding, 2015; Helf & Hlavacs, 2016). Performance-related features were shown to positively affect autonomy, competence, and relatedness within users (Sailer et al., 2017; Xi & Hamari, 2019). Examples of this can be achievement, points, stats, leaderboards, or challenges (Sailer et al., 2017; Xi & Hamari, 2019). One's sense of competition, whether it's towards another or themselves, can urge on improved competence and performance (Looyestyn et al., 2017).

Autonomy can be difficult to specifically target in an app. This concept is guided by the player feeling a sense of self-direction in their experience of completing a task (Ryan & Deci, 2000). Autonomy support has been shown to have a moderate association with all three psychological needs (Sweet et al., 2012). In the context of smartphone games, one would need to continue using the app of their own volition to maintain or improve autonomous choice (Xi & Hamari, 2019). Autonomy is high when it is the choice of the user to continue playing with an app without excessive external pressure (Xi & Hamari, 2019). Playing with a game is normally a voluntary decision; as such, autonomy should remain high when in play (Peng, Lin, et al., 2012).

Immersion was shown to be a moderate predictor of autonomy needs satisfaction among players (Xi & Hamari, 2019). Likewise, avatars were shown to be predictors of autonomy needs satisfaction by improving immersive elements to a game (Peng, Lin, et al., 2012). Providing a fun experience and letting players choose their preferred playstyle can limit players feeling dependent on the perceived health outcomes (Althoff et al., 2016; Höchsmann et al., 2019; Hosseinpour & Terlutter, 2019; Koivisto & Hamari, 2019b; Xi & Hamari, 2019). Likewise,

freedom of choice and expression of oneself can satisfy autonomy (Hosseinpour & Terlutter, 2019; Koivisto & Hamari, 2019b; Xi & Hamari, 2019).

Relatedness refers to the sense of connection and belonging one feels (Malo de Molina Ruiz & Martos Gisbert, 2017). Implementing features to target relatedness is commonly done through social features (Choi-Ki Wong et al., 2016; Deterding, 2015; Helf & Hlavacs, 2016). This can be either creating a game that can be shared with others, or a multiplayer (Deterding, 2015; Hamari & Koivisto, 2015; Helf & Hlavacs, 2016). A method to create affiliation among players using multiplayer or social networking responses such as a “like” button can have players support one another (Hamari & Koivisto, 2015; Helf & Hlavacs, 2016).

2.6 Gamification Applications

Exogenous and Endogenous Smartphone Games

For gamification to be shown as an effective method of behaviour change, it needs to exhibit a long-term impact while surpassing other forms of behaviour change designs. The current use of gamification apps is focused on promoting PA or as a system for educational purposes (Cotton & Patel, 2019; Koivisto & Hamari, 2019b). Promotion of other healthy behaviours is addressed, albeit less frequently. Alcohol reduction apps make up a small portion of apps and tend to provide basic in-the-moment tools or general support (Perski et al., 2017). This same type of design is seen in many smoking cessation apps (Perski et al., 2017). Games directed at improving nutrition mainly use it as a platform for self-monitoring and disseminating general knowledge (Mummah, King, et al., 2016). Gamification has been shown as an effective tool in aiding patients with diabetes (Akker et al., 2017; Dugas et al., 2018; Rose et al., 2013a; Theng et al., 2015). These games were able to offer a playful experience to fit within the routine of diabetes maintenance (Rose et al., 2013b; Theng et al., 2015). Dugas et al., (2018) showed that providing

an individual experience to users within the game improved their outcomes (Dugas et al., 2018). Similar to the implementation of gamification techniques, thoughtful design and tailored experiences are paramount. This difference in design can be viewed as exogenous or endogenous gamification experiences.

An exogenous gamification experience is described as having the game design principles fundamentally disconnected from the app (Floryan et al., 2019). Due to this, exogenous apps are less likely to enhance the game experience as effectively (Floryan et al., 2019). This type of design may even harm intrinsic motivation if the user views it as a simple novelty within the app (Cugelman, 2013; Floryan et al., 2019). Many apps will take convenient gamification elements to aimlessly apply them to the existing app to prompt a better outcome (Helf & Hlavacs, 2016). These design choices cannot provide more than a brief novelty and struggle to prove lasting results (Floryan et al., 2019; Helf & Hlavacs, 2016).

Endogenous apps have their included gamification characteristics aligned to the core content and goals of the app (Floryan et al., 2019). The experience of playing the game is tied to the user's ability to engage in the mechanics, which aims to provide a meaningful reward (Floryan et al., 2019). Endogenous apps separate themselves by being able to provide a purpose to the game while supporting the user playing it (Floryan et al., 2019). These apps can build an in-depth narrative for the user to immerse themselves into (Helf & Hlavacs, 2016). Pokémon GO is one example of a game that achieved this in-depth narrative paired with walking.

Endogenous Smartphone Apps to Promote Physical Activity

Pokémon GO sparked a new interest in using gamification to promote PA. As an endogenous app, it offers a variety of gameplay mechanics as well as a narrative for players to follow. It has been shown to increase PA levels consistently over the short-term (Althoff et al., 2016; Broom &

Flint, 2018). Pokémon GO's main gameplay is walking-focused as players visit virtual locations in the real world to capture Pokémon. Due to the game's focus on walking, it is more likely to increase light to moderate PA as opposed to vigorous intensity (Althoff et al., 2016; Broom & Flint, 2018). The more users played the app, the higher their daily steps increased (Althoff et al., 2016; Kaczmarek et al., 2017; Khamzina et al., 2020). Althoff et al., (2016) found that the average daily steps of Pokémon GO users would peak as high as 8000 steps per day depending on the playtime. Similar cases of step count increases were reported in a review by Khamzina et al. (2020). Playing Pokémon GO was associated with a 1446 step increase (Khamzina et al., 2020). The initial appeal of the app demonstrated the greatest improvement in activity behaviour (Althoff et al., 2016; Khamzina et al., 2020). However, the novelty of a new game wears off with certain users and the impact on activity weakens in time (Althoff et al., 2016; Khamzina et al., 2020). Khamzina et al., (2020) raise the issue of continued engagement in the app due to the attenuation of PA benefits. It is important to note, that the majority of the articles included by Khamzina et al., (2020) took place before recent additions to Pokémon GO such as battling, friends, new Pokémon inclusions, objectives, and community events. These new features target the social aspect of the game which are favored by users (Lindqvist et al., 2018). Users lessened their play over time, with many of them stopping play altogether (Khamzina et al., 2020). While the impact of Pokémon GO was modest, it demonstrated the value of combining game features with PA on a large scale (Khamzina et al., 2020).

Beyond Pokémon GO, Höchsmann et al, (2019) developed an endogenous app to improve intrinsic motivation for PA. The game centers on caring for a garden while warding off an inner 'Schweinehund' which is represented as one's nature to be lazy (Höchsmann et al., 2019). The app was shown to be effective and elicited a positive experience among the users (Höchsmann et

al., 2019). The average active minutes of moderate-to-vigorous PA increased from 39 to 143min after the intervention (Höchsmann et al., 2019). Users logged an average of 1800 steps in-game during the 24-week intervention (Höchsmann et al., 2019). Despite the user's need to walk in-game to maintain their garden, the perceived choice of the participants was not negatively impacted (Höchsmann et al., 2019). The perceived cost of maintaining the garden by engaging in PA was reduced by the user's enjoyment of the overall experience playing (Höchsmann et al., 2019). Furthermore, it adds evidence to the effectiveness of SDT as a construct to align gamification mechanics (Höchsmann et al., 2019).

The gamified health app, Healingo Fit, demonstrated improvements in low activity levels (Dadaczynski et al., 2017). Like the app developed by Höchsmann et al., (2019) it implemented a variety of different techniques into a comprehensive system (Dadaczynski et al., 2017). MobileKids Monster Manor (MKMM) is used alongside an activity monitor to transfer steps to an in-game currency that can be redeemed for additional playtime within MKMM (Garde et al., 2015). Some examples of game features are achievements, points, progression and competition/cooperation. Another component is the use of positive reinforcement within the game to encourage further real-life activity (Garde et al., 2015). The goal of the game is to set monsters free from mansions by completing active games and challenges (Garde et al., 2015). Both groups interacting with the game saw increases in steps and activity minutes per day (Garde et al., 2015). The response of children playing the game was positive as 81% of participants viewed the game as good or better and enjoyed being active to improve their scores within MKMM (Garde et al., 2015).

The Healingo Fit app utilized quizzes, challenges, teams, and goal setting (Dadaczynski et al., 2017). PA-related outcomes such as knowledge, intention, self-efficacy and minutes watched

improved while using the game (Dadaczynski et al., 2017). Participants using the Healingo Fit had approximately 83min more time spent walking relative to the control group (Dadaczynski et al., 2017). HealthyTogether detailed the importance of the social aspect of a gamified app (Chen & Pu, 2014). Cooperating to reach goals had a more positive effect than eliciting competition between users (Chen & Pu, 2014). Participants formed teams, received encouragement, badges, sent messages and completed goals while playing HealthyTogether which resulted in a mean daily step count of 9124 (Chen & Pu, 2014). These examples of endogenous apps highlight the importance of having multiple components come together to form a cohesive game concept.

2.7 Gamification Interventions for Children

Few empirical examples have been completed to examine the effects of gamification to modify PA behaviour in children. Those that have been completed do show there is potential to influence PA. Examples of interventions completed without the use of implementing a theory resulted in no significant changes (Coombes & Jones, 2016; González et al., 2016). An intervention combining a smartphone app and console to support exercise behaviour failed to demonstrate increased pleasure during gameplay (González-González et al., 2018). This intervention had participants match different exercises displayed on the active videogame TANGO:H while also learning about other healthy habits like nutrition (González et al., 2016). The game implemented points, leaderboards, challenges, and multiplayer functions to elicit a change in children's body mass and weight (González-González et al., 2018). The experience developed positive emotions towards the game system, there were no significant changes to biometric data relative to control after the 8-week intervention period (González et al., 2016). Coombes & Jones (2016) developed a 9-week intervention using a smart card to tag a sensor in the real world. 'Beat The Street' incentivized children to take active travel to school over 9

weeks by awarding points to tag sensors in three neighbourhoods (Coombes & Jones, 2016). Other than points, the authors relied on participants to develop their sense of competition between each other (Coombes & Jones, 2016). No intervention effect was found for changes in PA showing that the participants did not respond to the smart card as it offered no context to the experience beyond visiting a location to tag the card (Coombes & Jones, 2016).

Beemer et al., (2019) focused their game features on goal setting, allowing participants to create their own self-determined goals related to PA. By completing these goals, the participants competed for daily and weekly prizes (Beemer et al., 2019). The games increased in intensity over time to challenge the participants' progression of the activity (Beemer et al., 2019). This resulted in a 27% increase in student engagement during activity breaks and a significant positive change in MVPA during activity breaks relative to control (Beemer et al., 2019). Finally, Schäfer et al, (2018) used avatars to motivate children to increase their MVPA. By engaging in more MVPA the avatars would level up and share reinforcing messages to the user (Schafer et al., 2018). MVPA decreased over time in both the intervention and control groups (Schafer et al., 2018). However, the decrease in MVPA was weaker in the intervention group when compared to the control group (Schafer et al., 2018). If the avatar was viewed positively, it was able to slow the decay in engagement (Schafer et al., 2018). Similar to the novelty that Pokémon GO provided, depending on the user's enjoyment, gamification has merit to slow the attenuation of PA behaviour (Khamzina et al., 2020; Schafer et al., 2018).

Past examples of SDT guided gamification research for children are also scarce (Ahn et al., 2019; Corepal et al., 2018). Ahn et al., (2019) compared points-based game design using an SDT framework. In it, children created and completed self-determined goals to then play and improve a virtual dog's health using Microsoft Kinect (Ahn et al., 2019). The overall level of PA did not

have significant changes and children instead found ways to do lighter PA to earn easier points (Ahn et al., 2019). The intervention only lasted a 72 hours, which is too short to create a persistent change in behaviour (Ahn et al., 2019). The children approached significance with relatedness towards the virtual pet and the engagement with the system was high overall (Ahn et al., 2019). Corepal et al. (2019) did not perform a quantitative examination of gamification's effects on a group. Instead, themes of their trial were identified. These themes were competition, the influence of friends and incentives (Corepal et al., 2019). In respect to the constructs of SDT, autonomy suffered the most as many of the participants were less interested in engaging in the activities due to their views that they had little chance to win or it was boring (Corepal et al., 2019).

