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IMPROVING STUDENT MENTAL HEALTH
THROUGH HEALTH OBJECTIVES IN A MOBILE APP

BY

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Approval of Thesis

The undersigned certify that they have read the thesis entitled

IMPROVING STUDENT MENTAL HEALTH AND SPORTS MOTIVATION THROUGH HEALTH OBJECTIVES IN A MOBILE APP

Submitted by

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In partial fulfillment of the requirements for the degree of

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Dedication

I dedicate this work to my beloved grandmother – Iraida – whose boundless support, encouragement, patience, and kindness brought this work to light.

Acknowledgment

I would like to acknowledge and thank Dr. Maiga Chang for his guidance and support, as well as the supervisory committee – Dr. Oscar Lin, Dr. Wong Seng Yue, and Dr. Yang Yan – for their time and feedback with helping polish this work.

Abstract

This research sets out to validate a mobile app intervention that aimed to improve the participant's mental health by asking them to engage in daily challenges, which encouraged the participant to create better sleep, diet, and exercise routines. The study gathered 73 participants, of which 67 completed at least one challenge, 30 participated in multiple mental health surveys, and 8 completed the entire 8-week trial. Throughout the trial participants filled out a patient health questionnaire (PHQ-4) that evaluated their mental health, while analytics were gathered about their engagement with the app as measured by the number of days they opened the app, number of challenges they completed, number of points they collected, and so on. Correlation analyses were performed to measure the correlation of engagement and mental health. We observed a negative correlation between points gained and mental health score indicating that engagement had a positive effect on mental health.

Keywords: sleep, diet, exercise, physical activity, intention, intrinsic motivation, Measurement of the Intention to be Physically Active (MIFA), Patient Health Questionnaire (PHQ), System Usability Scale (SUS)

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List of Symbols, Nomenclature, or Abbreviations

API – Application Programming Interface

CBT – Cognitive Behavioural Therapy

CSV – Comma Separated Values

DMG – Demographics Survey

DNS – Domain Name Server

eHealth – Electronic Health

ENG – Engagement

ENG.LOG – Number of days the user logged into the system

ENG.NUM – Number of days the user requested challenges from the system

ENG.PTS - Points

GCP – Google Cloud Platform

IP – Internet Protocol

JSON – JavaScript Object Notation (used to encode data to transmit over the internet)

MH – Mental Health

mHealth – Mobile Health

MIFA – Measurement of the Intention to be Physically Active

MIFA^1 – The first MIFA survey issued at the beginning of the trial

MIFA^2 – The second MIFA survey issued at the end of the trial

MIFA.IN – Intention

OAuth – A framework for authentication to securely communicate from app to server

PHP – A programming language used to develop the server-side application

PHQ – Patient Health Questionnaire

PHQ^1 – The first PHQ survey issued at the start of the trial

RCT – Randomized Controlled Trial

SQL – Structured Query Language

SUS – System Usability Scale

UI/UX – User Interface / User eXperience

UUID – Unique User Identifier

Chapter 1. Mental Health Concerns

State of Affairs

Student mental health has been a concern for a long time (Choise, 2016; Pfeffer, 2016; Smith, 2016). Post-secondary education is a transitioning period for a lot of individuals and comes with a new set of responsibilities and challenges. Half of post-secondary students report struggling with anxiety, depression, or even suicide (CTVNews.ca Staff, 2016). Due to the overwhelming demand on the counseling system (Pfeffer, 2016) students may have to wait for weeks before receiving any help, which can make the difference between prevailing, or dropping out. Occasionally if the issues are severe, it can mean the difference between life and death.

Even though institutions have been increasing their support programs, many students are still not using these services. A survey discovered that about half (54%) of respondents with mental health difficulties did not seek help (Gil, 2015). Other studies confirmed that students are either unaware of the access they possess, or have stigma-related inhibitions about using such services (Carr, Wei, Kutcher, & Heffernan, 2017; Gronholm, Thornicroft, Laurens, & Evens-Lacko, 2017).

In many cases, preventative measures can help students cope with stress. Studies have shown that healthy sleep, diet, and exercise can contribute to healthier mental function (Haruka, Nishida, Tsuji, & Sakakibara, 2017; Schlarb, Claßen, Grünwald, & Vögele, 2017; Lutz, et al., 2017; Deslandes, et al., 2009). The Government of Canada published a guide to better mental health where it stated the top three ways to improve one's mental health are through eating a healthy diet, being physically active, and getting enough sleep (Government of Canada, 2015).

Motivation

Why This? Why Now?

It is important to nourish and foster learning environments that encourage behaviours inside and outside the institutions. Helping students stay active, eat healthy, and get enough sleep can have a positive effect on the student's academic experience, resulting in less likelihood of poor performance or dropping out. The goal of this research is to improve the student quality of life as well as improve the chances of student success and better academic output.

Recent studies have shown that there is a need for students to improve their sleep, diet, and exercise (Carter, Chopak-Foss, & Punungwe, 2016; Navarro-Prado, González-Jiménez, Perona, Montero-Alonso, & López-Bueno, 2017; de Vries, van Hooff, Geurts, & Kompier, 2016). Other studies suggest habits relating to sleep, diet, and exercise can be changed through interventions that can result in better quality of life, performance, and output (Ipjian & Johnston, 2017; Jenkins, 2016; Lutz, et al., 2017; Wong, 2017). By helping students improve these three habits, it is possible to positively affect their mental health (Macera, 2015; Government of Canada, 2015).

The recent COVID-19 pandemic events also had a negative impact on mental health and mobility. As lockdown and self-isolation mandates rolled out throughout the world more individuals turned to indoors and their mobility greatly decreased along with good eating habits and mental health (Carpio-Arias et al., 2021). This decline in mental health is also reflected in the Canadian labour force which showed an increase in mental health related disability (Government of Canada, 2022).

Now more than ever, young adults are turning to their mobile devices as a means of escape or coping mechanisms (Jiang & Li, 2018; Gul, Yurumez Solmaz, Gul, & Oner, 2018). It has been shown that from a young age children are engaging more and more with their screens and forming these habits into adulthood (Sigman, 2017). Studies have shown that these behaviours correlate with poor mental health and social habits (Kuss, et al., 2018; Sigman, 2017). However, using a mobile device doesn't need to have negative consequences. It is possible, through education, guidance, and coaching to enable individuals to use their mobile devices as tools to assist in their daily lives, rather than sources of compulsion.

How Can It Be Done?

Research has shown that using mobile apps as interventions for a variety of mental health issues can be successful (Batra, et al., 2017; Bakker, Kazantzis, Rickwood, & Rickard, 2016; Crookston, et al., 2017; Huang & Bashir, 2017; Rubanovich, Mohr, & Schueller, 2017).

Research has also shown that mobile app interventions can be used to improve sleep, diet, and exercise, and observe that digital technologies and mobile apps are an effective and sought-after means of intervention for improving physical or mental health, and that mobile apps can be used to influence and change behaviour (Robbins, Krebs, Rapoport, Jean-Louis, & Duncan, 2018; Korinek, et al., 2018; Carroll, et al., 2017).

The availability of mobile devices, the reach and low cost to the user of mobile apps, and the ease of engagement make apps an appealing means of intervention, as evidenced by a multitude of studies (Bakker, Kazantzis, Rickwood, & Rickard, 2016; Crookston, et al., 2017).

However, several papers note that there is a lack of standardized testing and validation of these interventions (Bakker, Kazantzis, Rickwood, & Rickard, 2016;

Crookston, et al., 2017; Grist, Porter, & Stallard, 2017). The aim of this research was to conduct a randomized controlled trial (RCT) that validates the effectiveness of the different aspects of the intervention. By designing the application in a way that allows for monitoring and logging of activity, progress, and engagement, a quantitative analysis can be carried out and an evaluation can be made about each aspect of the intervention.

Why Hasn't It Been Done Before?

Batra et al. reviewed studies over the last 10 years dealing with digital health technologies and noted that mobile apps were the most common, were primarily used for monitoring, and demonstrated feasibility for mental health care (Batra, et al., 2017). Grist et al. reviewed publications over the last 10 years to look for evidence supporting mobile app effectiveness (Grist, Porter, & Stallard, 2017). They note that despite the large number of mental health apps available on the market, only a few have been mentioned in any clinical studies, and fewer still have quality results. The commercial app market is developing much faster than academic research, so the data that is available is limited due to apps being removed from the market or lack of clinical testing of those apps in the first place (Grist, Porter, & Stallard, 2017; Naslund, et al., 2017; Zhao, Freeman, & Li, 2016).

Of the apps that have been developed and available on the market for managing mental or physical health, most were commercially developed rather than with considerations for clinical trials (Zhao, Freeman, & Li, 2016), or input from healthcare professionals during the design stages (Grist, Porter, & Stallard, 2017) as recommended by a publication on the design of mobile health interventions (Matthews, Doherty, Coyle, & Sharry, 2008). Similarly two recent systematic reviews of mobile mental health interventions note the need for more accurate evaluation and reporting on the efficacy of these interventions (Punukollu, Marques, 2019; Milne-Ives, Lam, De Cock, Van Velthoven, & Meinert, 2020). A recent review of mobile mental health app interventions draws from literature as well as analysis of available mental health apps and provides a list of sixteen recommendations that should be considered in future development to address issues and shortcomings of existing interventions (Bakker, Kazantzis, Rickwood, & Rickard, 2016). Using these recent studies as an example and guide, it is possible to put together an app designed for a clinical trial that will validate the effectiveness of different features.