Both mHealth and gamification are viable means to increase PA. For it to work, the design and choice of gamification elements must be thoughtful to allow for an engaging experience for the user. Certain traits from other intervention styles can be applied to gamification attempts. School settings excel at providing opportunities, goals, and education about PA (Trudeau & Shephard, 2008; Weatherson et al., 2017). The availability of smartphones has allowed many children across Canada access to health apps that provide useful information. Additionally, goals can be easily implemented as a gamification technique (Schmidt-Kraepelin et al., 2018). High access to smartphones allows gamification apps to overcome the issues of scalability that home and school interventions face (de Paiva Azevedo et al., 2019). Gamification apps have the potential to be motivational due to the gamification techniques targeting psychological needs (Schmidt-Kraepelin et al., 2018). These features offer a fun experience, overcoming the traditional perception that PA and exercise are boring (Brown et al., 2016; Pickering & Pringle,

2018). The user is more willing to continue using the app again if it elicits a sense of enjoyment (Hosseinpour & Terlutter, 2019; Pickering & Pringle, 2018).

There are several gaps in the literature surrounding gamification this study can address. The current app landscape has shown insufficient use of health behaviour change theory when designing smartphone apps (Payne et al., 2015). By building a novel smartphone app using SDT as a framework, it will add to a growing body of literature on the value that theory can provide to smartphone apps. Access to technology has grown through the past decade allowing children the opportunity to approach mobile technology (Schoeppe et al., 2017). Despite this, there are few empirical trials featuring children as a sample (Schoeppe et al., 2017). While this section of literature is growing, this research will further add to the impact mHealth and gamification can have on children (Schoeppe et al., 2017). Lastly,

2.8 Development of Draco

The development of the Draco smartphone app followed the format of integrate, design, assess and share (IDEAS) (Mummah, Robinson, et al., 2016). The IDEAS roadmap is used to guide practitioners in integrating behavioural theory into digital interventions (Mummah, Robinson, et al., 2016). This roadmap was broken into two different phases: intervention planning, intervention development (Liu et al., 2019). Major sections of the app such as the map, exercises, food, and the quiz were completed in early 2019. Intervention planning began by forming an interdisciplinary team of professionals in app development, and domain experts in PA, behavioural science, and gamification. This phase specified the behaviours to be targeted and identified the behavioural strategies within SDT for inclusion in the app.

Current PA rates have shown that Canadian children are not meeting the recommended activity minutes (Colley et al., 2017). Smartphones have become ubiquitous in society that

children of all ages have greater access to a mobile device. Smartphones have been used to engage different age groups in health behaviours. Caring for a virtual pet was decided as an appealing concept for children to engage with (Ahn et al., 2019). To care for the virtual pet children would have to engage in a handful of sections within the app to encompass a healthy lifestyle. Users would also feed the pet a variety of healthy foods from Canada's Food Guide. Additionally, the virtual pet will ask the user questions that cover topics primarily focused on PA.

Previous examples of gamification have demonstrated a target to improve PA behaviour for either steps or MVPA (Koivisto & Hamari, 2019a; Koivisto & Malik, 2020; Looyestyn et al., 2017). In particular, the Draco app would focus on promoting steps as a way to care for the virtual pet and progress through the game. Self-determination theory was chosen to support the intervention design. SDT has been used broadly in gamification research (Hosseinpour & Terlutter, 2019). Game features (points, challenges, progression, story etc.) can be implemented to act as process motivators that promote the targeted outcome (Mummah, Robinson, et al., 2016). Hosseinpour & Terlutter (2019) recommend incorporating SDT to support interactions with the app or social interactions among peers. Features such as immersion by caring for a virtual pet, achievements, challenges, and communication from the virtual pet were targeted as effective features to satisfy autonomy, competence, and relatedness (Deterding, 2015; Helf & Hlavacs, 2016; Hosseinpour & Terlutter, 2019; Xi & Hamari, 2019).

The intervention development phase focused on the design and content within the smartphone app. The inter-disciplinary team met weekly to ideate implementation strategies (Mummah, Robinson, et al., 2016). This would be to facilitate discussion on ideas, features, and sources to draw inspiration from. Content would then be agreed upon and drafted for the programmer to

implement within the app. Each member would provide feedback on the acceptability, appeal, and accuracy of the content. The goals of the feedback would be to ensure that the content is appropriate within the context of the app, fit within the SDT constructs and offered a playful element to the players. The lead programmer would then finalize the content to be user-tested. Content of the app was created with the target audience of children in mind, requiring the information of the app to be easily understood and accessible to that demographic. The app would be supported by information of healthy behaviours in the quiz and food sections of the app. The primary focus of the app is to promote PA. As such, the content of the app revolved around children engaging in bodyweight exercises and regularly walking to sync their steps to the game.

A preliminary run of the app was used to gather app usability. Based on the feedback, two issues of the app were identified: accessibility and variety. A dedicated app website with a review of features and the game's purpose was created. The Draco app was then made available to iOS users through TestFlight, Apple's Beta Testing platform. The Android version of the app was then developed for release to Google's Play Store for ease of installation.

To improve the variety, two more sections were added to the app: challenges and unlockable items. These concepts added to the progression of the game while incentivizing further activity within the app in the form of virtual items as achievements. Additionally, the number of questions Draco asked was expanded to include more information regarding PA. The questions Draco asks within the game will complement the exercises that are completed by users to further expand their knowledge of the benefits of PA. Foods available to Draco were adjusted to better reflect choices available through Canada's Food Guide.

Currently, we do not know the feasibility and preliminary effectiveness of the Draco app. This pilot RCT will examine the acceptability and user satisfaction of the Draco app among children. Additionally, this trial will examine the preliminary effectiveness of the Draco app to promote PA behaviours such as steps, MVPA, perceived autonomy for PA, perceived competence for PA as well as perceived relatedness towards the app.

Chapter 3: Methods

3.1 Trial Design

A CONSORT checklist for reporting a pilot or feasibility trial was followed for conducting this trial (Eldridge et al., 2016). This study used a 2-parallel group, randomized control design: two groups (control, intervention) by two assessments (baseline, 4-week follow-up). Participants were virtually screened, enrolled, and randomized into one of the two groups. A 1:1 simple randomization method was used for group allocation. The study received ethical approval from the University of Victoria Ethics Board on January 28th, 2019 (reference number: 18-1243). Participant recruitment took place from June 2020 to July 2020 and from January 2021 to July 2021. This study is a registered clinical trial: NCT04593199

3.2 Participants

Inclusion criteria included children between the ages of 8 and 14 years, with normal or corrected vision, living within Canada and not meeting the Canadian PA guidelines of 60min of MVPA per day. This was assessed during the eligibility meeting and by the Physical Activity Readiness Questionnaire Children's version (PAQ-C). Exclusion criteria were individuals with a diagnosis or injury that prevents PA participation.

3.3 Intervention

Draco is a gamified smartphone application where the children play as the caretaker of a virtual pet dragon named Draco (see appendix 2). The main storyline of the game revolves around helping Draco find their family by travelling through a virtual world, while also keeping Draco healthy using regular PA and a healthy diet. The amount of PA completed by the participant (tracked using Fitbit) in the real world is transferred into the game (ex. 5000 steps taken by the participants will equal to 5000 steps taken by Draco) by the player. The PA portions

of the app requiring users to perform exercises or reach step milestones are within the guidelines of the Canadian PA recommendation. The Draco app was designed using the SDT (see Appendix 2).

Perceived Autonomy

Draco targets autonomy by offering numerous exercises to the player. Overall, there are 15 unique exercises that all contribute to levelling up the virtual pet, and refilling Draco's health points (HP). There are also additional PA-related challenges that allow the participants to collect items (e.g., jewels, trinkets, trophies) or homes for their virtual pet. The participants can feed Draco to maintain its HP by selecting from a variety of vegetables, meat, drink, or whole-grain products to give to the pet.

Perceived Competence

Competence was targeted by offering a wide range of exercises with various difficulty levels. Progressive exercises are offered to players who need to practice basic form. Video demonstrations were available to show the participants how to perform each exercise. The app features quizzes where users can improve their knowledge about healthy lifestyle habits from the Canadian 24-Hour Movement Guidelines. The app includes several gamification features (e.g., map progression, challenge completion, unlocking collectables) that provide feedback and validate players' progression as they perform a greater amount of PA.

Perceived Relatedness

The sense of caring or connectedness was achieved through the interaction with the virtual pet Draco as the player maintains Draco's well-being. Each feature in the game contributes to the pet's level, progression through the storyline and ensuring Draco does not run away prompting a game restart. In-game messages are shared by the virtual pet to form a sense of interaction.

3.4 Control

Participants received a Fitbit Inspire HR and had access to a Fitbit account. Participants wore the Fitbit for 1 week to calculate baseline PA levels. Participants engaged solely with the Fitbit application to sync their steps with the device for 4 weeks. They were not given access to use the Draco app for the duration of the study period. Following the 4 weeks, a follow-up questionnaire was completed, and they were granted access to Draco.

3.5 Procedures

Due to the COVID-19 pandemic, this study was conducted online. Recruitment information was shared on social media pages through Twitter, Instagram, Facebook, as well as British Columbia's research recruitment platform REACHBC. Interested respondents wishing to participate were emailed details about the study and offered a time to arrange a screening meeting. Screening meetings were completed with video conferencing (Zoom) or telephone calls. A parent, guardian or caretaker completed the screening to determine the eligibility. Eligible participants were asked to complete consent forms, and an adapted version of the PAR-Q+ (Warburton et al., 2011).

During the virtual baseline meeting, participants complete a questionnaire alongside adapted from the PAQ-C, PACE and the short form Intrinsic Motivation Inventory (IMI) to evaluate their activity levels, perceived autonomy, and perceived competence towards PA (Ahn et al., 2019; Kowalski et al., 2004; Norman et al., 2005; Ryan, 1982). The questionnaire was completed by the children alongside a parent and research staff. Higher scores of this scale indicate more internal motivation and greater self-regulated behaviour (Ryan, 1982). Demographics for participants included the children's gender, age, height, and weight. Parental demographics were

also collected which included ethnicity, marital status, and household income. All questionnaires were completed online.

An anonymized Fitbit account was created for the participants for the study duration. All participants received a Fitbit Inspire HR to monitor PA. All participants were asked to wear the tracker for a week before the start of the intervention. Participants in the intervention group then received the Draco app to use. Those in the control group continued with the Fitbit application for 4 weeks. If needed, participants were loaned an Android smartphone to use during the intervention period. After the intervention period, participants completed the same questionnaire at baseline with additional questions from the IMI for perceived relatedness towards the app and satisfaction using the app (Ahn et al., 2019). All participants in the intervention group were given the choice to opt into an exit interview. The interview took place after the final questionnaire where the child would answer a series of questions with the parent or guardian present. Devices are then shipped back to the research staff and an honorarium (\$70) is sent to the participant for their study participation.

3.6 Primary Measures

Participant's satisfaction with the Draco app was assessed using a 5-point Likert scale (1= Not true for me, 5 = Very true for me) questionnaire adapted from the Intrinsic Motivation Inventory's interest/enjoyment subscale (Cronbach's α : .91) (Markland & Hardy, 2013; Ryan, 1982). Questions were adapted to inquire about the smartphone app. The following questions were used: 1) I enjoyed playing the app very much; 2) The app was fun to use; 3) I thought playing with the app was boring; 4) Playing with the app did not hold my attention at all; 5) I would describe playing with the app as very interesting; 6) I thought playing with the app was

quite enjoyable; 7) While I was playing with the app, I was thinking about how much I enjoyed it.

Additionally, I completed an exit interview for participants in the intervention group to assess acceptability with the Draco app. Example questions include: Can you tell me about your experience using the app; did you find the app useful, if so, how; what did you think of the game concept; are there any features you would like to see added; what do you think is the most effective way to help children be physically active?