Goals and Contributions

This research aims to build an open-source mobile app to encourage students to engage in self-care behaviour with the ultimate goal to improve mental health and inspire better habits. As part of the study a mobile app was designed, built, and made available to students world-wide. This study attempted to measure and prove the effectiveness of this app, as well as collect data to help refine and improve it in the future. The app remains open-source and free to download for the public and could be used by future cohorts to help improve sleep, diet, and exercise habits, and subsequently mental health. The application and intervention mechanism could be used by future researchers to elaborate on this study. Finally, the research aims to study the concept of improving physical and mental health in students with the aim of expanding the approach. Future research could focus on developing similar interventions for the elderly.

Outline

The rest of the paper is structured as follows. Chapter 2 discusses how health apps are currently used and analyzed. Then presents a literature review of current health app interventions and recommendations for future research. Chapter 3 discusses how this study is structured, and how the recommendations from prior research are applied. Then outlines the technical requirements of the mobile application, the overall system architecture, how the engagement is structured, the behaviours it tries to encourage, and what kind of measurements were taken to be analyzed to evaluate the hypotheses and answer the research questions. Chapter 4 describes how the app was implemented, deployed, and delivered. Chapter 5 discusses how the collected measurements were analyzed and which hypotheses were supported. Chapter 6 concludes with the summary of findings, limitations of the study, and direction for future research.

Chapter 2. Mobile Mental Health

Academic and Systematic Solution

Bakker et al. (2016) conducted a review of literature and mobile health apps to create a list of sixteen recommendations that should be used by developers and researchers to direct mobile mental health research (Bakker, Kazantzis, Rickwood, & Rickard, 2016). In short they suggest that Cognitive Behavioural Therapy (CBT) be used; that apps should be designed for use by regular individuals, not only those diagnosed with a disorder; that individuals are interested in prevention, rather than diagnoses and treatment; that the experience should be tailored; that recording thoughts, feelings, and behaviours elicits self-reflection, which is helpful for changing behaviour; that setting goals and schedules is an effective way to minimize avoidance; that education and literacy about mental health is a way to increase treatment credibility, and decrease stigmatization; that non-technology based engagements and interactions should be used; that gamification can be used to motivate the user, and should be done with user-set goals; that logs of past activity can be used as a way to review progress and draw narrative, which can help engagement; that reminders have been shown to reduce dropout rate and should be used to engage the user; that an intuitive interface and simple verbiage with non-action defaults that still allow participation are a good way to increase retention; and finally that randomized controlled trials need to be carried out to determine efficacy.

Another review of apps notes a high risk of bias in the analyzed work and suggest using the Cochrane Risk of Bias Assessment during the design of the experiment to ensure high validity, paying special attention to “random sequence generation, allocation concealment, blinding of participants, blinding of outcome assessment, incomplete outcome data, selective reporting" and completeness of follow-up to be above 80% (Zhao, Freeman, & Li, 2016). The study furthermore recommends the Consolidated Standards for Reporting Trials (CONSORT), and the mHealth Evidence Reporting and Assessment (mERA) checklists for more accurate trial reports (Zhao, Freeman, & Li, 2016). The CONSORT-EHEALTH checklist was developed specifically for electronic health (eHealth) reporting in 2010, refined based on feedback, and published in its current version in 2011 (Eysenbach & Consort-EHEALTH Group, 2011).

To help further standardise the results of this study, some popular questionnaires have been selected to evaluate the participants' physical and mental health, system usability, and attitude toward sports. Measurement of the Intention to be Physically Active (MIFA) (Hein, Müür, & Koka, 2004) is used to measure intention and observe the effectiveness of the intervention on either creating intention or motivating change if intention already exists. The Patient Health Questionnaire (PHQ-4) (Kroenke, Spitzer, & Williams, Löwe, 2009) is used to measure the participant's physical and mental state. And an industry-standard System Usability Scale (SUS) (Brooke, 1996) is used to evaluate the mobile app as a technological implementation of the intervention.

Mobile Health Apps

This generation finds themselves much more comfortable communicating through their mobile devices, which makes mobile apps an appealing, low-cost intervention (Adams, Liguori, & Lofgren, 2017; Zhao, Freeman, & Li, 2016). Current mobile health apps range from activity trackers, to building physical/mental resilience, to goal-setting and coaching for building self-confidence and self-efficacy, to health literacy as a means of prevention and coping (Teles et al., 2019).

One recent study on the use of mobile apps for student mental health found evidence to support literature that states almost half of all students experience mental health challenges with adjustment, relationships, and academic issues (Baras, et al., 2018). The research performed a series of field studies where data was gathered from a student population. The first survey observed how students communicate about their feelings, with whom, and what kind of feelings they were sharing. The second survey asked questions regarding what kind of problems (social, academic, etc.) the students were facing. Based on these findings the third study developed a prototype mobile app which provided a calendar, diary, and notifications. Students tested the app and gave feedback on the usefulness of the notification and time management features to help alleviate anxiety. The final study gathered metrics from the mobile phones of the participants about the duration and frequency of phone calls and SMS, physical activity, and self-assessed mood in an effort to correlate mood with activity and phone use. The research concluded that students would find a mobile application with these features helpful. However, the data gathered did not include any control group, so it is difficult to draw general conclusions.

Another recent review of 17 studies evaluating app-based health interventions found apps to be an effective mechanism for changing behaviour but concluded that more randomized controlled trials (RCTs) are still needed (Zhao, Freeman, & Li, 2016). The review also summarized suggested feature improvements and highlighted “self-monitoring, goal setting, feedback, and social networking features… amount of participant time required… user-friendly design, usefulness of the information, usability of the app… tailored advice, supplemented by additional background information" as useful features for mobile interventions.

Duncan et al. (2017) summarize the implementation of behaviour change techniques in different activity trackers and discuss the use of challenges, leaderboards, and social networks (Duncan, et al., 2017). They note that leaderboards for sleep may be ineffective, due to the anxiety that may be caused by a competitive component; rather sleep is best encouraged by personalized goal-setting and prompting the user of the approaching time. They note instead that challenges and leaderboards can be an engaging way to encourage regular activity breaks. They also note that there is only modest evidence to support the effectiveness of social networks.

A recent study sums up behaviour change research with a three-dimensional model – predisposing, enabling, and reinforcing. Apps which increase the user's knowledge and self-efficacy influence predisposing, while apps that allow the user to gather data and self-monitor are enabling, and apps that enable social interaction and feedback are reinforcing (Crookston, et al., 2017). To tap into some of these dimensions the app is designed in a way to predispose the user through education, information dissemination, and self-assessment; enable the user with suggested challenges, self-monitoring, and gamification; and reinforce the behaviour through in-game rewards and leaderboards.

Influential Factors

The study attempted to influence intention and behaviour using numerous approaches as recommended by previous studies. The usability of the mobile app itself is evaluated using the System Usability Scale (SUS) to ensure the overall quality of the application. The effectiveness of the intervention is measured by looking for improvement on the PHQ scale. Significant improvement was expected to be observed in the experiment group in comparison to the control group. To measure this we used the Measurement of the Intention to be Physically Active (MIFA) survey, which evaluated 4 factors of sports motivation - one of them being Intention (IN). We asked those 5 questions focusing on the intention (IN) again after the user has participated for 8 weeks and we attempted to isolate users with initial low intention hoping to measure the increase in intention (IN) after app use. Unfortunately only a small percentage of participants completed the post-trial MIFA questionnaire.

Chapter 3. Analysis & Design

To carry out this study we needed to implement a mobile app that would challenge the user to engage in better sleep, diet, and exercise habits and measure their participation against their mental health scores at a regular cadence. We needed an app that would ask the user to engage daily but at the same time not demand too much time or commitment, and while encouraging consistent participation also being accommodating to occasional use. We needed a way to start the user at a low challenge level and gradually build up as they gain mastery in each of the different areas. We needed a mechanism for gathering survey responses, and splitting participants into control/experiment groups, while at the same time keeping everything anonymous. Finally we needed a way to measure and record everything like the participant's engagement, their mental health, and their responses to occasional surveys.

We decided to give the user a lot of self-control and autonomy with completing the challenges. They should be able to participate by completing challenges of their choice, and not be hindered by not being able to complete or participate in a certain challenge. They should be slightly challenged by the activity goal, but not so much that it seems impossible, and build up more challenging goals as they complete existing ones. They should be able to complete the challenges throughout different times of day and easily record their metrics. The user should be able to receive reminders at key times of the day to encourage them to build better routines.

Technical Requirements and Architecture

The primary technical requirement was to deliver a mobile app to the user's device. We chose to develop an Android app due to cost limitations with developing for

Apple devices. Android devices contributed to ~70% (Mobile Operating System Market Share Worldwide, 2022) of worldwide mobile devices at the time of planning and development, which allowed for the majority of market coverage. The Android app could have been developed through a number of front-end libraries to facilitate deployment to multiple operating systems later, however due to the requirements to access hardware sensors we chose to develop it natively in Java.

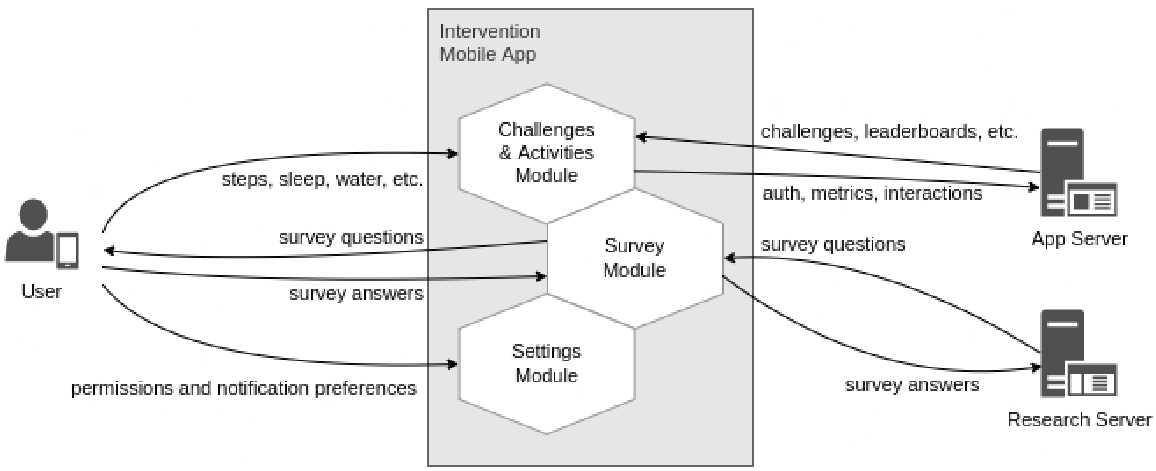
The app needed to have a clean and intuitive user interface (UI) that would allow ease of onboarding and ease of use. The interface needed to allow for bite-sized interaction of receiving a challenge and marking the completion progress. The interface should provide help for those who need it, yet be unobtrusive to those who don't. The participant should be able to easily jump in and out of completing their challenges any time. They should be able to see their progress at a glance and see details when they need them. The interface needed to allow the user to configure their notification preferences for push notifications and reminders. If the hardware capabilities are present and permissions are granted the device should be able to tap into activity monitoring to gather device pedometer data.

The secondary technical requirement was to deliver surveys and receive back responses from app participants anonymously. Some surveys needed to be delivered when the user first registered, then another survey throughout the trial, and then final exit surveys at the end of the trial. The survey responses needed to be able to relate to app usage, but without compromising anonymity.

With the above requirements in mind we decided to build an Android app that would connect with two microservice APIs. Figure 1 illustrates how the user would interact with the two microservices through the mobile app. The front-end UI would act as the intermediary between the user and the APIs. While the back-end services would handle database connectivity, keeping track of challenges and activities, tallying points and leaderboards, and delivering and receiving surveys.

Figure 1

Overall Architecture



Note. The diagram illustrates the overall architecture of the intervention mobile app, how it communicates with back-end application and research servers, and how the user interacts with it.

A microservice architecture was adopted to separate the concerns between the two main areas of the application. The challenges and activities module would keep track of activities and participation, while the survey module would keep track of survey questions and answers. This would allow for easier development of both systems independently of each other, and would better facilitate deploying the APIs to production when edits need to be made, as well as better reusability of the code in future projects.

Each microservice would expose a number of endpoints to the internet and allow mobile devices to communicate with them. The research module would allow the user to identify themselves to the system with a randomly generated unique identifier (UUID). This UUID would keep track of when the user has filled out the necessary surveys and assign new ones. Another endpoint would allow the mobile device to query for available surveys given the UUID. While another endpoint would allow receiving survey responses along with the UUID and record everything in a database. Similarly the activity module would keep track of all the users with their unique identifiers and assign challenges to each user based on their level. The more challenges a user completes of a specific type - the more points they earn in that category and the higher the level that is assigned to them - allowing them to receive more challenging activities the next day.

Both microservices would run on a cloud instance and securely connect to a cloud database. In an ideal scenario each microservice would run on their own instance and possibly even connect to their own database instance. However, for this study, both microservices are packaged into one container and connect to one cloud database instance for cost efficiency. To keep the two microservices separate they each run from their own location within the instance and connect to their own database even though the instance is shared. This would allow for easier scaling when the need arose.

Analysis

The data gathered by the application server can be used to measure engagement with the platform - how often the users are logging into the system and what kind of activities they are completing. This will allow us to observe active and participating users, as well as those who are active but are not participating, and those who are not active at all. Meanwhile the data gathered by the research server can help us understand how a user's mental health changes over time and how it correlates with the user's participation and interaction with the app. Additionally, the research server will be used to evaluate the participants intrinsic motivation for physical activity before and after the trial and compare the results to see if motivation can be encouraged through the use of the app. Finally, a questionnaire will be used to evaluate the usability of the system by those who completed the trial to determine if technology was a barrier to using the app and if the interaction was successful.

To evaluate mental health a Patient Health Questionnaire-4 (PHQ-4) was used. It was chosen for its terseness to encourage regular participation. The test reduced the number of questions from 20 in the original PHQ-20 down to 4 and was still found to explain 80% of the variance of the two primary factors - depression and anxiety.

To evaluate intrinsic motivation for physical activity a Measurement of the Intention to be Physically Active (MIFA) survey was chosen. Based on the work by Pelletier et al. (1995) the original Sports Motivation Scale was used to measure three factors for intrinsic motivation - to experience stimulation (ES), to know (KN), and to accomplish (AC). The modified scale has an additional factor for intention (IN) that is evaluated for changes after the completion of the trial.

Finally a System Usability Scale (SUS) is used to evaluate the app overall from a usability perspective. This helps determine if the implementation lacked anything that may have acted as a barrier to participation.

The challenges assigned by the system have a point value. As the user completes the challenge they are awarded the amount of points they have earned. The more points a user gains in a particular challenge the higher the user’s level in that activity. Next time the user requests a challenge for that activity, they receive one in line with their skill level in that category. So the more pushups a user does, the more difficult the challenges become to eventually even out with the user's ability. The points can be shown to the user on a timeline as a self-monitoring tool in an effort to encourage and motivate more active participation. The points can also be summarized on a leaderboard in a similar effort to encourage friendly competition with the community.

These gamification features in particular will be tested in our study by comparing participation and mental health between a control and an experiment group. The experiment group will receive the entire app experience with surveys, challenges, and the ability to see their points on a timeline and leaderboards. The control group will receive a reduced experience with no visibility into their points either via timeline or via leaderboards. In the end we will be able to evaluate whether the gamification features had any influence on application usage and desired outcomes.

Design

The mobile app was developed for the Android operating system using Android Studio v3.3.2. At the time of design and development Android contributed to ~70% of global mobile devices, so it was considered that the app would be accessible by the majority of mobile users. The app was developed natively rather than using an abstraction framework like Xamarin, Flutter, or ReactNative to take full advantage of the Android APIs when interacting with physical sensors. In the future the app codebase could be improved by implementing the front-end in a cross-platform framework.

The main purpose of the app was to allow the users to participate in daily challenges and anonymously submit responses to surveys. A clean, simple, yet detailed interface would allow the users to have brief interactions, while at the same time helping the study evaluate only the bare elements of the gamification without letting an attractive interface or engaging gameplay influence participation. The interaction with the app was meant to be minimal to avoid burdening the user with having to spend time on data entry and instead encourage engaging with the challenge to be the key element.

Since the app wanted the participant to focus on multiple areas of their routine (sleep, diet, and exercise) it was decided to slowly build the interaction and only ask the user to complete a few small challenges to start, then slowly build the engagement by offering new challenges every day and as the user engages more with the app. Such that if time goes by and the user doesn’t engage with the app, they don’t come back to an interface suddenly asking them for a dozen new challenges, but rather increase the challenges as the user consistently interacts with the app. The goal was to roll out all the challenges to the user over the course of 4 weeks and so at first the app would only challenge the user to have a healthy breakfast, and in a few days challenge the user to have a healthy breakfast and lunch. And while increasing the diet challenges, also adding more challenges for different types of exercises, as well as going to bed and getting up on time.

Additionally, as the user successfully completed a challenge for three days the user’s level for that particular challenge increased, and the next time they are assigned this challenge it will require more from the user. For example the basic task of drinking a glass of water in a day, when completed three times then begins asking the user to drink two glasses of water in a day, and so on until the user drinks 8 or more glasses of water per day. Similarly with physical challenges to perform 5 pushups or squats eventually asks the user to do 10, then 15, and so on until 100.

The front-end interface allowed the user to interact with the app, which in turn communicated these interactions to back-end services. There were two application servers with which the app communicated. The research server was used during registration to receive a randomly generated unique identifier (UUID) and group assignment (control or experiment). This UUID was then assigned a random password generated by the device and communicated to the application server, which created a profile for the participant and started them off on the first level with a hydration, walking, and a random exercise challenge. All future interactions were authenticated with the random password generated by the device and the participant UUID. This ensured that only the user of the profile could send and receive data associated with that profile.

All communication to both servers used small JSON payloads to send the activity, survey, and settings data. Most activities were self-reported so the user had to perform the activity (such as a push up or squat) and then enter the number of repetitions they had completed. One activity metric was gathered automatically using a built-in pedometer sensor, if it was available, and if the user granted the permissions for access. The pedometer would keep track of steps taken throughout the day and periodically send this value to the application server. In future app improvements perhaps more metrics could be gathered automatically for an improved user experience.

The app was bundled as an Android App Bundle (AAB) for optimized delivery and uploaded to the Google Play Store for distribution. It was advertised on the university internal network and social media as well as through word of mouth.

Chapter 4. Implementation

This chapter outlines how the application was built, implemented, and deployed, how the gamification features were developed and applied to this research, how objectives were suggested and increased with participation, how measurements were taken throughout the trial, and how the experiment was administered.

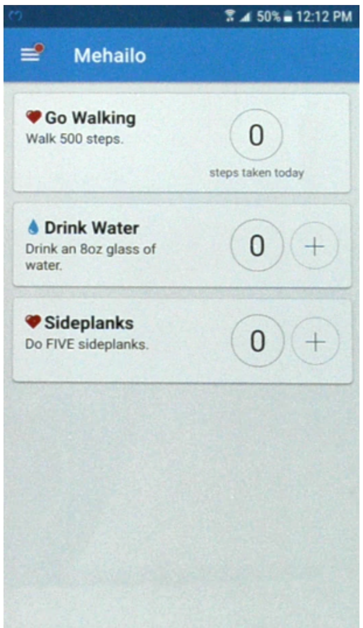
Front-End

The interface was designed in a way to give the user quick at-a-glance information about their daily challenges when they initially open the app. This view is illustrated in Figure 2 - showing a challenge to walk 500 steps, drink a glass of water, and a random physical activity of 5 repetitions - in this case side planks. The user can tap on a challenge to get more details on how to perform the physical activity as illustrated in Figure 3. As the user engages with the app every day and completes the challenges they unlock the ability for more challenges to be assigned to them per day and with increasing difficulty. Figure 4 illustrates a challenge view for a more advanced user who is now asked to complete walking, hydration, diet, multiple physical activity exercises, and more repetitions on the challenges they've engaged with and consistently completed. After several weeks of continuous engagement the user unlocks all challenges to be assigned to them with walking, hydration, multiple diet, and multiple physical activity challenges.