3.7 Secondary Measures: Physical Activity and SDT Constructs

Daily Steps

Fitbit Inspire HR was used to collect daily step measurements. Fitbit has been shown to be a valid and reliable measurement tool for PA in both adults and children (Diaz et al., 2015; Feehan et al., 2018; S.-K. Kang et al., 2017; Voss et al., 2017). Average daily steps were calculated using the mean step over 7 days until the intervention was completed at 28 days (Balbim et al., 2021).

Daily MVPA

Time spent engaging in MVPA will be calculated by the Fitbit Inspire HR. MVPA was calculated by collecting the sum of time spent in the moderate and vigorous heart rate zones (Balbim et al., 2021; Mishra et al., 2017). The Fitbit Inspire HR has been shown as a valid instrument for collecting MVPA using the Fitbit HR zones (Chow et al., 2016; Kang et al., 2017). MVPA was calculated by the sum of the fairly active and very active intensity zones. Fitbit calculates fairly active as a metabolic equivalent task (MET) range of 3 up to 6. MET ranges collected by the Fitbit exceeding 6 are categorized as very active.

Perceived Autonomy for PA

These measures are collected using adapted questionnaires from the IMI (Cronbach's α : 0.71) (Ahn et al., 2019; Ryan, 1982). The following statements (5-point Likert scale: 1 = Not true for me, 5 = Very true for me) were asked relating to perceived autonomy: 1) I believe I had some choice about being physically active; 2) I was physically active because I had no choice; 3) I was physically active because I wanted to; 4) I didn't really have a choice about being physically active; 5) I was physically active because I had to.

Perceived Competence for PA

These questions were acquired and adapted from the IMI (Cronbach's α : 0.8) (Ahn et al., 2019; Ryan, 1982). The following six statements (5-point Likert scale: 1 = Not true for me, 5 = Very true for me) were asked related to perceived competence: 1) I think I am pretty good at being physically active; 2) I think I was pretty good at being physically active, compared to other kids; 3) After being physically active for a while, I felt I became pretty good at it; 4) I am satisfied with my performance at being physically active; 5) I was pretty skilled at being physically active; 6) Being physically active is something I cannot do well.

Perceived Relatedness to the App

These questions were acquired and adapted from the IMI (Cronbach's α : .82) (Ahn et al., 2019; Ryan, 1982). The following six statements (5-point Likert scale: 1 = Not true for me, 5 = Very true for me) were asked related to perceived autonomy: 1) I felt like the app and I were not close at all; 2) I really doubt that the app and I would ever be friends; 3) I would like a chance to interact with the app more often; 4) I felt like I could really trust the app; 5) I felt close to the app.

3.8 Statistical Analysis

App satisfaction was evaluated using descriptive statistics. Mean and standard deviation was calculated for the satisfaction subscale of the IMI. Themes were summarized from the exit interviews for each question and for the participant's overall experience to determine app acceptability (Vaismoradi et al., 2016). The process for thematic analysis began by writing reflective notes during the live exit interview session (Vaismoradi et al., 2016). These notes highlighted meaningful answers to each question which were then confirmed while reviewing the recorded sessions (Vaismoradi et al., 2016). Answers were then classified and labelled based on the reference point of their experience and gameplay or feature-related descriptions (Vaismoradi et al., 2016). These themes were used to describe the experience of playing the Draco app to determine if the app itself was accepted among the users. Additionally, it was used to determine future gameplay changes.

Descriptive statistics were calculated for demographic measures. I used an independent t-test and chi-square test to compare differences between these baseline demographic measures for continuous and categorical variables. Fitbit compliance was calculated as the proportion of total study days worn with the Fitbit tracker (Hartman et al., 2018).

Repeated measures analysis of variance (ANOVA) 2x2 was used to evaluate whether daily steps, MVPA, autonomy, competence, and relatedness and user satisfaction significantly changed following the interventions relative to control. Specifically, I evaluated group (intervention vs. control) and time (pre- vs. post-intervention) interaction and main effects for time by calculating the effect sizes for the following dependent variables (daily steps, MVPA, perceived autonomy towards PA, perceived competence towards PA). Partial eta squared (η^2) is interpreted as: small = 0.01, medium = 0.06, large = 0.14). The effect size for perceived

relatedness to the app were calculated using Cohen's d (small = 0.2, medium 0.5, large 0.8).

Mean imputation was used to replace missing data (Catellier et al., 2008; M. Kang et al., 2005).

Participants who dropped out of the study during the trial were not included in the analysis. Due to the present study being a pilot trial, effect sizes are assessed for secondary outcomes.

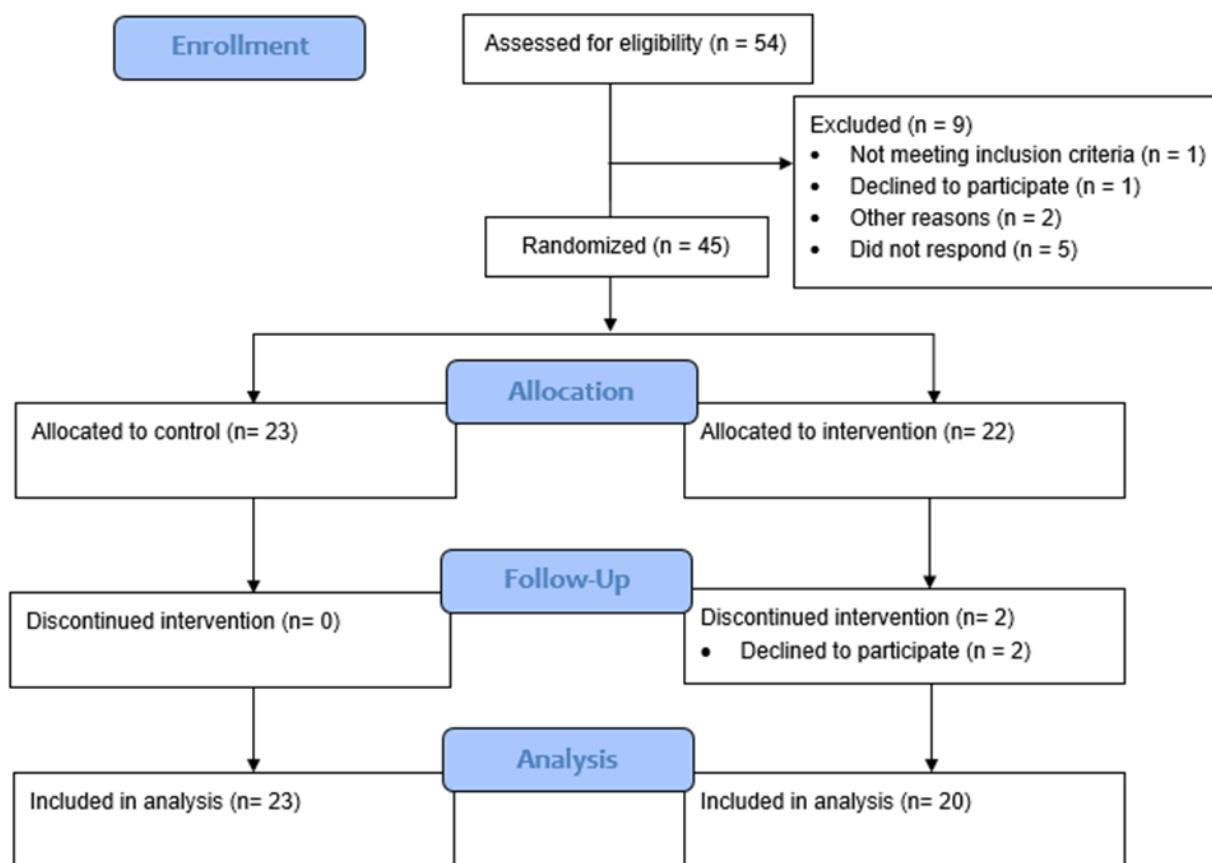
Quantitative analyses were conducted in SPSS 27.

Chapter 4: Results

4.1 Participants

A total of 45 participants were allocated to study groups (see Fig. 2 for CONSORT recruitment diagram). Initially, 22 participants were allocated to the intervention group, and 23 to the control group. Fitbit compliance for the trial was 86%.

Figure 2. Recruitment Consort diagram



Demographic characteristics for the participants can be viewed in table 1. The study sample was 60% female, 16% male with a mean (SD) age of 10.60 (1.47) years, a weight of 42.20 (17.57) kg and a height of 147.74 (13.46) cm. Height of the participants was significantly different. However, this was due to a single child over the height of 6ft. Of the parents, 91% identified as Caucasian and 9% as Asian. 42% of parents had a household income of \$140,000 or

more, 94% of parents were married or living with their partner and 87% had college or university level education.

Table 1. *Participant Characteristics*

	Total n = 43	Control n = 23	Intervention n = 20	P-value
Age, M (SD)	10.60 (1.47)	10.35 (1.37)	10.90 (1.55)	.22
Height, M (SD)	147.74 (13.46)	143.90 (11.43)	152.74 (14.52)	.04*
Weight, M (SD)	42.20 (17.57)	40.92 (21.59)	43.68 (11.76)	.61
Sex, <i>n</i> (%)				.33
Female	26 (60%)	14 (61%)	12 (60%)	
Male	16 (37%)	8 (35%)	8 (40%)	
Other	1 (3%)	1 (4%)	0	
Parent Ethnicity, <i>n</i> (%)				.89
Asian	4 (9%)	2 (9%)	2 (10%)	
Caucasian	39 (91%)	21 (91%)	18 (90%)	
Parental Household Income, <i>n</i> (%)				.19
Below \$19,000	0	0	0	
\$20,000 - \$39,999	2 (5%)	1 (4%)	1 (5%)	
\$40,000 - \$59,999	3 (7%)	1 (4%)	2 (10%)	
\$60,000 - \$79,999	3 (7%)	1 (4%)	2 (10%)	
\$80,000 - \$99,999	9 (21%)	4 (18%)	5 (10%)	
\$100,000 - \$119,000	5 (12%)	3 (13%)	2 (10%)	
\$120,000 - \$139,000	3 (7%)	1 (4%)	2 (10%)	
\$140,000 or more	18 (42%)	12 (53%)	6 (30%)	
Parent Marital Status, <i>n</i> (%)				0.91
Married or living with partner	40 (94%)	21 (95%)	19 (95%)	
Single or living alone	1 (2%)	1 (5%)	0	
Single or living with others	1 (2%)	1 (5%)	0	
Separated	1 (2%)	0	1 (5%)	

Parent Education				0.46
Grade School	1 (3%)	0	1 (5%)	
High School	6 (10%)	3 (13%)	3 (15%)	
College/University	15 (41%)	9 (40%)	6 (30%)	
Graduate	21 (46%)	11 (47%)	10 (50%)	

Note: * Significant outcome (p < .05)

4.2 App Acceptability and Satisfaction

The overall satisfaction with the Draco app was 2.83 (1.29). Answers for each of the questions ranged from scores of 1 to 5 for both groups. See table 2. Intervention participants had the highest agreement in the app being enjoyable (2.95) and fun to use (2.79). The lowest agreement from intervention participants was given to the app holding one's attention (2.93).

Qualitative Exit Interview

In total, 14 participants completed the exit interview. Three overall themes emerged from the exit interviews: content, usability, and effectiveness. Individual themes were determined for each of the questions. See table 4. The usability of the app was generally regarded as both easy to understand and navigate. Reception of the app content varied. Many participants noted that the most useful component of the app was the gifs demonstrating the exercises. However, more content was needed in other areas to maintain engagement. Some examples mentioned by participants included: battling, customization, or more exercises. The most common negative feedback included the technical issues and that the game would restart too soon if they were inactive.

The app and using games were viewed as an effective method to promote PA. Participants stated that the most effective way to promote PA in children was to make it fun. The game concept of caring for a virtual pet by being physically active was received positively. Finally,

participant motivation once the intervention finished was divided between increased feelings of motivation or no changes.