Each challenge card shows a large number or icon on the right with a plus ('+') and minus ('-') button on either side. The user can tap the plus button to increment the counter, and tap the minus to decrement in case they've made an error. The button can also be long-pressed (press and hold) to bring up a tumbler dialog where the user can select a number of repetitions they have completed when it becomes inconvenient to tap the plus button dozens of times. This simple interface was aimed to give the user the fewest possible steps for data entry.

Figure 2

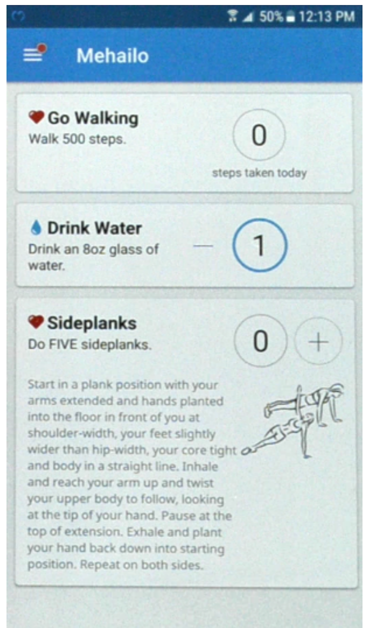
Beginner Challenges



Note. A screen showing 3 tiles with challenges to walk 500 steps, drink a glass of water, and do 5 sideplanks.

Figure 3

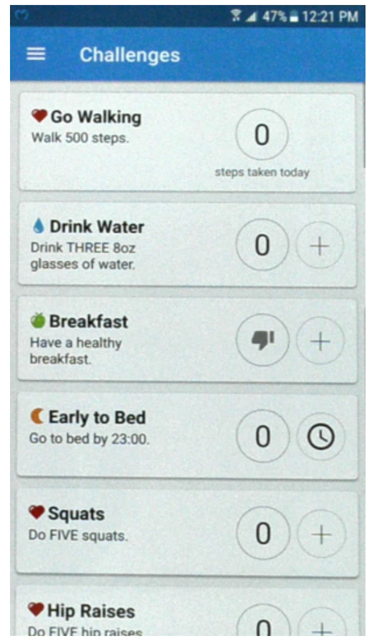
Challenge Details Expanded



Note. A screen showing 3 tiles with the sideplans challenge expanded showing a description and a diagram of how to perform the exercise.

Figure 4

Advanced Challenges



Note. A screen showing a list of many challenge tiles.

A separate navigation item and user flow was designed for the survey portion. A red notification badge alerted the user of new content, and the “Surveys” navigation item directed the user to a list of available surveys as shown in Figure 5. The user can see how many questions are in the survey and approximately how long it would take to answer them as a way to encourage participation. Once the user opened a survey questions were presented to them one-by-one as shown in Figure 6 until the user had answered all of them, at which point the answers were submitted and the survey was removed from the list of available surveys.

The user received demographic (DMG) and sports motivation (MIFA[1]) surveys at the beginning of the trial, and a system usability (SUS) and sports motivation (MIFA[2]) surveys at the end. Throughout the trial the user also received a wellbeing (PHQ-4) questionnaire which became available every 7 days. When the user filled out the PHQ questionnaire it was removed from the list, and a week later was added back again with a red indicator badge to draw the user's attention. Occasionally a push notification was also sent to users who had outstanding surveys to encourage participation.

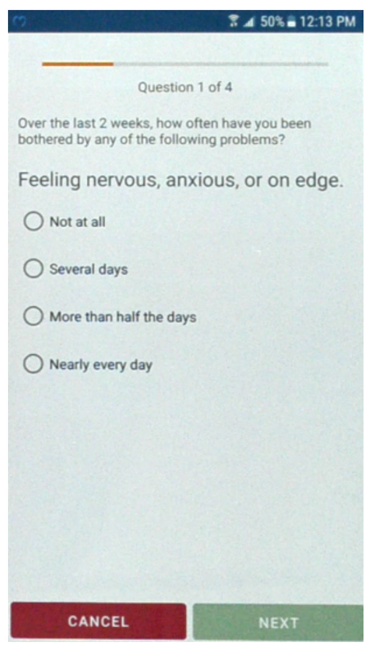
Figure 5

Surveys List

Note. A screen showing two survey tiles indicating the name of the survey, how many questions it has, and approximately how long it would take to fill it out.

Figure 6

Sample Survey Question

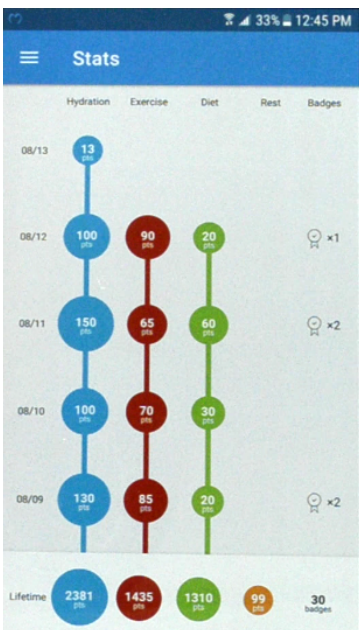


Note. A screen showing a sample multiple choice question with a progress bar at the top, followed by a question, and radio button answer options, with "Cancel" and "Next" buttons at the bottom.

Additional navigation items allowed the user to view their participation points on a vertical timeline as illustrated in Figure 7. The four possible lanes indicated the user's points for that day in those categories, which were 'Hydration', 'Exercise', 'Diet', and 'Rest'. The size of the circle indicated the size of the value relative to other values on the screen. Another screen allowed the user to view a leaderboard of their accumulated points overall and in different categories, and how they compared to other participants in the trial as illustrated in Figure 8.

Figure 7

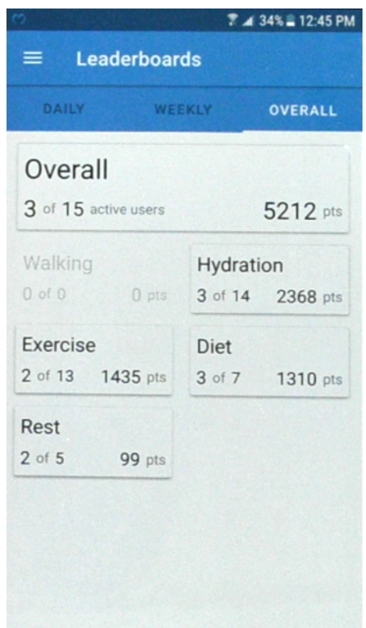
Points Summary



Note. A screen showing a vertical timeline with several columns of challenge types (e.g. "Hydration", "Exercise", "Diet") and the points achieved in that category.

Figure 8

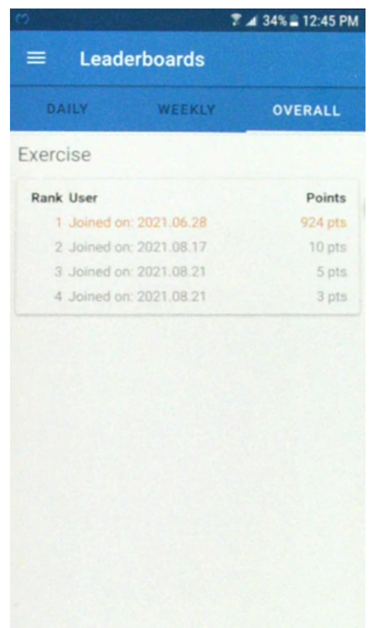
Leaderboards



Note. A screen showing 3 tabs (e.g. "Daily", "Weekly", "Overall") and tiles for different challenge types (e.g. "Hydration", "Exercise", etc.) with a ranking of "x of y" and a total sum of points achieved in that category.

Figure 9

Leaderboard Details



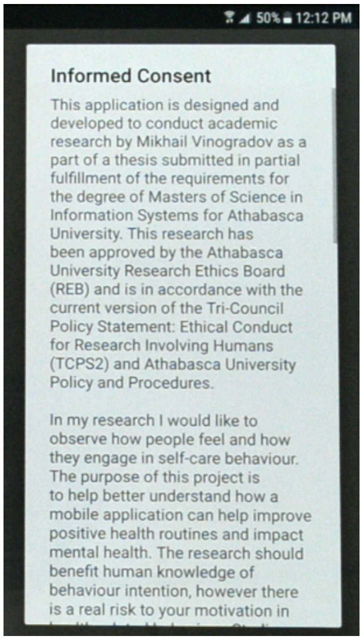
Note. A detail screen showing a list of all the participants in a particular challenge category and their point rankings with one entry highlighted indicating this is the participant's rank. The names are anonymised as "Joined on some date".

The leaderboard tile could be tapped for a detailed view of the rankings including other players' points as shown in Figure 9. In order to keep participants anonymous no personally identifying information was displayed on the leaderboard - rather just the date they joined, their rank, and their points amount. The leaderboards were meant to encourage friendly competition and drive participation with the challenges when users could see themselves as they progressed through the ranks.

These gamification features were only available to half of the participants. The other half was in a control group and saw all the other screens and interactions, but did not visually receive any feedback about the points they were earning by completing the challenges. The group assignment was determined randomly at the time of registration and the user was unaware to which group they were assigned. Prior to beginning any interaction in the app, the participant had to acknowledge that they understood they were participating in a study, that their anonymous data will be collected and used in aggregate reporting, and the potential risks that come with using the app. This informed consent screen is illustrated in Figures 10 and 11.