Table 2. *Satisfaction and Acceptability*

	Intervention (19)	
	M (SD)	Range
I enjoyed playing with the app very much	2.63 (1.3)	1, 5
Playing with the app was fun to use	2.79 (1.36)	1, 5
I thought playing with the app was boring	2.63 (1.46)	1, 5
Playing with the app did not hold my attention at all	2.93 (1.58)	1, 5
I would describe playing with the app as very interesting	2.68 (1.38)	1, 5
I thought playing with the app was quite enjoyable	2.95 (1.51)	1, 5
While I was playing with the app, I was thinking about how much I enjoyed it	2.32 (1.42)	1, 5
Satisfaction (Total)	2.83 (1.29)	

Note: *Significant outcome ($p < 0.05$)

4.3 Physical Activity Related Outcomes

Steps

At baseline, steps between the intervention and control groups were different ($d = 0.28$) with the intervention group showing a higher number of daily steps. Following the intervention, a medium effect size for a group and time interaction ($p = .11$, $\eta^2 = .06$) was present. Intervention participants increased their steps by 909 (SD = 1701). During the same period, participants in the

control group had an increase of 46 (SD = 1507) steps. There was a large effect size for time ($p = 0.06$, $\eta^2 = 0.13$). Overall, 80% ($n = 16$) of participants increased their steps in the intervention group and 57% ($n = 13$) of participants in the control group saw increases.

MVPA

MVPA was different at baseline between the intervention and control groups ($d = 0.26$). The intervention showed higher MVPA relative to the control group. Following the intervention, a small effect for group and time interaction ($p = .23$; $\eta^2 = .03$) was present. There was a small main effect for time ($p = 0.60$, $\eta^2 = 0.01$). Participants in the intervention group had an increase of 4.68 (19.61) min of daily average MVPA after four weeks. Control participants decreased their steps by -2.1 (20.20) min. A total of 70% ($n = 14$) of intervention participants increased their MVPA, and 39% ($n = 9$) showed an increase in the control group.

Perceived Autonomy

At baseline, there was a small difference in perceived autonomy for PA between the intervention and control groups ($d = 0.04$). There was a small effect size after the intervention for group and time interaction ($p = .96$, $\eta^2 = < .01$). There was a large main effect for time ($p = .004$, $\eta^2 = .17$). Autonomy scores increased in the intervention group by 0.29 (0.68). Participants in the control group increased their autonomy by 0.26 (0.58).

Perceived Competence

Perceived competence for PA was different at baseline between the intervention and control groups ($d = 0.24$). After the intervention, there was a small effect for group and time ($p = .84$, $\eta^2 = < .01$). The control group showed greater perceived competence for PA at baseline compared to the intervention group. There was a small main effect for time ($\eta^2 = 0.01$). Competence scores

for the intervention group increased by 0.12 (0.88). Control participants increased in competence by 0.08 (0.74).

Perceived Relatedness

There was a small effect size for perceived relatedness towards the app between the intervention and control ($p = .97$, $d = .07$). Participants in the intervention group scored 2.95 (1.07) in perceived relatedness to the app. Control participants scored 2.87 (1.14).

Table 3. *Physical Activity and Self-Determination Constructs*

	Baseline		Follow-up		<i>time * group</i>	<i>Effect size (η^2)</i>	<i>time</i>	<i>Effect size (η^2)</i>
	Control N = 23 <i>M (SD)</i>	Intervention N = 20 <i>M (SD)</i>	Control <i>M (SD)</i>	Intervention <i>M (SD)</i>				
Steps	7,564 (3214)	8,488 (3340)	7,641 (2892)	9,385 (3811)	.11	.06	.07	.13
Δ Steps			46 (1507)	909 (1701)				
MVPA	32.13 (19.96)	38.35 (29.69)	30.04 (19.69)	43.65 (29.63)	.23	.03	.60	.01
Δ MVPA			-2.1 (20.20)	4.68 (19.61)				
Autonomy	3.38 (0.40)	3.40 (0.54)	3.64 (0.39)	3.69 (0.57)	.96	< .01	.004*	.17
Δ Autonomy			0.26 (0.58)	0.29 (0.68)				
Competence	3.56 (0.79)	3.35 (0.93)	3.63 (0.80)	3.47 (0.99)	.84	< .01	.42	.01
Δ Competence			0.08 (0.74)	0.12 (0.88)				
Relatedness			2.87 (1.14)	2.95 (1.07)				

Note: * Significant outcome ($p < .05$), Δ relative to baseline

Chapter 5: Discussion

The purpose of this present study was to evaluate the acceptability and satisfaction of a virtual pet smartphone app to promote greater daily steps relative to a control group after four weeks of use. The secondary objectives were to explore the preliminary efficacy of the app relative to a control group in improving daily steps, daily MVPA, perceived autonomy for PA, perceived competence for PA, perceived relatedness to the app. Results suggest that participants viewed the Draco app with high levels of satisfaction with reasonable levels of acceptability. Additionally, the app demonstrated small effect sizes in improving daily steps, MVPA, PA autonomy, PA competence and relatedness to the app. Improvements to the Draco app (e.g., usability, content, technical issues) are needed for it to move to a future efficacy trial.

5.1 App Acceptability and Satisfaction

My hypothesis stated that the Draco app would lead to high levels of satisfaction and acceptability. Findings from the analysis support my hypothesis that Draco led to high levels of satisfaction. Results from the exit interviews showed that the overall acceptability of the app was moderate.

Acceptability with the app was high. Numerous children expressed a positive experience with the app, its functionality, and its purpose. Of the 14 children who increased their MVPA, all but one of them also increased their daily average steps. A total of 80% of intervention participants increased their steps after four weeks of using the Draco app. The interest/enjoyment subscale of the IMI is an indicator of intrinsic motivation (Ryan, 1982). As such, one's overall satisfaction with an activity is dependent on perceived autonomy, competence, and relatedness. Perceived autonomy and competence increased for participants in the intervention group. Additionally, perceived relatedness scored above average on the 5-point Likert scale. Despite this, the

satisfaction subscale scored lower than the other subscales used in this trial. While the foundation for the game design supports some level of needs satisfaction, there is still a gap to promoting intrinsic behaviour. This gap could be explained by the choice of game features implemented within the game. Achievements or social-like features have been shown to have a positive association satisfying all three psychological needs (Xi & Hamari, 2019). Likewise, game features focused on performance can also adequately target all three psychological needs (Sailer et al., 2017). Achievements are noteworthy in that they act as markers for performance and can be implemented in a way to compare progress with other users (Xi & Hamari, 2019). These same performance features also contribute to greater perceived value with the activity (Sailer et al., 2017). Many participants cited the usefulness of the Draco app knowing the design intended to promote healthy behaviours.

The results from participants using the Draco app differ from Höchsmann et al., (2019) analysis of their gamification app using IMI. Scores for interest/enjoyment and autonomy exceeded those reported by Draco users in the present trial (Höchsmann et al., 2019). Competence scores from users playing with Mission: Schweinehund were comparable to those in Draco users (Höchsmann et al., 2019). The acceptability of the app was high as a large number of walking minutes were spent with the app open (Höchsmann et al., 2019). However, strength exercises had the lowest completion rates showing that users struggled with these exercises (Höchsmann et al., 2019). Draco users in the exit interviews expressed that a variety of the strength exercises were either new or activities they had not done often. These considerations may have impacted the perceived competence scores in both trials.

The gamified interface developed by Schafer et al. (2018) showed similarities in app acceptability, but overall satisfaction based on needs satisfaction was higher on average in both

pre-test and post-test. Very little change was present at trial completion for perceived autonomy, competence and relatedness in the gamified interface used (Schafer et al., 2018). Despite higher scores, Schafer et al. (2018) also experienced technical issues that negatively impacted their trial. Their game required large storage, internet access and had a high battery drain (Schafer et al., 2018). Participants also expressed that the game was not effective at getting them to participate in PA (Schafer et al., 2018). The technical issues and low PA agreement from participants were likely major contributors to the gamified interface not leading to an increase in PA (Schafer et al., 2018).

Like Schafer et al. (2019), the Draco app also experienced technical limitations that impeded overall enjoyment with the app. Of the participants who completed the exit interview, each one who encountered the technical issues spoke negatively about dealing with these issues before the bug fixes could be addressed. Another issue with the game design was the forced game restart due to inactivity. Children who encountered this felt disheartened that their progress was gone. Considering the importance of performance-based features, having a user completely lose their progress would negatively impact needs satisfaction. These two factors likely impacted the first and final items of the satisfaction subscale exploring the overall enjoyment and instinctive feelings of enjoyment towards the app. To overcome negative feelings of competence from strength exercises, more progressive exercises should be available. Or video demonstrations featuring the target demographic could be added to better model the behaviour.

Three implications arose from the analysis of themes. First, the game features targeting the ability to customize the app and social interactions are key features that should be incorporated into future design. Analysis of the individual questions revealed that children desired more content within the app. The most common feature suggested was more customization.

Customization acts on supporting needs satisfaction. Notably, users are more likely to have their need for perceived autonomy fulfilled by tailoring the game to their personal interests (Bol et al., 2018). It is also associated with an immersive game experience by having control of their experience (Kim et al., 2015). Suggestions provided by the children were customizing homes, items, appearance of the pet or choosing a different type of pet altogether.

The other gap related to content was the lack of social features. Evidence has shown a positive association to fulfill autonomy, competence, and relatedness (Bol et al., 2019; Kim et al., 2015; Xi & Hamari, 2019). Pokémon GO includes many social features within the game that require social contact such as Pokémon trading, battling, a friends list, or sending gifts. Pokémon GO users who were more socially oriented were more likely to continue playing the game after six weeks (Kaczmarek et al., 2017). Leaderboards can act as a motivator through social comparison (Sailer et al., 2017). Having an opt-in for users to share their daily, weekly, or overall steps taken with Draco could be implemented onto a leaderboard. To overcome the risk of non-competitive users losing engagement, goals can be implemented that require teamwork to complete (Chen & Pu, 2014; Sailer et al., 2017).

Second, the results highlight the importance of “how-to” exercise content. Numerous participants cited that the most useful feature within the Draco app was the gif demonstrations of each exercise. Demonstration of behaviour is regarded as an active ingredient of behaviour change as a form of modelling (Michie et al., 2013). The gif demonstrations are shown before each exercise begins. Children can see an observable example of how each exercise is performed as a form of modelling. The interviews revealed that children were able to attempt new exercises they had either not done or were unable to do previously. This can be further improved by having

the target users (e.g., children) included in the video demonstration to improve relatedness to the exercise.

Lastly, the appropriateness of the game design needs to be considered. Integrating the game features to the core content and goals of the app will create an endogenous game experience (Floryan et al., 2019). These apps provide a greater purpose to the user experience and are associated with lasting engagement (Floryan et al., 2019; Helf & Hlavacs, 2016). Previous examples of endogenous apps are more positively associated with improving PA-related outcomes (Dadaczynski et al., 2017; Garde et al., 2015; Höchsmann et al., 2019). Participants frequently spoke about the importance of fun activities to promote PA and recommended using games. Each user's interest in a concept is different as evidenced by several participants finding the game concept childish. Tailoring the game design requires involving the target demographic within the design phase (Mummah, Robinson, et al., 2016). Using the IDEAS framework aided in tailoring the experience to children who commonly spoke about the ease of using the app.

5.2 Physical Activity Outcomes

Steps

My hypothesis stated that the Draco app would result in a medium effect at promoting average daily steps in children relative to a control group after four weeks. Findings from the analysis indicated that the Draco app showed small effects in improving average daily steps when compared to a control group.

This finding is consistent with previous literature that smartphone apps offer a positive, but often small, influence on PA when compared to a control group (Romeo et al., 2019). The systematic review completed by Romeo et al., (2019) presented a mean increase of 476 steps per day. Their analysis suggests that apps may have a greater influence on PA over a period of fewer

than 3 months (Romeo et al., 2019). Participants in the intervention group showed a comparably larger increase of 897 steps per day. Additionally, the intervention participants exhibited week-by-week increases in daily average steps before trial completion. It is unclear if participants in the current trial reached the peak steps over four weeks.