Figure 10

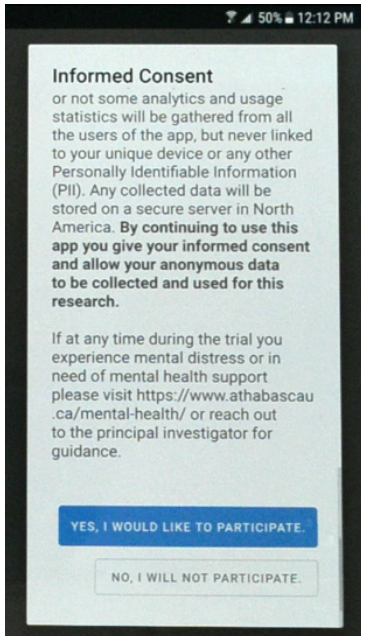
Informed Consent Form



Note. A screen showing the informed consent popup.

Figure 11

Informed Consent Form (cont'd)



Note. A screen showing the end of the consent text with two buttons – one reads "Yes, I would like to participate" and the other reads "No, I will not participate".

Back-End

The mobile app communicated JSON payloads to two backend servers. Both servers had similar architecture and framework but exposed different endpoints to perform different database operations. The servers were written in PHP and based off of the Slim framework, which communicated with MariaDB databases.

The Research Server API allowed users to register with the trial, which randomly assigned them into a group and issued a unique identifier (UUID) as an anonymous tracker. This token was then used to communicate with the Application Server API to register an account with a random 32-bit password and later authenticate before being able to access daily challenges and submit participation data. The Research API had an administrative end where the researcher could configure the parameters of the trial, group splitting, and the surveys and questions that will be sent and when. The trial was configured with Demographics (DMG) and Sports Motivation (MIFA) surveys to be delivered upon registration, the Patient Health Questionnaire (PHQ) to be delivered every 7 days for a duration of 8 weeks, and a System Usability (SUS) with 5 questions from MIFA focusing on the Intention (IN) factor delivered 8 weeks after registration. The answers were stored in a way that only identified the unique account, the answer, and the date it was received.

The Application Server API allowed users to register or login with existing credentials and have access to participate in daily challenges. The login worked by authenticating the UUID against the random password generated by the user's mobile device, to which only they would have access. The system issued an OAuth token back to the user that would expire every few days. This allowed the user to engage quickly with the app if they were a frequent user, and if not, they would have to wait a few seconds longer the first time the app would authenticate. Afterwards every time the user queried for challenges with their UUID and OAuth token the system would check to see if they were already assigned challenges for today and return those, otherwise assign a new set of challenges based on the user's current seniority and participation level.

Throughout the day the user would be able to send participation data about their progress. To keep payloads small they only included the ID of the challenge they are doing and the value. For instance the ID of the challenge to drink a glass of water and "+1", or the ID of the push ups challenge and "+5". Similarly the device could send back

"-5" in case the user made an error. When the user queried for the challenge status the daily activity values were summed up and the user would see their current standing. The Application Server could also return back aggregate data for the user for all of their challenges grouping by day and challenge type to drive the Points Summary screen (Fig. 7), or aggregate for all users grouping by challenge category and time frame to drive the Leaderboard screens (Fig. 8, 9).

Each API could be packaged into their own Docker container to be deployed to the internet, however, for economic reasons they were both packaged into one and deployed as a single application providing two different back-end services at different URLs. The URLs were aliased to a subdomain so that the front-end only had to know which subdomain and host it should be communicating with, and the servers could be redeployed and their IPs could change, but it would not affect the mobile application. For example the page describing the project and providing a link to download the app was hosted on https://mehailo.interfacemaster.ca/. The Application API was found at the `/api/mhl` path. The Research API was being served from `/api/rct` and referenced from rctrials.interfacemaster.ca. This separation allows the two projects to be maintained separately in an effort of making the Research API an open-source community project.

The Docker container was deployed to the internet with the help of Google Cloud Platform (GCP). A cloud repository was used to store the container image binaries. Compute instances were used to deploy those containers and have publicly-accessible IPs, which were then mapped using DNS records to the research web URL. And a Google Cloud Database was used to store the research and application data.

Administration

To administer the infrastructure of the project, accounts were created with Google Cloud Platform (GCP) (for the database and servers), the Google Play Store (for hosting the mobile app), and Firebase (for error logging, analytics, and push notifications). The researcher created and managed a profile on the Google Play Store for the MEHAILO App, which also connected with the Firebase account to gain insights into app crashes, usage analytics, and facilitated push notifications.

To configure the trial on the Research Server a front-end interface was created and used to create and manage the surveys and questions. For the Application Server, however, the available challenges were pre-populated in the database, and the user was assigned a random challenge from the available pool. In the future, the system could be improved by allowing participants to enter their own challenges for a more self-guided experience.

During the trial the researcher would perform occasional database backups by logging into the GCP console and issuing a command to dump the database contents into an SQL file on a cloud storage bucket. These backups were kept in case of database failure and to be able to instantiate a copy of the live database locally for development and debugging.

At the end of the trial custom queries were executed against the Research and Application databases to export CSV files including UUIDs, daily activity summaries, and survey responses. Since the UUID generated by the Research server was later used to register with the Application server, this value was then cross-referenced to link user activity to their survey responses and observe if there is a relationship between the two.

Chapter 5. Experiment and Discussion

The experiment was carried out by advertising the study through the Athabasca University bulletin board and social media. 74 participants were recruited and received at least one challenge and 67 participants completed at least one. While the average participant received 143 challenges and completed 59 (~40%), the top 10% was 8 participants with over 470 attempted challenges and between 200 and 600 completed challenges. Of the 74 participants only 56 filled out the demographics survey, 54 filled out the Sports Motivation pre-trial survey, and only 8 filled out the post-trial Sports Motivation and System Usability surveys. The mental health questionnaire was filled out by 58 participants in total, however 29 participants only filled it out once, 13 filled it out twice, 11 between 3 and 7 times, and only 7 participants filled it out 8 or more times. The participation data was analyzed using SPSS v28.0.1.1 by performing t-tests, regression, and correlation analyses and looking for correlation between specific data points that would help support the proposed hypotheses. The data reliability and validity was tested by looking at the Cronbach's alpha and values to be greater than .7 which was observed for MIFA[1], PHQ, and SUS surveys.

User Experience

Participants were recruited through the university bulletin and social media channels. A link to an information page was shared which described the study, the application, and the requirements from the participants. A short video demonstrated the use of the app to familiarize the viewer with the interface and the expected interactions. The page provided information on the purpose of the app, the measurements that will be taken and what will be analyzed. The only piece of information that was not openly shared with the participants was that the app has gamification features to view points, badges, and leaderboards, since only half of the participants would see those features. The page informed the visitor that no personally identifying information will ever be collected during the trial and that participation in all activities is completely voluntary. A disclaimer warned the visitor of potential side effects of using the app such as developing dependency on the feedback from the app and losing intrinsic motivation to engage in self-care behaviour. The page also provided a link to university mental health resources in case the participants found the weekly mental health questionnaire triggering. A link to download the app from the Play Store brought the user to the app profile page which provided more information about the types of permissions the app would require, the participant data that will be collected and what will be done with it.

Once the user downloaded the app and opened it, they were presented with a disclaimer screen outlining once again the purpose of the research, the data that will be collected, the risks of participation, and asked the user to give informed consent. Once the user acknowledged the disclaimer the mobile device registered with the Research and Application servers, received the initial surveys and daily challenges, and brought the user to the interaction screen. From here the user would begin engaging in their daily challenges or filling out the surveys.

The first day the app would only request 3 challenges to be completed - drink one glass of water, walk 500 steps, and a random physical activity of 5 repetitions (e.g. push ups, or crunches). The user could tap on any challenge to see a description of how to perform the activity - correct form, posture, breathing, etc. The next day the user would again receive 3 challenges - to drink water, walk 500 steps, and another random physical activity. After 3 days of successfully completing a challenge, the difficulty would begin to increase. For instance after 3 days of drinking at least one glass of water, the challenge would begin requiring the user to drink two glasses. If the user was able to walk at least 500 steps every day for 3 days the challenge would then ask for 1000 steps. Because the physical activity challenges were random, it was unlikely that the user would level up in any one challenge in the first week, however, after 3 days of participating with the app a fourth challenge would be added asking the user to have a healthy breakfast.

The diet challenges were a simple data entry of true or false defaulting to false until the user indicated otherwise. The description of the challenge allowed for a flexible understanding of the term “healthy breakfast” asking the user to make their own judgement and evaluate for themselves whether they believe their meal was “healthy”. This sort of autonomy put the power in the user’s hands, and at the same time allowed people with different dietary preferences to easily participate in the challenge without feeling confined to someone else’s definition of “healthy”.

After 3 more days of participation the user would get a fifth challenge to go to bed on time in an effort to get an adequate amount of sleep. Since everyone’s routine is different it was difficult to suggest absolute times or durations of sleep, so similar to the diet challenge the power was placed with the user to select their own goal for an ideal bedtime and wake time. The user would be awarded points based on how close to the goal time they actually went to bed. This challenge did not level up with completion like the others, however badges were awarded for continuous completion of the task after 3 days, 5 days, and so on.

As the user continued to engage more challenges were unlocked every three days - eventually asking the user to have a healthy lunch, and dinner, as well as getting up on time, and having between 6-8 hours of sleep between bedtime and wake time. After 30 days of engagement the user would have unlocked all the challenges from the different categories. However, their participation in the physical activity category determined how many physical activity challenges would be assigned. As the user leveled up in a particular challenge, their overall physical activity level would increase as well. The higher the level - the more challenges could be received.