In contrast, participants in the control group had a trivial increase of 46 steps. Compared to prior research, this amount is smaller than expected (Ringeval et al., 2020; Romeo et al., 2019). A review of 16 Fitbit interventions by Ringeval et al (2020) showed that individuals wearing the Fitbits had a mean increase of approximately 950 steps per day. However, only one study included in their review included a sample younger than 18 years old (Ringeval et al., 2020). This present trial featured individuals between the ages of 8 and 14 years old. Despite a large main effect for time being found, participants in the control group experienced far fewer average steps per day compared to Ringeval's analysis (Ringeval et al., 2020). It is apparent the children in this trial were less responsive to the Fitbit app to increase their physical activity. The primary feature of the Fitbit app is through self-monitoring of activity levels (Hartman et al., 2018; Ringeval et al., 2020). Instant and objective feedback of activity may be beneficial, but there is little attention spent on that information (Hartman et al., 2018; Ringeval et al., 2020). By comparison, the Draco app provides the same objective feedback of steps while also making the information relevant across multiple sections of the game to progress or meet challenges. This aspect of playfulness may be the differentiator from participants solely using the Fitbit app.

Previous examples of smartphone apps implementing gamification to promote steps in children are generally positive. Those that have measured daily step counts such as The Monster Manor app, FIT game, or Healthy Together each lead to greater increases in steps compared to the current trial (Chen & Pu, 2014; Garde et al., 2015; Joyner et al., 2019). HealthyTogether

relied on different interpretations of social features such as cooperation or competition dyads to promote steps (Chen & Pu, 2014). The phases employing teamwork all eclipsed an average of 10,000 steps (Chen & Pu, 2014). Likewise, participants playing the Monster Manor app who received feedback from teammates experienced an increase of 1191 steps (Garde et al., 2015). A gap in the design of Draco is the apparent lack of social features. The use of social-like features is positively associated with needs satisfaction (Deterding, 2015; Hamari & Koivisto, 2015; Helf & Hlavacs, 2016; Xi & Hamari, 2019). Using the virtual pet as a replacement for social features with other players may have alleviated major issues in this area (Ahn et al., 2019).

Interestingly, the attenuation of average daily steps was not present for participants in the control group. In contrast, users playing with the Draco app exhibited greater increases in daily average steps. An issue that eventually arises with games to improve PA is the attenuating engagement over time (Khamzina et al., 2020; Romeo et al., 2019; Schafer et al., 2018). Over time, interest in a smartphone app can diminish without introducing updates with new content. The gamified interface by Schafer et al., 2018 showed a varied decrease of MVPA among participants. The slowest attenuation of activity occurred in the intervention group interacting with the gamification interface (Schafer et al., 2018). In the present trial, neither steps nor MVPA attenuated before the trial was completed. Whereas the control group had a minimal increase in steps and a decrease in MVPA over time. The different game features available to those with the Draco app (e.g., virtual pet, challenges, progression) provided longer-lasting content to complete. Using gamification can act as a method to lessen the attenuation of PA engagement.

MVPA

I hypothesized that the Draco smartphone app would have a medium effect at promoting average daily MVPA minutes in children relative to a control group after four weeks. Findings from the analysis indicated that the Draco app showed small effects at improving average daily MVPA when compared to a control group.

The findings of this study contrast with other examples of gamification to promote MVPA (Broom & Flint, 2018; Dadaczynski et al., 2017; Garde et al., 2015; Höchsmann et al., 2019; Schafer et al., 2018). The game features differed compared to Draco app. Both Pokémon GO, Healingo Fit and MobileKids Monster Manor have social features meant to promote PA (Broom & Flint, 2018; Dadaczynski et al., 2017; Garde et al., 2015). In particular, comparison of progress through milestones are used in both Healingo Fit and Mobile Kids Monster Manor which are positive motivators to satisfy needs (Dadaczynski et al., 2017; Garde et al., 2015; Xi & Hamari, 2019). The Draco app has progression in the map section (see appendix 2) but no way to show it to peers for comparison. Additionally, Draco was not intently developed for MVPA. Syncing steps and walking were the primary ways to progress through the game and leveling up Draco. This is more likely to promote lower levels of activity. However, strength-based exercises can be used to promote MVPA (Höchsmann et al., 2019). Mission: Schweinehund consists of 130 exercises which is a stark contrast to the 15 exercises available in the Draco app (Höchsmann et al., 2019). Several participants spoke about wanting more content for within the app, increases the number of exercises to complete would

This trial has shown a comparable effect at promoting physical activity to other methods. Watson et al. (2017) demonstrated that classroom-based physical activity had a small, but consistently positive, effect on overall physical activity levels. The increases ranged from 2% to

16% across the included interventions (Watson et al., 2017). After-school programs also demonstrated small effect sizes but had not as strongly associated with promoting PA outcomes (Atkin et al., 2011). Text messaging interventions are shown to have a wide range of effectiveness depending on the heterogeneity of the designs (Buchholz et al., 2013). The use of text messages to reinforce behaviours has demonstrated a modest effect on promoting PA in adults (Agboola et al., 2016; Buchholz et al., 2013). This can be replicated in smartphone games with push notifications. These can prompt certain activities within the app or as a reminder to use the app after a given time. Overall, Draco's effect is comparable with these intervention methods. Moreover, the Draco app does not act as a replacement for these options. It can be used alongside other methods to fill in the required time for a child to reach 60min of MVPA per day.

5.3 Psychological outcomes

Autonomy

My hypothesis stated that the Draco app would have a medium effect at promoting perceived autonomy for PA in children relative to a control group after four weeks. Findings from the analysis indicated there was a small effect at promoting autonomy in children relative to the control group. There was a large main effect for time.

Autonomy refers to one's sense of desire for self-direction and volition when completing a task (Ryan & Deci, 2000). This concept is guided by the player feeling a sense of self-direction in their experience using the app (Xi & Hamari, 2019). However, this feeling can be a difficult psychological component to target within an app. Introducing features that force engagement with the app due to external pressure may harm one's sense of autonomy. However, if these activities are seen as enjoyable it can stimulate continued app usage (Xi & Hamari, 2019).

Autonomy for PA increased for participants in both the control and intervention groups to them during the four-week study period. The apps functioned as a moderator in which participants were able to engage in and increase their PA. Consistent with previous research, autonomy needs satisfaction remained high when the smartphone apps were in use (Ahn et al., 2019; Peng, Lin, et al., 2012). The apps target autonomy in different manners. A straightforward step syncing app provides a simple method for children to track their progress. As such, it allows participants to easily access the app to sync their steps and view their day's progression. The Draco app encourages consistent usage with a similar step syncing system, as well as the features to progress through the game, practicing different exercises and caring for the virtual pet.

The concept of a virtual pet game has the potential to differentiate itself in satisfying one's autonomy. Beemer et al., (2019) showed having users choose their own goals made them more willing to engage in PA. Having a tier of multiple challenges an individual can choose to complete may be sufficient to satisfy this. Balance in structured requirements is needed for certain individuals. Bol et al., (2019) noted that participants with a decreased need for autonomy had a lower intention to engage in exercise while interacting with a gamification interface. Immersion is viewed as effective examples to promote autonomy (Xi & Hamari, 2019). Having Draco's avatar be present as the primary focus of the app was relied upon for all components of needs satisfaction. Expanding on the immersive aspects of the avatar through communication and customizations would improve this feature. The virtual pet currently provides simple dialogue, and messages of endorsement related to the 24-Hour Movement Guidelines. This can be expanded to include reinforcing messages or to offer empathy and acknowledgement of difficulty the user may feel learning the exercises available in the app (Thøgersen-Ntoumani & Ntoumanis, 2007). Autonomy can be further supported by presenting the rationale more

explicitly elsewhere in the game, either through the tutorial or at the beginning of the game (Thøgersen-Ntoumani & Ntoumanis, 2007). Additional customization options for the virtual pet could be implemented (Bol et al., 2019; Kim et al., 2015). Participants in the exit interviews brought up the possibility of multiple virtual pets available to start their journey with. Either as different designs for dragons or other fantastical creatures to choose. Currently, only single option for a virtual pet dragon was available to users. Providing an opportunity to choose a different pet or customize the look of their virtual pet can increase needs satisfaction of autonomy through immersion and choice (Kim et al., 2015).

Competence

My hypothesis stated that the Draco app would have a medium effect at promoting perceived competence for PA in children relative to a control group after four weeks. Findings from the analysis indicated small effect at increasing perceived competence to PA compared to a control group.

In previous literature, gamification techniques such as points, achievements and challenges had been used successfully to foster competence (Peng, Lin, et al., 2012; Xi & Hamari, 2019). The Draco app features gifs of the exercise form, challenges, unlockable items and replenishing their virtual pet's happiness by completing exercises. In contrast, the step tracking app only provided a simple overview of one's steps completed that day or weeks prior. The existing gamification features targeting competence may not have been concrete enough to influence competence. The challenges encouraged users to complete a variety of different exercises alongside each other but provided no reward beyond unlocking a trinket that the virtual pet now owned. Likewise, the collectables did offer unlockable items for progressing through the game. Neither item available to users after unlocking provided any gameplay interactions. Similar to

satisfying the need for autonomy, reinforcing messages can be added to improve perceived competence and promote behaviour change (Hamari & Koivisto, 2015; Michie et al., 2013; Xi & Hamari, 2019). Examples of this are implementing dialogue options, adding a help menu for exercises, or including a greater variety of messages.

Children often cited the exercise instruction gifs as either their favourite or most useful feature of the app. The app provides a potential landscape to learn through demonstration and practice new activities by using the gifs as well as expanding dialogue options to reinforce behaviours (Michie et al., 2013). Likewise, achievements are positively associated with each of the three psychological needs (Xi & Hamari, 2019). Achievements can be used to show one's progression through a game (Xi & Hamari, 2019). The Draco app has similar features with challenges and unlockable items. More explicit examples of achievement could be shared by the virtual pet when reaching milestones within the game.

Relatedness

My hypothesis stated that the Draco app would have a medium effect at promoting perceived relatedness to the app in children relative to a control group after four weeks. Analysis indicated that the Draco app had small effects at increased relatedness towards the app compared to a control group.

To foster relatedness, an empathetic, positive environment is needed (Teixeira et al., 2012). The virtual pet itself offered lines of communication but could not be prompted by the user. A dialogue option to check in on the user could further a sense of relatedness. Dialogue trees prompted by the user answering if they are having difficulties completing exercises could provide further health information and encourage the child to continue practicing. The Xbox Kinect game selected by Ahn et al. (2019) potentially created a more immersive environment for

participants by use of motion sensing. The virtual dog grew fitter, happier, and responsive to command as the participants met their PA goals (Ahn et al., 2019). Social features associated with other users are another inclusion which impacts relatedness (Xi & Hamari, 2019). Working cooperatively or competitively can influence relatedness (Xi & Hamari, 2019). Leaderboards are one interpretation of this. These act as a mean for competition or comparison with among peers (Looyestyn et al., 2017). They also provide further meaning to points in a game when used as a measure on a leaderboard (Looyestyn et al., 2017). Cooperating to reach a goal or sharing an achievement such as completing a challenge are also associated with positive outcomes (Koivisto & Hamari, 2019a, 2019b).

Previous analysis has shown that gamification can satisfy the psychological needs to support behaviour change (Xi & Hamari, 2019). This is done primarily by structuring game design around supporting autonomy, competence, and relatedness (Xi & Hamari, 2019). By supporting these, one's motivation to can be influenced to engage in a behaviour (Ryan & Deci, 2000). The design of the Draco app implemented game features such as an avatar, progression, challenges, choice, and points as motivational affordances in which to reach the psychological needs. Despite small improvements in steps and MVPA in the intervention group, the psychological needs did not change from baseline to follow or in comparison to the control group.

It is unclear what factors influenced the increase in PA for intervention participants. During the exit interviews, several participants spoke about interacting with the app together with their parents. Similarly, the parents would remind their child to use the app. Two participants shared that their younger siblings were interested in the Draco app. There were no expectations from the parents to engage with the Draco app or encourage its use with their children. However, children are reliant on their parents and the structure of the family environment to learn from (Brown et

al., 2016; Naisseh et al., 2015). The adapted version of the relatedness measure of the IMI focused on the feelings of connectedness with the app and Draco. As such, it did not account for interactions with the family environment. By comparison, another leading behavioural theory in smartphone interventions is social cognitive theory which places a distinct emphasis on environmental influences (Hosseinpour & Terlutter, 2019).