By the end of the trial if the user engaged with all the different activities, they would be receiving the walking challenge, a hydration challenge to drink 8 glasses of water, to have a healthy breakfast, lunch, and dinner, to get to bed on time, get up on time, and have between 6 and 8 hours of sleep, and up to six different physical activity challenges (e.g. pushups, crunches, squats, lunges, side planks, and hip raises) with varying amounts of repetitions based on the user's achievements for those challenges. These challenges were chosen as some of the most common and accessible physical activities that don't require equipment, setup, or specific physical locations. In the future the app could be improved by allowing the participant to select their own physical activities that they find most rewarding.

Research Model and Hypotheses

The research attempted to investigate how a mobile app could be used to improve the user's mental health and create motivation to continue engaging with physical activities beyond the app. To make this observation we first needed to take baseline measurements of mental health and motivation to engage in physical activity. Then engage the user in self-care behaviour over a period of time while measuring their mental health status. At the end, we needed to take another measurement of sports motivation, and evaluate the usability of the mobile app.

Observing the participants' change in mental health as well as engagement with the app we could measure correlation which would suggest that engagement could in part be responsible for the change in mental health (H1). If the System Usability survey came back with positive results we could also infer that the app was usable as desired and that technology was not a barrier to participation (H2). If engagement does indeed contribute to positive mental health change and the app was well-designed and implemented we could also suggest that the positive user experience in the app is a contributor to the positive mental health change (H3).

Measuring initial Sports Motivation could help explain the reason for engagement and participation (H4) where we could expect to see individuals with no pre-existing motivation for engaging in physical activity to discontinue using the app very quickly. Similarly the initial mental health state could help explain the motivation for physical activity (H5) and engaging with the app (H6). Finally, measuring the post-trial Sports Motivation and observing correlation with engagement could help answer the question of whether using the app could help create motivation towards physical activity (H7).

These seven hypotheses form the research model illustrated in Figure 12. By employing the Measurement of the Intention to be Physically Active (MIFA), System Usability Scale (SUS), and Patient Health Questionnaire (PHQ) surveys we could gather measurements to help us evaluate these hypotheses and help answer the research questions of whether mood can be influenced by a mobile app, and if motivation can be generated in unmotivated participants. The hypotheses are summarized in Table 1.

Figure 12

Research Model

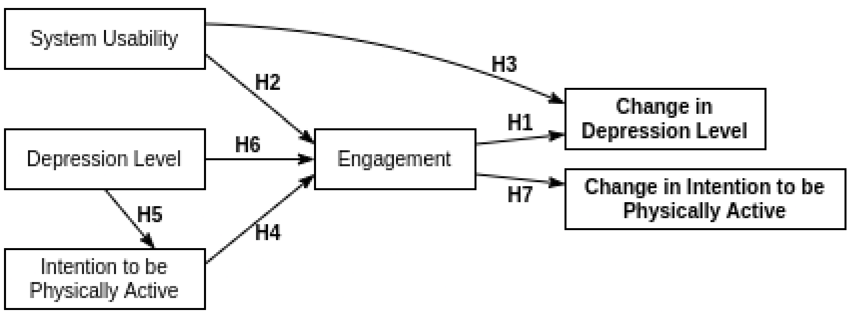


Table 1

Research Hypotheses

H1	Engagement (ENG) will influence change in Mental Health (**Δ**PHQ)
H2	System Usability (SUS) will influence Engagement (ENG)
H3	System Usability (SUS) will influence change in Mental Health (**Δ**PHQ)
H4	Intention to be Physically Active (MIFA[1]) will influence Engagement (ENG)
H5	Initial Mental Health (PHQ[1]) will influence Intention to be Physically Active (MIFA[1])
H6	Initial Mental Health (PHQ[1]) will influence Engagement (ENG)
H7	Engagement (ENG) will influence change in Intention to be Physically Active (**Δ**MIFA.IN)

To observe engagement, app analytics were used to measure the number of times the user opened the app over the duration of the trial, the number of challenges in which they engaged, and the number of points they gained by completing those challenges.

Mental health level was measured with the PHQ-4 survey, which is a four-question survey measuring two factors - Depression and Anxiety. The survey was offered every 7 days to better observe change over time. Of the 58 participants in the PHQ survey the average participation was every 12 days with 30 participants having more than one entry. Intention towards physical activity was measured with the Intention factor (IN) from the Measurement of the Intention to be Physically Active (MIFA) questionnaire. The entire 17-item survey was delivered before the trial, and only the 5 questions pertaining to the intention factor (IN) were delivered at the end of the trial to measure the change in intention over time. Observing a significant change in intention could be attributed in part to the intervention.

The System Usability Scale (SUS) helps evaluate if the intervention was successfully implemented. If the user interface (UI) or experience (UX) were hindering the desired engagement or flow for the user, then we could explain lack of user engagement by the usability of the system. The average score given was 73.125. Recent research consider the SUS score 68's correspondent adjective rating is OK, the score value between 68 to 80.3 means Good, and a score higher than 80.3 indicates Excellent for the perceived usability (Sauro, 2011).

Nielsen (2012) suggests to test five users in a usability study and finds that with five users researchers can get close to the maximum benefit-cost ratio. He also suggests to have 20 users for a study that aims for quantitative studies. Hwang and Salvendy (2010) find that there are many discussions on optimal sample size for usability studies and the “magic number five” rule (which is also called “4 +/- 1” rule) could detect 80% of usability problems. With meta-analysis results, they conclude “10 +/- 2” rule is a general rule for optimal sample size for major usability evaluation methods. Therefore, the usability of the proposed mobile health app is Good as classified by 8 users (~10%) who filled out the SUS survey.

Correlation analysis was used to validate the hypotheses. Correlation between app engagement (ENG) and mental health (PHQ) would validate that mental health can indeed be influenced by an app (H1). Correlation between engagement (ENG) and change in intention to be physically active (ΔMIFA.IN) would validate that intention can be created by using the app (H7). Correlation between system usability (SUS) and engagement (ENG) would confirm that app use is influenced by usability (H2). Similarly if H1 and H2 are true, then a correlation between system usability (SUS) and mental health (PHQ) could be attributed in part to the app (H3). Correlation between initial intention to be physically active (MIFA^1) and engagement (ENG) or initial mental health (PHQ^1) and engagement (ENG) could help explain the reason for engagement with the app or lack thereof (H4 and H6). And a correlation between initial mental health (PHQ^1) and intention to be physically active (MIFA^1) could help explain the reason behind lack of intention if that is the case (H5).

Reliability and Validity

All analyses were carried out using SPSS version 28.0.1.1. The Measurement of Intention to be Physically Active (MIFA^1) pre-trial questionnaire contained 17 questions and evaluated all 4 factors of sports motivation - Experience Stimulation (ES), to Know (KN), to Accomplish (AC), and Intention to be Physically Active (IN^1). While the post-trial survey only contained the 5 questions for the Intention to be Physically Active (IN^2)

factor. The following Table 2 shows Cronbach's Alpha scores for the MIFA[1] scale overall and for each factor separately.

Table 2

MIFA Reliability Analysis

	Cronbach's Alpha	N
Overall (MIFA[1])	.941	54
Experience Stimulation (ES)	.883	54
To Know (KN)	.888	54
To Accomplish (AC)	.915	54
Intention Pre-Trial (IN[1])	.767	54
Intention Post-Trial (IN[2])	.927	8

The individual principal component analysis showed that two items for the Intention (IN[1]) factor had loadings of < .7 and were removed (q14, q15). After the removal of those two items, the overall and individual alphas changed as follows:

Table 3

MIFA Reliability Analysis (Without Questions 14 and 15)

	Cronbach's Alpha	N
Overall (MIFA[1])	.944	54
Intention Pre-Trial (IN[1])	.815	54

PHQ responses were grouped by participant and by date and analyzed for reliability. The 4 items testing 2 factors for Anxiety and Depression together had a Cronbach's Alpha value of .932 as shown in Table 4. The responses were also analyzed using principal component analysis and a single component was extracted based on eigenvalues greater than 1. The results are shown in Table 5.

Table 4

PHQ Reliability Analysis

	Cronbach's Alpha	N
PHQ	.932	155

Table 5

PHQ Principal Component Analysis

PHQ-4	Component 1
Q4	.932
Q1	.915
Q2	.909
Q3	.891

Analysis Results and Findings

The primary focus of the study was to evaluate whether mental health could be improved through app use and based on the evaluated data this hypothesis was confirmed. We observed a negative correlation between engagement (ENG) measured by the number of points (PTS) a participant gained and their score on the mental health questionnaire (PHQ) (H1). In all the cases analyzed together we observed a slight but significant Spearman's rho correlation between PHQ and ENG.PTS. When we separated the results into control and experiment groups we observed the correlation as well, and slightly stronger in the experiment group. The results are summarized in Table 6. It makes more sense in our case to rely on Spearman's rho as opposed to Pearson r since the PHQ is affected with the duration of engagement (ENG) over time, and Spearman's rho can more accurately evaluate ranked data, which in our case was ranked by the date of the survey.

Table 6

Correlation of PHQ & ENG.PTS

	Spearman's ρ	N
All Cases	**-.315*** **	127
Control	**-.315*** **	66
Experiment	**-.359*** **	61
*: p < 0.05, **: p < 0.01, ***: p < 0.001		

When looking at the PHQ scores of each participant we also looked at the average of those scores for each participant, and then the average of all those scores. When separated by group we observed that the mean PHQ score was higher in the control group than in the experiment group. Similarly we observed the average of the points gained by the experiment group to be higher than the control group. These two observations suggest that the gamification features could have influenced more participation to gain points, which in turn caused PHQ scores on average to be lower. The PHQ and points means are shown in Table 7.

Table 7

PHQ and ENG.PTS Means by Group

	PHQ			ENG.PTS		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N
All Cases	3.56	3.82	127	859.02	1447.81	127
Control	3.86	3.17	66	841.02	1483.57	76
Experiment	3.23	4.42	61	877.76	1419.65	73

Additionally we also observed a negative correlation between the mean of all the PHQ scores for a given user and the number of days that user engaged with the app as measured by the number of days the user queried the system for challenges (ENG.NUM), and the number of days the user logged in (ENG.LOG). These correlations are shown in Table 8 and Table 9. This correlation was not observed with other forms of engagement such as challenges completed or points earned. This suggests that the more a participant engaged with challenges (not necessarily completed them), but actively queried for challenges daily, the more likely their average PHQ score over the trial was lower suggesting better mental health.

Table 8

Correlation of PHQ.MEAN & ENG.NUM

	Pearson *r*	N
All Cases	-.273*	58
Control	-.201	31
Experiment	-.345	27
*: p < 0.05, **: p < 0.01, ***: p < 0.001		

Table 9

Correlation of PHQ.MEAN & ENG.LOG

	Pearson *r*	N
All Cases	-.303*	58
Control	-.237	31
Experiment	-.395*	27
*: p < 0.05, **: p < 0.01, ***: p < 0.001		

We did not observe any correlation between SUS scores and app usage as may be reflected by duration of engagement, frequency of engagement, points collected, days participated, or challenges completed (H2). Similarly we did not observe correlation between SUS and initial PHQ, average PHQ, or slope of PHQ over the trial (H3). The caveat being that only 8 participants completed the exit survey and filled out the SUS questionnaire, which is not enough data to make broadly conclusive statements.

The hypotheses that initial mental health (PHQ^1) will influence sports motivation ($MIFA^1$) or engagement (ENG) or that engagement (ENG) will be influenced by sports motivation ($MIFA^1$) were not supported. We did not see any correlation of initial Intention ($MIFA.IN^1$) with any form of engagement (ENG) as measured by duration of engagement, frequency of engagement, points collected, days participated, or challenges completed (H4). Similarly we did not observe a correlation between initial Intention ($MIFA.IN^1$) and the participants first mental health survey (PHQ^1) (H5). There were also no significant correlations between initial mental health (PHQ^1) and any form of engagement (ENG) such as days participated, days engaged, or achievements completed, so the hypothesis that initial mental health level will influence app engagement is also unsupported (H6).

The hypothesis that motivation could be inspired through intervention engagement was not supported. We did not observe a strong average change in intention (**Δ**MIFA.IN), nor did we observe a correlation between engagement (ENG) and change in intention to be physically active (**Δ**MIFA.IN). The caveat is that only 8 participants completed the full 8-week trial and filled out the post-trial $MIFA^2$ survey for us to be able to calculate **Δ**MIFA.IN. From the 8 results we observed an increase in MIFA.IN in 3 participants, a decrease in 3 participants, and no change in 2 participants. Due to the low number of responses it is uncertain if motivation could be inspired through app use, however in this sample there was no statistical significance in any of the differences observed or their relationship to engagement to support the hypothesis (H7).

Discussion

The study aimed to answer two primary questions - whether mental health could be improved through app use, and whether app use could help motivate and create intention towards physical activity. The negative correlation between PHQ scores and the number of points a participant gained suggests that engaging with the app and completing the challenges has a chance at reducing the participant's depression and anxiety. Additionally the negative correlation between PHQ mean and the number of days the user engaged with the app suggests that continued engagement increases the likelihood of the desired outcome. Our original thought that these activities, when performed regularly, can have a positive impact on mental health and could be suggested through the app as a self-directed mental health hygiene practice were indeed supported.

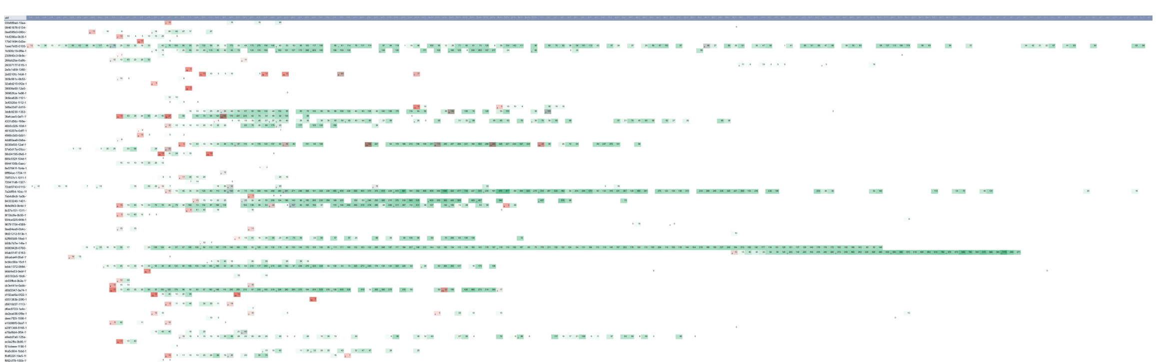
Unfortunately due to low completion rate we could not validate the hypothesis that engagement would result in an increase in intrinsic motivation and so we cannot answer the question of whether app use could generate intention. Similarly we could not test the hypothesis that system usability would impact engagement or have downstream impact on change in mental health.

Our hypothesis that initial mental health would influence intention to be physically active was also not supported as we did not find a correlation between the first mental health questionnaire (PHQ^1) and MIFA^1. Out of the 73 participants in the trial, where 67 users completed at least one challenge, 53 individuals completed the MIFA^1 and a PHQ questionnaire. This observation could signal that mental health was not an influencing factor for sports motivation. With intention (IN) values ranging from the lowest possible value of 5 and to the almost maximum value of 24, with the average 17.7, and standard deviation of 4.1 – there was a broad range of respondents. Those respondents' PHQ scores were also well represented with values ranging from the extremes at 0 and 12, average at 5.4, and standard deviation of 4.1. The lack of correlation suggests that mood does not influence one's intention to be physically active. We also did not observe any correlation between the MIFA scores and any form of engagement, suggesting that users engaged whether they were motivated towards sports or not. Of course there was a percentage of users who disengaged or did not use the app at all, however, the observation suggests that it was not related to initial mental health or sports motivation. This could be an important finding in the context of a self-help mobile app suggesting that an intervention like this could be used by individuals of varying mental health and high or low sport motivation. If the app is there and is being used then it is possible that it could be the self-help routine that can nudge the participant towards action and a better mental health.

Our hypothesis that initial mental health would also influence engagement with the app was also not supported as we did not observe any statistical correlation between PHQ[1] and engagement (ENG). This suggests that depression or anxiety did not influence the participants ability to engage with the app. However, due to the low participation numbers it is difficult to say this with certainty. We constructed a heat map to observe engagement points (ENG.PTS) and PHQ entries together grouped by UUID over time. The result is shown in Figure 13. Although we observed no statistical significance between PHQ and engagement, it was visually more apparent that of the users engaging with activities, there were many not engaging with PHQ surveys, and only a few who continually engaged with both.

Figure 13

Heatmap of Points Earned with PHQ Scores by UUID Over Time

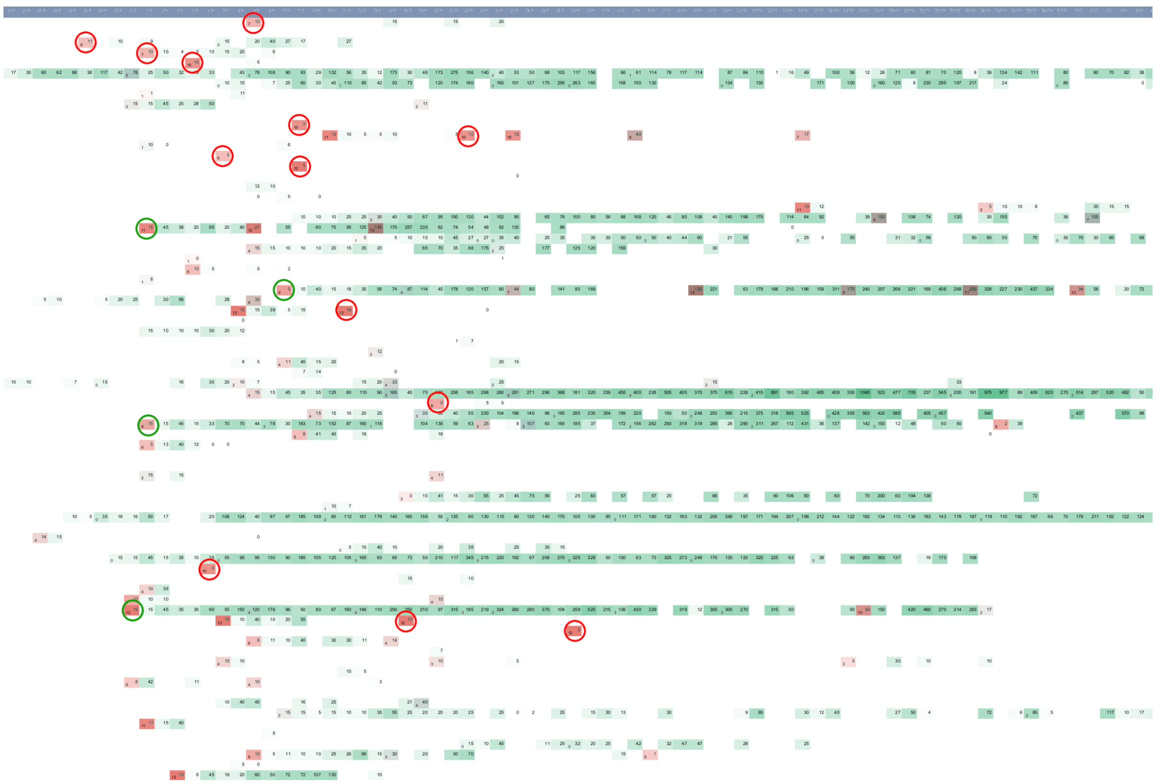


Note. Each row represents a user as they engaged with the intervention over time

It is also quite apparent where users discontinued using the application after a high PHQ entry, as illustrated in Figure 14. The 13 red circles highlight the users who did not engage with the challenges and had relatively high PHQ scores, and the 4 green circles highlight the resilient participants who continued to fill out PHQ questionnaires and engage in challenges. Majority of other participants did not truly engage with the intervention (blank lines), and some who did suddenly dropped off (green lines), rather than gradually disengaging.