95% of intervention participants had parents who were married or lived together with a partner. Both fathers and mothers can influence children's PA as role models and provide opportunities for PA (Edwardson & Gorely, 2010; Naisseh et al., 2015). Parents who are more willing to engage in PA themselves can lead to children doing the same (Brown et al., 2016; Naisseh et al., 2015). Many commercial apps have the capability to set up family accounts where parents can monitor their children's usage. The Draco app has existing structure for performance markers, challenges and health information that can be supplemented by sharing the experience with parents. Educational elements, sharing activities, individualized experiences and markers of performance have high levels of interest among families (Meixner et al., 2019). A parent version of health apps could be an educational resource improve parent's PA knowledge, reinforce the importance of PA or offer encouragement when their child progresses through the game (Brown et al., 2016; Meixner et al., 2019; Naisseh et al., 2015). This could be expanded by allowing parents to assign goals for their children to reinforce the health information through active usage (Brown et al., 2016). This considerations can offer a comprehensive app experience where families can learn and engage in PA together.

5.4 Study Implications

Satisfaction with the Draco app was high after four weeks of usage. Despite the technical issues that persisted through the trial, users enjoyed many aspects of the app. A greater number

of participants in the intervention group experienced increases in steps, MVPA compared to the control group. Overall, the Draco app demonstrated small effects on promoting PA behaviour. In comparison to a commercial product such as the Fitbit, participants produced noticeably higher PA rates. This highlights the potential of a gamification design to promote high levels of acceptability towards using an app to promote PA in children.

Furthermore, this trial provides evidence for the acceptability of several gamification techniques for children. The current design of the app uses a variety of game features such as an avatar, points, challenges, levels, and progression. These aspects were important in delivering a fun experience with the app even with the technical issues present. During the exit interviews, children frequently mentioned the importance of making PA a fun experience and how enjoyable the game concept of Draco was. They also noted the ease of use with the app and had no difficulties understanding the information presented within the app. This further supports the importance of personalizing game design to the target demographic (Kappen et al., 2017).

Previous studies have shown that smartphone apps can have a positive influence on steps between one-to-three months (Romeo et al., 2019). The findings of this study suggest a similar positive effect of smartphone apps to increase average daily steps. Autonomy for PA remained high throughout the trial. Demonstrating that the participants were interested in voluntarily engaging in PA by using the smartphone apps as a medium in which to do so. Moreso, the gamification design acted as a motivational affordance in which to promote PA behaviour (Kappen et al., 2017). Children can achieve partial fulfillment of the Canadian PA guidelines through school, organized sport, or outdoor play (Andermo et al., 2020; Watson et al., 2017). Considering the number of children not meeting the PA guidelines in Canada, smartphones app can serve as an accessible method to further bolster PA rates.

Future research should aim to implement a longer intervention period. A four-week period may not be sufficient to explore the longer-term effects of app usage. Users in both groups continued to increase their average weekly steps up to the trial completion. The activity peak may not have been reached during this trial. Further research should consider an 8–12-week intervention design. The impact of the individual game features remains unclear. Many of the game features included in the Draco app have previously influenced the psychological needs in prior research (Xi & Hamari, 2019). However, this trial demonstrated inconsistency in this regard. A more detailed analysis of the game techniques that target each psychological need could provide further knowledge into their impact on motivation. This may be done by removing a specific game feature (e.g., Draco's avatar) to examine the impact on outcomes. Lastly, as this is a pilot trial, progression to a definitive RCT should be considered (Eldridge et al., 2016). The app was shown to promote PA behaviour and was well received among participants. Design changes to address app stability and new game features should be prioritized. Power analysis for a definitive RCT indicates that a minimum sample size of 162 participants is needed to meet sufficient power (Faul & Lang, 2009).

5.5 Strengths & Limitations

There is a limited number of trials evaluating the effectiveness of a novel gamification app intently designed to promote PA in children. Smartphone apps and the field of gamification require rigorous trials to examine the effectiveness of apps to provide health benefits (Koivisto & Hamari, 2019a; Romeo et al., 2019). This study adds to the growing body of research evaluating the use of gamification apps to promote PA in children. The IDEAS framework contributed a straightforward foundation for design, and implementation (Mummah, Robinson, et al., 2016). Each new feature was supervised by a team of programmers and health behaviour change

researchers to determine its usefulness to achieve objectives and meet the theoretical framework. Children participating in the study commonly cited the ease of use of function and information within the app. The exit interviews contribute design choices that can be implemented strategically using the IDEAS framework. The use of Fitbit trackers showed to be a reliable instrument to objectively measure PA rates across participants (Feehan et al., 2018). Participants were provided de-personalized Fitbit accounts for use during the trial to collect anonymized PA data. Collecting both steps and MVPA provided a more complete view of each participants' PA rates.

Implementation of study recruitment took place entirely online due to the COVID-19 pandemic. Screenings were reliably completed with telephone and video conferencing. Sanitized devices were delivered to each participant with clear instructions on sending back the devices. This not only remained faithful to COVID-19 restrictions but also improved availability to individuals interested in participating across Canada. Additionally, the Draco app was compatible with both major operating systems (Android and iOS). These endeavors to improve accessibility with recruitment improved the generalizability of the results.

However, there are several limitations present in the current study. Technical issues persisted through the trial. Minor issues arose at various points but were quickly resolved. Prior to the conclusion of the trial a major issue arose which impacted the allocation of participants. These technical issues negatively impacted the experience for certain participants in the intervention group. Exit interviews with participants who experienced technical issues generated unfavourable responses. While some understood the issues, a small number of participants expressed frustration that the app was not working as intended. Due to this, user satisfaction with

the app may have been negatively impacted. Likewise, it may have impacted the engagement with the app during the trial.

Additionally, more outcome measures could be collected. There is no record of app usage time. Participants in each group accrued at least 30min of average MVPA. It would be interesting to view if time spent using the app resembled the time spent doing moderate-to-vigorous activities. Furthermore, there is no record of steps taken by participants when the Fitbit tracker was not worn. It is conceivable that the Fitbit may not have been worn at times and only the smartphone was used by the participant. Considering the variation in smartphones available to consumers, it would be difficult to expect reliable step counts from a smartphone's hardware. Since the Draco app was developed for this trial, a reminder message by the virtual pet to wear their Fitbit could be given. There was no measure to assess the participant's level of motivation. The behavioural regulation of exercise questionnaire-2 can measure the level of behavioural regulation along the continuum of motivation within SDT (Markland & Tobin, 2004). This measure has been used in a prior gamification trial with a similar sample (Schafer et al., 2018). The adapted IMI used in this trial collected only satisfaction which is an indicator of intrinsic motivation (Ryan, 1982). It does not consider if participants reach lower levels of regulations such as identified or integrated regulation.

5.6 Conclusion

The Draco app was viewed with high satisfaction and acceptability by children. Three themes emerged from the exit interviews: content, usability, and effectiveness. Design implications for these results included implementation of social-like features, customization, content personalization and the importance of modelling behaviour. The Draco app also produced small effects in promoting average daily steps and average daily MVPA. Participants had an increase

of 909 steps and 4.68min of MVPA relative to baseline. A greater number of participants increased their steps and MVPA compared to the control group. Additionally, the Draco app produced small effects at influencing psychological needs for motivation. Technical limitations impacted user experience with the Draco app and interrupted recruitment. Despite this, the study emphasizes the positive influence gamified smartphone apps can have to promote satisfaction and PA in children. Additional development time should be taken to stabilize the app and implement new game features for a definitive RCT.

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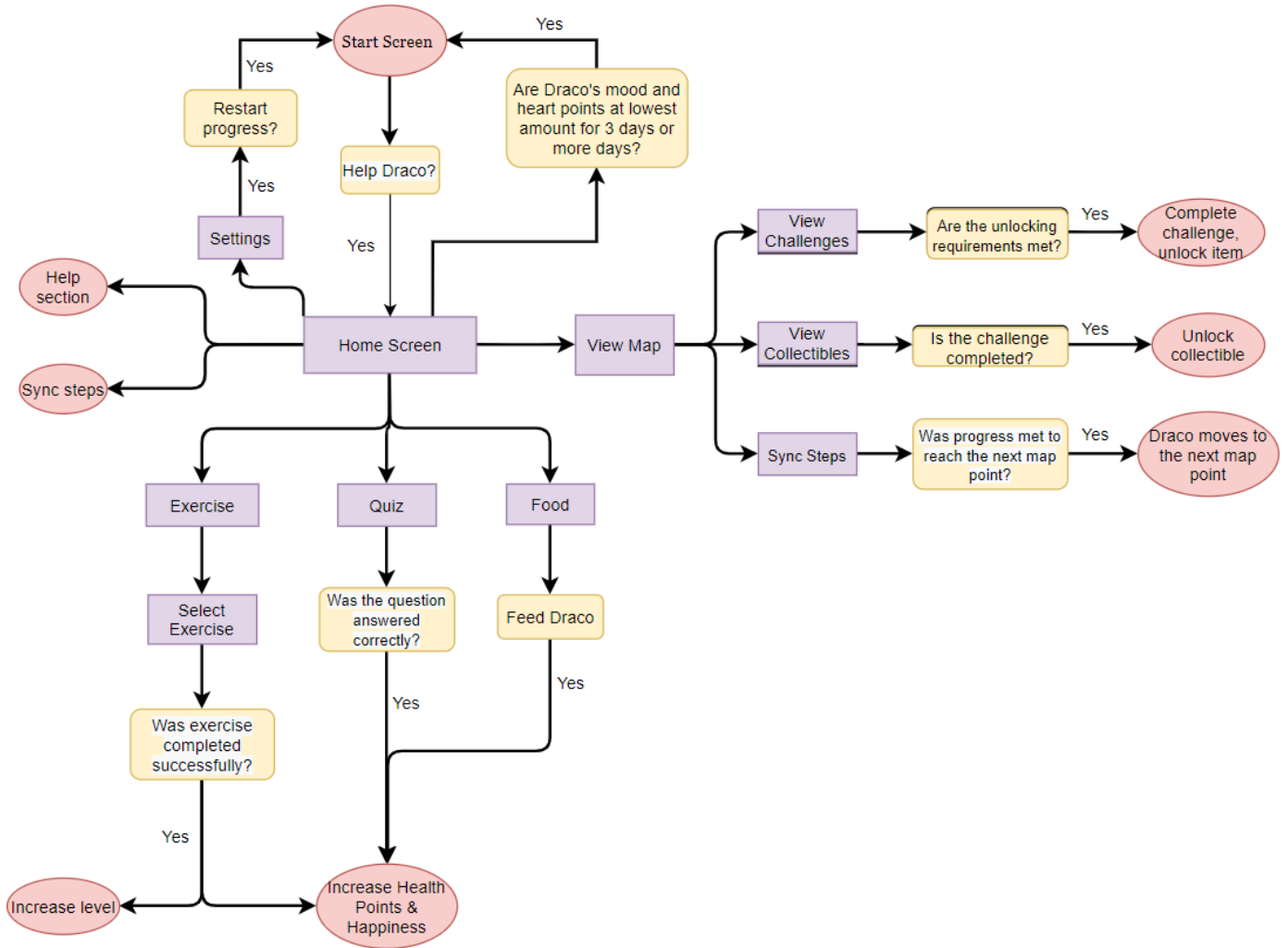
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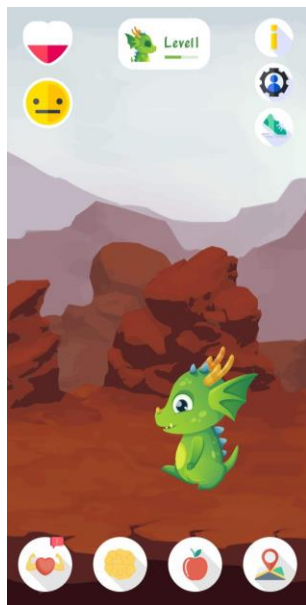
Appendix 1

Draco's gameplay logic diagram.



Appendix 2

Draco gameplay sections



MIND POWER UP!

breathing Garland pose

Cobra pose dancer pose

STRENGTH POWER UP!

walking jumping jacks

squats sit-ups

Go Back

BRAIN POWER!

Short exercise sessions of 10 - 20 minutes are an easy way to fit in my daily physical activity goals.

True

False

Next

Go Back

Vegetables and Fruit

Protein

Whole Grain Products

Beverages

Go Back

Challenges

?