Figure 14

Users Who Dropped Off After a High PHQ Score vs Resilient Participants



Note. Red circles indicate users who stopped engaging with challenges after a high PHQ score; green circles show resilient participants who continue to engage despite high PHQ

The lack of correlation between SUS scores and engagement, initial PHQ, average PHQ, or slope of PHQ over the trial suggests that system usability was not influenced by mood, or amount of time engaging with the app. This observation would suggest that this minimal implementation was sufficient for being usable and even eliciting change in certain individuals. The caveat being that although 8 participants is enough of a sample to rely on the results of the SUS survey, the correlations that those 8 participants had or didn’t have with engagement or PHQ may not be representative of the entire population.

Chapter 6. Research Findings

Summary and Contribution

In the end the study did not gather enough participants to make general conclusions or even confirm some of the hypotheses. We did observe that indeed the more a participant engaged with the activities, the more likely they were to score lower on the mental health questionnaire. This suggests that such an app could be used as a self-directed mental health hygiene tool and potentially help improve mental health and resilience in certain individuals.

Other hypotheses were tested and not confirmed or left uncertain. Of the seven posed hypotheses, three were left uncertain due to low post-trial survey completion, and another three were rejected due to lack of evidence supporting any relationship between the variables. The rejected hypotheses could suggest that the intervention can be used by individuals with no existing sports motivation, since MIFA had no influence on engagement, and by individuals with varying mental health states, since initial PHQ score did not seem to influence MIFA or engagement. Overall the study was unable to prove or disprove some of the posed hypotheses, however, we did find evidence supporting the idea that using an app such as the one built for this project to engage users with positive sleep, diet, and exercise habits can have a positive effects on their mental health.

One of the participants of the study took the time to contact the primary investigator and provide heartfelt positive feedback. The participant stated that prior to using the app they have struggled with mental health and had no physical activity routine. After having used the app they now feel much better, have a daily workout routine, and actively seek out large walks. They stated that small prompts were enough to motivate them to get into it at the start, and the points encouraged them to come back every day and check in. Their constructive feedback was to include more customization to replace built-in exercise challenges and allow the user more control over what exercises to perform and how many reps. This feedback supports our findings and observations.

As part of the study two open-source projects were created. One is the MEHAILO project that is the mobile application and the server architecture to enable participants to receive random challenges, and level up their skills in the three key areas of sleep, diet, and exercise. The second project is the RCTrials tool, which is a front-end interface and a server-side API that allows a researcher to configure the parameters of a trial, then have participants register into that trial via the mobile app, be split into different groups, and submit anonymous survey responses. The tool could be used by other researchers looking to integrate anonymous surveys into their projects and can be built upon by the community.

Limitations

The biggest challenge for this project was finding participants and keeping them engaged for the entire 8-week trial. Most users discontinued using the app after a few weeks or even days of usage. This indicates that the app interface, reward system, gameplay, and other aspects of the implementation were not ideal for the solution. Users engaged with the app, completed the challenges, and even filled out survey questionnaires. However, it was a small subset of the users who saw the app, downloaded the app, or even used the app with some success. This indicates a lack of interest in the app, the activities, and the health benefits.

Participation in PHQ questionnaires decreased rapidly over time. Where 58 participants filled out the first PHQ survey, only 30 carried on to fill it out a second time, and only 17 filled it out a third time. By the fourth survey only 13 participants remained, who continued to fill out a fifth and sixth surveys (less one participant). By the 7th survey however, only 8 participants remained, and after that only 2 participants finished 8 PHQ questionnaires. This is different from overall participation with the app as some users continued to engage with challenges and activities and simply not fill out the mental health survey. The PHQ participation totals are shown in Table 10.

Table 10

PHQ Participation Totals and by Group Over Time

PHQ	N	Control	Experiment
1st	58	31	27
2nd	30	16	14
3rd	17	9	8
4th	13	6	7
5th	13	6	7
6th	12	5	7
7th	8	4	4

The research focused mainly on recruiting student participants, although participation was open to anyone who downloaded the app. Of the 73 responses to the demographics survey, 17 (23.3%) were blank, 27 (37%) were studying full time, and 18

(24.7%) were studying part time, with 10 (13.7%) indicating they were not studying. At the same time 27 (37%) indicated they are working full time, and 6 (8.2%) indicated they are working part time. The majority of the users were between ages of 25 and 39. Additionally, the majority of participants were female, not indigenous, and not visible minorities. The results of the study may not be generalizable to other demographics without further research.

Future Possibilities

Future research could focus on mitigating issues and barriers around using the app in order to gain more data and insight and potentially answer the hypotheses that could not be properly tested due to low participation. A key question that still remains is the reason for participant disengagement. Since the study was completely anonymous there was no way to follow up with participants and study those reasons, however a future study could focus on gathering more information from participants after they've disengaged, possibly with a follow-up email to help better understand those reasons.

Future research could also focus on expanding the MEHAILO project and building more functionality. Some design improvements that could be made include allowing users to enter their own exercises and milestones they wish to track instead of the existing ones. The app could also use better integration with hardware sensors to detect changes in the environment such as light or motion. This information can be used to determine when the participant is going to bed and getting up instead of relying on manual entry. Also tracking biometric data like heart rate or oxygen levels can help gauge physical engagement, and assign rewards based on this data as well. A social aspect could be expanded in the app where participants could compete more openly, join in group challenges or discussions, or give "likes" on the progress and improvements of others to encourage a sense of community and support.

Additionally, there is research that suggests that certain aspects of gamification could be harmful to the participant as they may lose any intrinsic motivation they had before engaging with the gamified experience. To address this concern - self-guided and self-managed tasks can be implemented that would help participants remain in control.

To help curb participant disengagement improvements could be made to the application service that could attempt to re-engage participants. Even though our implementation had a feature to send reminders to the user, if the application was shut down the user would not see those alerts and be less likely to come back to the app. Participant re-engagement strategies could be used to send push notifications to users who begin disengaging or have already disengaged. If the app is shut down and does not receive the notifications a follow-up email could be sent to help draw interest with a weekly challenge, or a team tournament. Additionally a service could be built into the app that would run in the background and restart the app when it is shut down or when the device restarts. This feature would have to be implemented carefully with full control given to the user to disable such a feature as it could be perceived as invasive.

Other improvements to this research could be made with the RCTrials project. Feature improvements could be made to the API to allow researchers finer control over the trial, easier implementation in existing projects, and adding preconfigured common questionnaires to allow one-click configuration of complex surveys. Improvements can be made to the RCTrials mobile standalone app to have a better UI, which may improve the overall participant experience. The app could also become a scaffold project for researchers to build upon with their own research and functionality, but with survey functionality already built into the template. This could improve the researcher developer experience and allow trials to be deployed faster. Finally a social network feature could be added to allow researchers to connect with each other and with trial participants. The project could become a network for participants looking to participate in trials as well as researchers looking for participants for their trials.

Finally, both projects could be rebuilt using more modern technology. Using React Native (or equivalent) to build the UI once and deploy to multiple mobile operating systems would increase the market coverage of the users these projects could engage. Using serverless architecture for the backend by using cloud functions would eliminate the need and cost of running application servers during times when the projects aren't being used. Using cloud storage could also be more economical than dedicated storage for a relational database which is mostly empty. Possibly even eliminating the need for a database by allowing users to store any necessary data on their own devices and significantly reducing operational costs.

All these improvements could have a positive impact on the usability of the projects and user retention. With a better and more sustained user experience more research could be carried out to answer the hypotheses that were left uncertain in our study. Machine learning could be applied to study patterns of user engagement to help predict disengagement and possibly intervene with a notification or re-engagement incentive. Other areas of research could explore correlations between personality types and engagement with different challenges. This could help understand if different personalities prefer different self-care routines and possibly build the app in a way to accommodate those personality types. Different features could also be tested separately to measure the effect of each feature on engagement, retention, and mental health.

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Athabasca University
RESEARCH CENTRE

Appendix: Certification of Ethical Approval

CERTIFICATION OF ETHICAL APPROVAL

The Athabasca University Research Ethics Board (REB) has reviewed and approved the research project noted below. The REB is constituted and operates in accordance with the current version of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2) and Athabasca University Policy and Procedures.

Ethics File No.: **24342**

Principal Investigator:
Mr. Mikhail Vinogradov, Graduate Student
Faculty of Science & Technology\Master of Science in Information Systems (MScIS)

Supervisor:
Dr. Maiga Chang (Supervisor)

Project Title:
Improving Mental Health Through Gamification of Health Objectives

Effective Date: July 19, 2021 **Expiry Date**: July 18, 2022

Restrictions:

Any modification or amendment to the approved research must be submitted to the AUREB for approval.

Ethical approval is valid *for a period of one year.* An annual request for renewal must be submitted and approved by the above expiry date if a project is ongoing beyond one year.

A Project Completion (Final) Report must be submitted when the research is complete *(i.e. all participant contact and data collection is concluded, no follow-up with participants is anticipated and findings have been made available/provided to participants (if applicable))* or the research is terminated.

Approved by: **Date: July 19, 2021**

Jon Dron, Chair
School of Computing & Information Systems, Departmental Ethics Review Committee

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