Unlock by doing 5 of each: Friendlier Pushups and Friendlier Plank!

?

Unlock by doing 5 of each: Dancer pose, Garland pose and Cobra pose!

Go Back



Collectables

?

Unlock by doing exercises and walking!

?

Unlock by doing exercises and walking!

Go Back

The “Exercise” section contains a variety of bodyweight exercises, yoga poses and meditation for the participants to complete. Selecting the exercise will prompt the user of the exercises’ benefits and show a video demonstration of the exercise. Participants are then given an allotted time to complete the exercise themselves. The “Nutrition” section allows the users to feed their virtual pet with a variety of common, healthy foods. Foods represented in this section were taken from Canada’s Food Guide, a public resource for healthy eating recommendations.

The “Collectables” and “Challenges” sections offer additional content for the user to complete. Both sections can be completed by doing a specific series of exercises and progressing to certain points in the “Map” section. These will unlock shelters or items for the virtual pet. Completing activities in the “Exercise”, “Quiz” or “Nutrition” sections will give the virtual pet health points (HP). If the HP is depleted for 3 days, the virtual pet will abandon the player and the game will restart. The activities will also increase the level of the virtual pet.

Draco was developed using the SDT framework.

The “Quiz” section consists of 81 unique questions primarily focused on physical activity and features others about nutrition, sleep and sedentary behaviour. Participants can complete up to three unique quiz questions daily for 27 days; after which the question will rotate back to the beginning. Quiz questions were inspired by publicly available resources such as Canadian 24-Hour Movement Guidelines, Canada’s Food Guide.

The “Map” section shows the user their progress through the game. Users can sync their steps into the app to get their virtual pet closer to reaching its home. Collectible items and challenges can be accessed from this page as well, thus providing users with additional content to strive for while playing.

Appendix 3

Table 4. *Exit Interview Themes & Sample Quotes*

	Theme	Sample Quote
Can you tell me about your experience using the app?	Positive experience playing Technical issues were frustrating	“...you watch the dragon and help a dragon. And you realizing what the dragon should do is what you should do.” “It was pretty glitchy.”
Did you find the app useful?	Provided useful information	“I felt like I could exercise more and it was helping me exercise”
What did you like about this app?	Exercise information	“I liked being able to take care of a dragon while exercising”
What did you not like?	Game restart due to inactivity	“Draco kept on leaving me and I was sad about that”
Did the app get repetitive?	More content needed	“It got repetitive after a while”
How easy is the app to use?	Easy to use	“It was very easy to use”
Is the app easy to navigate?	Easy to navigate	“The app was easy to navigate”
Was the content of the app easy to understand?	Easy to understand	“Easy to understand. No problems”
Did you notice any change to your behaviours as a result of the app?	Increased exercising No major changes	“I felt more confident in how strong I was” “I didn’t notice a changes, no”
Before this, had you started any new technique or method to increase your physical activity?	No attempts prior to the study participation to increase PA	“I hadn’t started anything new”
What impact did the information of the app have on you?	Useful health information	“I learned different facts and forms of exercise”
What information did you find most useful?	Video demonstrations	“It would be a better way to do exercises, with the videos and such”
How motivated were you at the start of the study to be physically active?	Moderate motivation for PA	“I was feeling pretty motivated at the start”
How motivated are you now to be physically active?	Moderate motivation for PA	“About the same when I started”

What did you think of the game concept? Enjoyable concept
 Are there any features you would like to see added? Customization
 Greater variety of exercises

What do you think is the most effective way to help children be physically active? Fun activities
 Apps and games

“I liked being able to take care of a dragon while exercising”

“What if you could customize Draco’s looks?”

“Add other gameplay elements. When you’re exercising with the gameplay elements. You aren’t thinking about exercising”

“I do think games are effective. I think more where you build your skill”

“Something enjoyable. Fun to do and participate in then it’s more likely to happen”

Appendix 4
Parent and Child Consent Form



**University
of Victoria**

Parent Consent Form

You are invited to participate in a study entitled “Evaluating the effectiveness of an exercise mobile application to promote physical activity among children” that is being conducted by XXX

XXX, the principal investigator of this study, is a faculty member at the School of Exercise Science, Physical & Health Education at the University of Victoria and you may contact him if you have further questions by

Email: XXX@XX.XX or Tel: XXX-XXX-XXXX

Purpose and Objectives

The purpose of this research project is to evaluate whether a smartphone application (app) is effective in helping children increase their physical activity levels.

Importance of this Research

Research of this type is important because it can provide valuable information about the usefulness of app-based physical activity interventions in a real-world setting. Physical activity is critical to children’s development and health. Our results will ultimately lay the foundation to understand ways to use digital technology to promote physical activity.

Participants Selection

You are being asked to participate in this study because your child meets the following criteria:

- 1 Aged 8-14 years old and is not meeting the recommended Canadian physical activity guidelines of 60 min per day
- 2 English-literate
- 3 Have access to a smartphone/tablet
- 4 Normal to corrected vision

What is involved?

We need written consent from you and your child in order to participate in this study. If both of you and your child consent to voluntarily participate in this research, we will randomly put you and your child into one of the two groups (Intervention or Control group). Both groups will be using smartphone apps designed to improve a child’s physical activity. Your child will be asked to use the app for 4 weeks. Your child will be asked to download the app on a smartphone/tablet.

We will ask you and your child to remotely meet with the researcher before (baseline visit) and after (follow-up visit) using the smartphone app. Each visit will last up to 60 minutes. We will

ask you and your child to complete an online health and wellness questionnaire during each meeting. We ask for measurements for height and weight.

Following the baseline visit, we will ask your child to wear a small activity monitor (Fitbit) for 1 week before starting using the smartphone app for 4 weeks. Your child will be wearing this monitor throughout the 4-week intervention.

The pedometer does not require an app. Both the apps described below are developed by Dr. XXX's team and are free for download.

Intervention: Children in the intervention group will be asked to download an app called "Draco". Draco is a virtual pet simulation game. The child keeps a virtual pet and learns to keep it healthy and happy by taking it on regular walks, feeding it, and maintaining its hygiene. Your child can care for the pet as much or as little as he/she chooses, and the outcome depends on his/her actions. Draco may run away due to lack of attention. The activity of your child is tracked using the accelerometer.

Control: Children in the control group will be asked to use another smartphone application that will provide the same physical activity and health-related information as the Intervention group. However, the app will contain no gamification features. Your child will have the option to download the Draco app at the end of your study participation.

****You or your child will not be able to choose which group he/she belongs to. The study team will assign your child to one of the groups at random****

During the follow-up visit, we will ask you and your child to complete the same assessment as during the baseline. In addition, we will interview you and your child to evaluate your experience using the smartphone app. The interview will be audio recorded. The recording will be used for analysis.

Inconvenience

Participation in this study may cause some inconvenience to you and your child, including time taken to finish the activities and surveys and having to answer some questions about yourself.

Risks

There are no known risks to you by participating in the assessments. You or your child may feel some fatigue when answering the questions. However, you and your child will be encouraged to take breaks whenever necessary. Your child's safety will be monitored throughout the session. There is some risk involved when using the smartphone apps when he/she is outdoors. Accidents may happen if he/she is not paying attention to his/her surroundings. He/she is reminded to be mindful of your surroundings (especially traffic) when using the apps outdoors and we highly encourage all caregivers to supervise their children when they are using the app. There will be periodic reminders in the app to remind your child of safety. He/She is also highly encouraged to use this app with your parent/caregiver.

Benefits

The potential benefits of your participation in this research include trying out new technology, and possibly increasing your physical activity levels.

Voluntary Participation

Your and your child's participation in this research must be completely voluntary. If you or your child do decide to participate, you may still withdraw at any time without any consequences or any explanation. If you do withdraw from the study, your data will be discarded unless you give permission for us to use it for data analysis.

On-going Consent

To make sure that you continue to consent to participate in this research, the research team will check with you and your child verbally at the beginning of every session if you are both willing to participate. As a reminder, you or your child can withdraw at any point in time during the study.

Anonymity

In terms of protecting your anonymity, all data collected from you and your child will be linked to a participant ID which only members of the study team have access to.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected. Hard copies of the questionnaire and physical measures data will be stored in a locked file cabinet in a locked room (Digital Health Research Lab, McKinnon Building 0026) at the University of Victoria. The response from the questionnaires will be entered into an excel spreadsheet and stored on a secure server with a firewall provided by the University of Victoria. Data can only be accessed by the study investigators. The data we retain will not have your name linked to it.

Application Data

The apps used in this study currently do not collect any data of the user (your child). All app data will be stored on the user's device. Therefore, uninstalling the apps will permanently delete all data related to them. The user has full custody of the data on the app. If a participant withdraws from the study, all app-related data can be deleted by the user.

Fitbit Data

Please be advised that information about you that is gathered for this research study uses an app that stores data in the U.S. As such, there is a possibility that information about you may be accessed without your knowledge or consent by the US government in compliance with the US Freedom Act.

SurveyMonkey Data

Questionnaires and assessments will be delivered with SurveyMonkey.

Please be advised that this research study includes data storage in U.S.A. As such, there is a possibility that information about you that is gathered for this research study may be accessed without your knowledge or consent by the U.S. government, in compliance with the U.S. Freedom Act.

Dissemination of Results

It is anticipated that the results of this study will be shared with others through publications and presentations that will potentially be available to the public.

Disposal of Data

Data from this study will be kept indefinitely for the research team's reference as the development of the apps is ongoing. There are no plans for analyzing the data for other purposes or for the data to be shared with other researchers. However, consent forms will be destroyed appropriately once the study is complete.

Contacts

You may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

Name of Participant

Signature

Date

A copy of this consent will be left with you, and a copy will be taken by the researcher.



You are invited to participate in a study. The name of the study is “Evaluating the effectiveness of an exercise mobile application to promote physical activity among children” that is being conducted by XXX.

XXX, the principal investigator of this study, is a faculty member at the School of Exercise Science, Physical & Health Education at the University of Victoria and you may contact him if you have further questions by
Email: XXX@XX.XX or Tel: XXX-XXX-XXXX

Purpose and Objectives

The purpose of this research project is to understand whether a smart phone application (app) is useful in helping children increase their physical activity levels.

Importance of this Research

Research of this type is important because it can provide valuable information about the usefulness of application-based physical activity program in a real-world setting. Physical activity is important to children’s growth and health. Our results will help us understand ways to use digital technology to promote physical activity.

Participants Selection

You are being asked to participate in this study because you are/have:

- 5 A child aged 8-14 years old, who does not meet the recommended Canadian physical activity guidelines of 60 min per day
- 6 English-literate
- 7 Access to a smartphone/tablet
- 8 Normal to corrected vision

What is involved?

We need written consent from you and your parent (caregiver) in order to participate in this study. If both you and your parent (caregiver) consent to voluntarily participate in this research, we will randomly put you into one of the two groups (Intervention or Control group). Both groups will be using smartphone apps designed to improve your physical activity level. You will be asked to use the app for 4 weeks. You will be asked to download the application on your smartphone/ tablet.

We will ask you and your parent (caregiver) to visit our lab located at the University of Victoria two times before (baseline visit) and after (follow-up visit) using the smartphone app. Each visit will last up to 60 minutes. We will ask you to complete health and wellness questions during each visit. We will also measure your height and weight.

Following the baseline visit, we will ask you to wear a small activity monitor (similar to a pedometer) for 1 week before using the smartphone application for 4 weeks. Participants will be wearing this monitor throughout the 4-week intervention.

The pedometer does not require an app. Both the apps described below are developed by XXX's team and are free for download.

Intervention: If you are in this group, you will be asked to download an app called "Draco". Draco is a virtual pet simulation game. You will care for a virtual pet and keep it healthy and happy by taking it on regular walks, feeding it, and maintaining its hygiene. You can care for the pet as much or as little as they choose, and the outcome will depend on your actions. Draco may run away from a lack of attention. Your activity is tracked using the accelerometer.

Control: If you are in the control group, you will be asked to use an application that will provide the same physical activity and health-related information as the Intervention group. However, the app will contain no games. You will have the option to download the Draco app at the end of your study participation.

****You will not be able to choose which app to download during the study. The study team will assign you to one of the groups at random****

During the follow-up visit, you will be asked to complete the same questions as you did during the first lab session. In addition, we will ask you and your parent (caregiver) about your experience using the smartphone application. This will be audio recorded. The recording will be used for analysis.

Inconvenience

Participation in this study may cause some inconvenience to you, including time taken to finish the activities and surveys and having to answer some questions about yourself.

Risks

There are no known risks to you by participating in the assessments. You may feel tired when answering the questions. However, you will be encouraged to take breaks whenever necessary. Your safety will be monitored throughout the session. There is some risk involved when using the apps when you are outdoors. Accidents may happen if you are not paying attention to your surroundings. You are reminded to be mindful of your surroundings (especially traffic) when using the apps outdoors. There will be periodic reminders in the app to remind you of safety. You are also highly encouraged to use this app with your parent/caregiver.

Benefits

The potential benefits of your participation in this research include trying out new technology, and possibly increasing your physical activity levels.

Voluntary Participation

Your participation in this research must be completely voluntary. That means that nobody can force you to take part if you do not wish to. If you do decide to participate, you can still stop at any time without any consequences or any explanation. If you stop participating in this study, your data will be discarded unless you give permission for us to use it for data analysis.

On-going Consent

To make sure that you continue to consent to participate in this research, the research team will check with you verbally at the beginning of every session if you are willing to participate. You can withdraw at any point in time during the study.

Anonymity

In terms of protecting your anonymity, all data collected from you will be linked to a participant ID which only members of the study team have access to.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected. Hard copies of the questionnaire and physical measures data will be stored in a locked file cabinet in a locked room (Digital Health Research Lab, McKinnon Building 0026) at the University of Victoria. The response from the questionnaires and the app data will be entered into an excel spreadsheet and stored on a secure server with a firewall provided by the University of Victoria. Data can only be accessed by the study investigators. The data we retain will not have your name linked to it.

Application Data

The apps used in this study currently do not collect any of your personal data. All app data will be stored on the device you are using. Therefore, uninstalling the apps will permanently delete all data related to them. You have full ownership of the data on the app. If you stop taking part in the study, you can delete all app-related data.

Fitbit Data

Please be advised that information about you that is gathered for this research study uses an app that stores data in the U.S. As such, there is a possibility that information about you may be accessed without your knowledge or consent by the US government in compliance with the US Freedom Act.

SurveyMonkey Data

Questionnaires and assessments will be delivered with SurveyMonkey.

Please be advised that this research study includes data storage in U.S.A. As such, there is a possibility that information about you that is gathered for this research study may be accessed without your knowledge or consent by the U.S. government, in compliance with the U.S. Freedom Act.

Dissemination of Results

It is anticipated that the results of this study will be shared with others through publications and presentations that will potentially be available to the public.

Disposal of Data

Data from this study will be kept indefinitely. However, consent forms will be destroyed appropriately once the study is complete.

Contacts

You may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

Signature of Child

Date

Printed name of child

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Appendix 5 Child Questionnaire Form

Behaviours

About my physical activity					
<u>Instructions</u>					
We are trying to find out about your level of physical activity from <i>the last 7 days</i> (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.					
Remember:					
1. There are no right or wrong answers – this is not a test.					
2. Please answer all the questions as honestly and accurately as you can – this is very important.					
1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Check only one box per row.)					
Please answer all questions	No	Yes			
		1-2	3-4	5-6	7 times or more
a) Skipping					
b) Rowing/canoeing					
c) In-line skating/rollerblading					
d) Tag					
e) Walking for exercise					
f) Bicycling					
g) Jogging or running					
h) Aerobics					
i) Swimming					
j) Baseball, softball					
k) Dance					
l) Football					
m) Badminton					
n) Skateboarding					
o) Soccer					
p) Street hockey					
q) Volleyball					
r) Floor hockey					
s) Basketball					
t) Ice skating					
u) Cross-country skiing					
v) Ice hockey/ringette					
w) Downhill skiing/snowboarding					
x) Martial arts					
y) Other: (please list)					
z) Other: (please list)					

<p>2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)</p> <ul style="list-style-type: none">a) I don't do PEb) Hardly everc) Sometimesd) Quite oftene) Always
<p>3. In the last 7 days, what did you do most of the time <i>at recess</i>? (Check one only.)</p> <ul style="list-style-type: none">a) Sat down (talking, reading, doing schoolwork)b) Stood around or walked aroundc) Ran or played a little bitd) Ran around and played quite a bite) Ran around and played hard most of the time
<p>4. In the last 7 days, what did you do most of the time <i>at lunch</i> (besides eating lunch)? (Check one only.)</p> <ul style="list-style-type: none">a) Sat down (talking, reading, doing schoolwork)b) Stood around or walked aroundc) Ran or played a little bitd) Ran around and played quite a bite) Ran around and played hard most of the time
<p>5. In the last 7 days, on how many days <i>right after school</i>, did you do sports, dance, or play active games in which you were very active? (Check one only.)</p> <ul style="list-style-type: none">a) Noneb) 1 time last weekc) 2 or 3 times last weekd) 4 times last weeke) 5 times last week
<p>6. In the last 7 days, on how many <i>evenings</i> did you do sports, dance, or play games in which you were very active? (Check one only.)</p> <ul style="list-style-type: none">a) Noneb) 1 time last weekc) 2 or 3 times last weekd) 4 or 5 times last weeke) 6 or 7 times last week
<p>7. <i>On the last weekend</i>, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)</p> <ul style="list-style-type: none">a) Noneb) 1 timec) 2 to 3 timesd) 4 to 5 timese) 6 or more times
<p>8. Which <i>one</i> of the following describes you best for the last 7 days? Read <i>all five</i> statements before deciding on the <i>one</i> answer that describes you.</p>

- a) All or most of my free time was spent doing things that involve little physical effort.
- b) I sometimes (1-2 times last week) did physical things in my free time (e.g., played sports, went running, swimming, bike riding, did aerobics).
- c) I often (3-4 times last week) did physical things in my free time.
- d) I quite often (5-6 times last week) did physical things in my free time.
- e) I very often (7 or more times last week) did physical things in my free time.

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one).

a) Yes – What prevented you?

b) No

11. On an average weekday (Monday to Friday), about how many hours a day do you watch TV or videos or play video games (including Wii®)?

- a) I do not watch TV or videos or play video games
- b) Less than one hour a day
- c) 1 to 2 hours a day
- d) 3 to 4 hours a day
- e) 5 to 6 hours a day
- f) 7 or more hours a day

12. On an average weekday (Monday to Friday), about how many hours a day do you spend on a computer (working, playing games, e-mailing, chatting, surfing the Internet, etc.)?

- a) I do not use a computer
- b) Less than one hour a day
- c) 1 to 2 hours a day
- d) 3 to 4 hours a day
- e) 5 to 6 hours a day
- f) 7 or more hours a day

13. On an average weekend day (Saturday and Sunday), about how many hours a day do you watch TV or videos or play video games (including Wii®)?

- a) I do not watch TV or videos or play video games
- b) Less than one hour a day
- c) 1 to 2 hours a day
- d) 3 to 4 hours a day

<p>e) 5 to 6 hours a day f) 7 or more hours a day</p>
<p>14. On an average weekend day (Saturday and Sunday), about how many hours a day do you spend on a computer (working, playing games, e-mailing, chatting, surfing the Internet, etc.)?</p> <p>a) I do not use a computer b) Less than one hour a day c) 1 to 2 hours a day d) 3 to 4 hours a day e) 5 to 6 hours a day f) 7 or more hours a day</p>

- 1 During the week, how many hours per day do you usually spend watching TV shows or videos?
 - 1.1 I don't want TV or videos
 - 1.2 Less than 1 hour a day
 - 1.3 1-2 hours a day
 - 1.4 3-4 hours a day
 - 1.5 More than 4 hours a day

- 2 During the week, how many TV shows do you usually spend watch each day?
 - 2.1 I don't watch TV or videos
 - 2.2 Less than 1 hour a day
 - 2.3 1
 - 2.4 2
 - 2.5 3 or more

- 3 During the weekend, how many hours per day do you usually spend watching TV shows or videos?
 - 3.1 I don't want TV or videos
 - 3.2 Less than 1 hour a day
 - 3.3 1-2 hours a day
 - 3.4 3-4 hours a day
 - 3.5 More than 4 hours a day

- 4 During the weekend, how many TV shows do you usually spend watch each day?
 - 4.1 I don't watch TV or videos
 - 4.2 Less than 1 hour a day
 - 4.3 1
 - 4.4 2
 - 4.5 3 or more

- 5 During the week, how many hours per day do you usually play video games like Nintendo, PlayStation, or use the computer to surf the internet?
 - 5.1 I don't play video games or use the computer
 - 5.2 Less than 1 hour a day

- 5.3 1-2 hours a day
- 5.4 3-4 hours a day
- 5.5 More than 4 hours a day

6 During the weekend, how many hours per day do you usually play video games like Nintendo, PlayStation, or use the computer to surf the internet?

- 6.1 I don't play video games or use the computer
- 6.2 Less than 1 hour a day
- 6.3 1-2 hours a day
- 6.4 3-4 hours a day
- 6.5 More than 4 hours a day

Sleep

7 On an average weeknight (Sunday – Thursday night) what time do you go to bed (to go to sleep)? Please fill in the blank using 30-minute increments [e.g. 9 – 9:30 [AM/PM]

8 On an average weekday (Monday-Friday morning) what time do you get out of bed (to start your day)? Please fill in the blank using 30-minute increments [e.g. 6-6:30 [AM/PM]

9 On an average weekend night (Friday or Saturday night), what time do you go to bed (to go to sleep)? Please fill in the blank using 30-minute increments [e.g. 1:00 – 12:30 [AM/PM]

10 On an average weekend day (Saturday or Sunday morning) what time do you get out of bed (to start your day)? Please fill in the blank using 30-minute increments [e.g. 8:00 – 8:30 [AM/PM]

Mental Health

11 How true is each statement for you?

a. In most ways my life is close to the way I would want it to be.

Disagree a lot Disagree a little Neutral Agree a little
 Agree a lot

b. The things in my life are excellent.

Disagree a lot Disagree a little Neutral Agree a little
 Agree a lot

c. I am happy with life.

Disagree a lot Disagree a little Neutral Agree a little
 Agree a lot

d. So far I have gotten the important things I want in life.

Disagree a lot Disagree a little Neutral Agree a little
 Agree a lot

e. If I could live my life over, I would have it the same way.

Disagree a lot Disagree a little Neutral Agree a little
 Agree a lot

12 How happy are you with your life as a whole these days? Please fill in the blank with one number on a scale of 1-10, with 1 being “not at all happy” and 10, “very happy”

Perceived Autonomy

Please read each sentence and tell us how true it is for you.

	Not true for me	Not really true for me	Sometimes true for me	Often true for me	Very true for me
I believe I had some choice about being physically active	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I was physically active because I had no choice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I was physically active because I wanted to	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I didn't really have a choice about being physically active	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I was physically active because I had to	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Perceived Competence

Please read each sentence and tell us how true it is for you.

	Not true for me	Not really true for me	Sometimes true for me	Often true for me	Very true for me
I think I am pretty good at being physically active	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

I think I was pretty good at being physically active, compared to other kids	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After being physically active for awhile, I felt I became pretty good at it	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am satisfied with my performance at being physically active	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I was pretty skilled at being physically active	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Being physically active is something I cannot do well	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Perceived Relatedness

Please read each sentence and tell us how true it is for you.

	Not true for me	Not really true for me	Sometimes true for me	Often true for me	Very true for me
I felt like Draco and I were not close at all	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I really doubt that Draco and I would ever be friends	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I'd like a chance to interact with Draco more often	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I felt like I could really trust my Draco	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I felt close to Draco	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Interest/Enjoyment

Please read each sentence and tell us how true it is for you.

	Not true for me	Not really true for me	Sometimes true for me	Often true for me	Very true for me
I enjoyed playing with Draco very much	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Playing with Draco was fun to do.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I thought playing with Draco was boring	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Playing with Draco did not hold my attention at all	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would describe playing with Draco as very interesting.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I thought playing with Draco was quite enjoyable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
While I was playing with Draco, I was thinking about how much I enjoyed it.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>